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AEROSPACE TESTING INTERNATIONAL

SEPTEMBER 2014

F-35/QEC simulator

BAE Systems Warton's dedicated F-35B simulator has proven itself as a valuable testing tool

A350 TEST PHILOSOPHY
Discover how Airbus has shortened the airworthiness approval process, while improving product reliability

RNLAF F-16 EXCLUSIVE
Chief test pilot Major Ralf 'Lucky' Lukkien's personal insights into the RNLAF's Orange Jumper test jet

AVIONICS: SVS
Synthetic vision systems continue to present design challenges for their manufacturers

MITSUBISHI REGIONAL JET • ASTRAEA UPDATE • 787-9 FLIGHT TESTING • RAAF F-35

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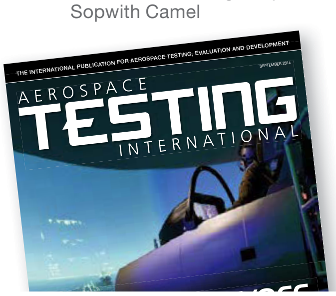
PRODUCTS & SERVICES

REGULARS



Imagine walking out of the house one morning to drive to work, only to discover on the driveway a plain metal shape on four wheels, with no glass. A door opens. You sit down and in place of the windshield is a screen giving you a camera's-eye view (in widescreen) of the road ahead. You don't even have to face forward or be at the front... Unnerving? It certainly sounds it, but as far as aviation is concerned, it could become a reality.

In July, Airbus was awarded a patent for a windowless cockpit that uses 3D view screens in place of conventional windows. It is a concept that could have many advantages. The current position of the cockpit makes sense: pilots are able to see where they're going in the air and on the ground, and any potential hazards. However, this does tend to affect the aerodynamics quite dramatically. Imagine a completely smooth cone.

The patent is timely; in August 2014, new aircraft designs were released with a windowless cabin. Paris-based design company Technicon Design actually won an award for its IXION Windowless Jet Concept, which can provide a 360° view using cameras mounted on the airplane's fuselage to capture the genuine outside view and then project that via a high-res screen across the interior cabin walls and ceiling as if the airplane were made of glass. Again, somewhat unnerving. In fact, any view can be projected, so if it were cloudy, occupants could be treated to a walk down 5th Avenue, or a riverboat cruise along the Rhine.

You see, aerospace designers dislike windows. As research proves, they may be popular with passengers, who like to see the view (I do), and pilots, who like to avoid other aircraft or storm clouds, but engineers see them as nothing but massive points of weakness in what, from a design perspective, should be an unbroken cylinder. In the 1950s, the hugely advanced Comet airliner suffered massive failures that were traced back to poor window design fatally weakening the fuselage.

A windowless cockpit could mean a huge shift in aircraft design. With this in mind, I took to social media to gauge what members of the industry feel about this somewhat controversial subject. Regarding windowless commercial airliners, Johnny Sadiq, who describes himself as an airliner professional, was anxious about the safety aspect: "The concept is fine as a novel approach, rather like 3D films. However, I don't like the idea of applying it to the cockpit. We have already emasculated pilots to the stage where they are becoming irrelevant. I flew as an airline pilot, instructor and check pilot for close to 20,000 hours on airplanes such as the B707, DC-10 and B747. I never saw a system, in 37 years of airline flying, that didn't go wrong at some point."

Frank Taylor, an airline professional, agreed: "Like many ideas, this could be fine when working properly, but not very nice (extremely scary) when the system plays up a bit or fails completely."

Another pilot disagreed. He said that flying on instruments was normal at night and in any form of bad weather, as long as safety and consistent tests were applied, as they are to all instruments, so can only be a step forward into the 21st century.

Strangely, Airbus plays the patent down. In a statement to *Aerospace Testing International* it said: "Airbus files some 600 patents each year in order to protect its intellectual property. This doesn't necessarily mean that all the patents are adopted on an aircraft." The company did admit, however, that this patent is rather major.

The idea of a cockpit like this seems strange, although there are some genuine advantages if it ever gets off the ground. The proposed system could greatly widen the pilot's field of view, which is good, and provides more flexibility about information and touch displays. It could reduce the weight of the aircraft, increasing fuel efficiency and offering much improved aerodynamics. Structural testing and weakness would also be greatly reduced.

The biggest consideration will be safety. There would surely have to be a window somewhere in case there was a full system failure (so why bother?). There is also the cost to consider. Airbus would have to design and maintain a fluid, uninterrupted visual feed with cameras that could weather the elements that might blind a pilot. In future, airplanes' onboard visual systems might be replaced by a combination of satellite and ground-based imagery that could be combined to form a realistic cockpit view. But the technology required for such a system could be prohibitively expensive, if not impossible, to produce.

However, our feature on Synthetic Vision Systems on page 24 would suggest the technology is there to make this happen. It also notes that the idea of a windowless cockpit is not entirely new: NASA has been flight testing external vision systems for future supersonic transport aircraft since the mid-1990s.

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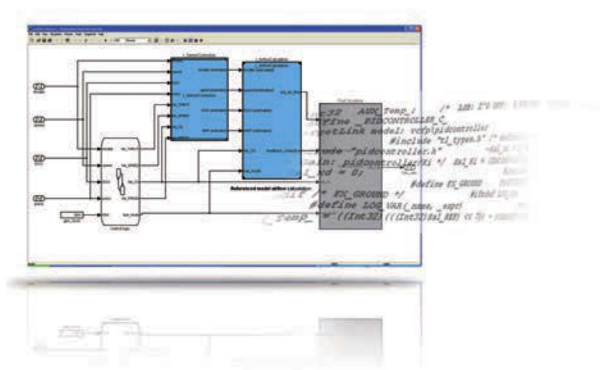

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WORLD TEST UPDATE

1 737 MAX EUROPEAN COMMITMENT

The latest member of the 737 MAX family has been launched with a commitment from Ryanair for 100 airplanes. The airline will be the first to operate the 737 MAX 200, a variant based on the successful 737 MAX 8 that can accommodate up to 200 seats, increasing revenue potential and providing customers with up to 20% better fuel efficiency per seat than today's most efficient single-aisle airplanes. In addition to the commitment, valued at US$11bn at current list prices, Ryanair has options to purchase another 100 737 MAX 200s.

New York, USA

2 UNMANNED AIRCRAFT REACHES MILESTONE

Research students and staff from Warsaw University of Technology have demonstrated the first phase of flight test and integration of unmanned aircraft platforms with an autonomous mission control system. The demonstration marks an important milestone in a partnership between the university and Lockheed Martin. "This is an excellent opportunity for our students to collaborate with a global leader in aerospace engineering to develop complex control software," said Professor Janusz Narkiewicz, the leader and scientific manager of the project at Warsaw University of Technology.

Warsaw, Poland

3 F-15E TAKES FIRST FLIGHT WITH NEW RADAR SYSTEM

The first 389th Fighter Squadron F-15E Strike Eagle has received a Radar Modernization Program upgrade. The inaugural flight with the new radar system was flown by Captain Matthew Riley, 389th Fighter Squadron pilot, and Major Jacob Lindaman, 389th Fighter Squadron weapon systems officer. "The new radar system does everything faster, is extremely precise and requires less maintenance," Riley said. "It can designate air-to-air and air-to-ground simultaneously, enabling us to track enemy aircraft and identify ground targets at the same time."

Mountain Home Air Force Base, Southwestern Idaho

4 JAPAN'S FIRST STEALTH FIGHTER JET

A group of Japanese firms are planning a test flight for the country's first home-grown stealth fighter jet. The consortium, led by Mitsubishi Heavy Industries, is developing a similar jet to US-made F-35 stealth fighters, with a prototype set for a test run in January 2015. Following the initial flight, the jet will undergo around two years of testing at the defense ministry, with Tokyo set to decide by early 2019 whether to buy the airplane.

Tokyo, Japan

5 THE A350 XWB ON FINAL CERTIFICATION

The A350-900 has taken off for the final stage toward certification. The route proving tests are designed to demonstrate readiness for airline operations and will include high airfield performance, auto-landing trials, and airport turnaround and handling services. Some flights will have passengers on board. The A350 world tour itinerary includes 14 major airports worldwide and one route across the North Pole.

Toulouse, France

6 FIRST RAF A400M

The first Airbus A400M ordered by the Royal Air Force took off from Seville, Spain on its maiden flight. One of 22 ordered by the UK, it will be available by the end of September 2014. Edward Strongman, chief test pilot, said "It was very satisfying to conduct this first flight of the first A400M for the RAF. I have no doubt that its combination of true tactical capability with strategic range will be an enormous contributor to future air mobility in the RAF."

Seattle, USA

7 SUKHOI SUPERJET TO OPERATE ON SMALL RUNWAYS

The Russian Aviation Register of Interstate Aviation Committee (IAC AR) has confirmed that the Sukhoi Superjet 100 can now be operated on narrow 30m-wide runways. Operating conditions of the SSJ100 were expanded under the aircraft's certification program. This did not require any changes in design of the aircraft or its systems.

Ramenskoye aerodrome, near Moscow, Russia

8 MUOS SATELLITE FINAL TRIAL BEFORE LAUNCH

Environmental testing of the US Navy's third Mobile User Objective System (MUOS) satellite has been completed by Lockheed Martin. It recently cleared thermal vacuum trials, which validate performance in simulated space conditions, and the satellite is now in final check out. The Navy plans to launch this addition to the constellation in January 2015.

Sunnyvale, California

14 E-2D ADVANCED HAWKEYE PRELIMINARY DESIGN REVIEW

Northrop Grumman and the US Navy team have successfully conducted the preliminary design review (PDR) for their E-2D Advanced Hawkeye aerial refueling system. This milestone allows the program to proceed to its critical design review, moving closer to manufacturing the system and installing it on new production E-2Ds as well as retrofitting it onto E-2Ds currently operating in the Navy fleet.
"Adding an aerial refueling capability to the E-2D Advanced Hawkeye will extend its critical mission of providing continuous information to the war fighter who depends on it," said Captain John Lemmon, program manager, E-2/C-2 Airborne Tactical Data System Program Office (PMA-231).
Melbourne, Florida

15 FUEL CELLS FOR COMMERCIAL AIRLINERS

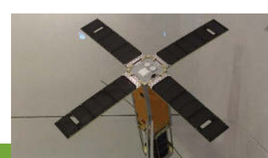
In the quest to make commercial air transport more environmentally and economically sustainable, a co-agreement has been set up by South Africa's National Aerospace Centre to jointly fund research by Hydrogen South Africa (HySA) and Airbus into the application of fuel cells on airliners. The three-year project will be undertaken by HySA Systems Competence Centre at its University of the Western Cape research facility. With demand for air transport doubling every 15 years, the global airline industry will require nearly 30,000 new aircraft (over 100 seats) by 2032. Simultaneously, the dual factors of high jet fuel costs and industry commitments to halve 2005 CO_2 emissions levels by 2050 are driving the search for alternative solutions to fossil-fuel based propulsion and energy sources.
Cape Town, South Africa

9 PRO LINE FUSION SOFTWARE FOR KC-390 AIRCRAFT

Embraer has taken delivery of Pro Line Fusion flight test software from Rockwell Collins for use in the KC-390 military transport aircraft. The aircraft's initial test flight is expected to take place in 2014, followed by entry into operational service in 2016. Rockwell Collins Americas vice president and managing director Alan Prowse said "This milestone is very important for Embraer to progress to their first flight."
São José, Brazil

10 FIRST HONDAJET TAKES TO THE SKIES

The first production HondaJet achieved its initial flight, marking another milestone toward aircraft certification and entry into service in 2015. The event took place at the company's world headquarters in Greensboro, North Carolina. "With this first flight, the HondaJet program has entered the next exciting phase as we prepare for delivery," said Honda Aircraft president and CEO Michimasa Fujino.
Greensboro, North Carolina



11 SINGAPORE'S FIRST NANO-SATELLITE

Singapore's first nano-satellite, VELOX-I, has been launched, signalling a big step forward for the country's aerospace industry. Designed and built by students and researchers from Nanyang Technological University's Satellite Research Centre, the satellite was launched from the Satish Dhawan Space Centre at Sriharikota in Andhra Pradesh, on a space rocket owned by the Indian Space Research Organisation.
Nanyang, Singapore

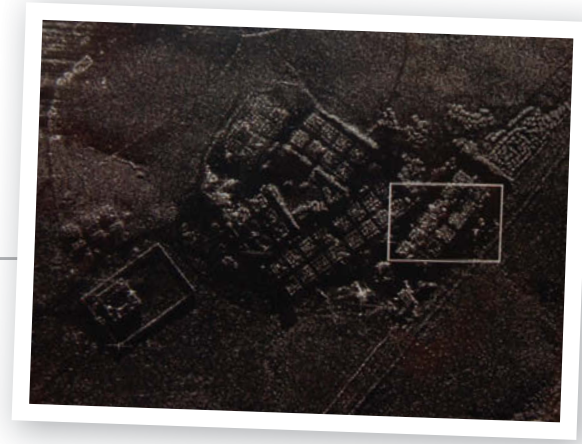
12 BOEING RECEIVES FAA CERTIFICATION

Boeing will begin offering global customers the Enhanced Medium Altitude Reconnaissance and Surveillance System Risk Reduction Prototype (ERRP) now that the aircraft has received Supplemental Type Certification (STC) from the FAA. "ERRP's FAA certification gives us another approved modification in Boeing's growing family of ISR airplanes," said John Rader, vice president of Electronic and Sensor Solutions.
Fairfax, Virginia

13 TRIALS ON C-SERIES

Bombardier conducted the first test flight of its CSeries jet since an on-the-ground engine failure in May set back efforts to introduce the airliner in 2015. The CSeries took flight on September 7 at Bombardier's facility in Mirabel, Canada. The flight followed an in-depth review and analysis of an engine-related incident that occurred during stationary ground maintenance testing of the jet's engines. The jet is expected to enter service in the second half of 2015.
Mirabel, Canada

SENTINEL SPY PLANE GETS NEW TRIAL MISSION



Enhanced surveillance systems are to be trialed on one of the Royal Air Force's Raytheon Sentinel R.1 airborne stand-off radar (ASTOR) aircraft as part of an effort to boost its multimission capabilities.

The move was revealed by RAF officers and Raytheon the day after UK Prime Minister David Cameron announced on July 14 at the Farnborough International Airshow that funding had been secured to keep the aircraft and its support infrastructure in service after British troops return from Afghanistan at the end of this year.

Funding has been found from the Ministry of Defence's underspend to keep the Sentinel in service until at least 2018, although it is anticipated that the manning and equipment operated by the joint RAF-British Army unit responsible for the system, 5 (Army Cooperation) Squadron based at RAF Waddington in Lincolnshire, will undergo some reduction to prune back running costs. After the end of the year, when the last of its aircraft and personnel return from Afghanistan, 5 Squadron will no longer have to sustain its operations at war-time levels, allowing some streamlining of spend and activities.

The upgrade move is part of a £1.1bn (US$1.8bn) package of funding to enhance the intelligence, surveillance, targeting, acquisition and reconnaissance (ISTAR) across the UK armed forces to improve their ability to track terrorists and other threats in complex environments around the world. Cameron cited the crisis in Nigeria, where a RAF Sentinel was, as he spoke, deployed to hunt for 200 kidnapped schoolgirls, as the type of mission he aims to focus on.

According to Raytheon officials, the intention is to introduce four enhanced capabilities onto the Sentinel platform: a specific maritime function for the aircraft's radar system (which works in dual synthetic aperture radar and ground moving-target indicator modes); options for long-range optics – most likely based around the DB-110 dual-band electro-optical airborne reconnaissance sensor; options for signals intelligence (SIGINT); and an enhanced airborne mission system. The maritime radar mode is especially seen as a quick win, given that this would largely be a software upgrade to the sensor.

Wing Commander Dave Kane, officer commanding 5 Squadron, told the Farnborough briefing: "We have another three to four years in the game so we have the opportunity to develop the systems further. There is a lot of engagement out there – we are interested in a good platform."

In the post-Afghanistan world, the squadron would be expected to support the UK's new aircraft carrier, HMS Queen Elizabeth, in littoral, amphibious and humanitarian operations. "This is a big area for us to get involved in after Afghanistan," he said.

According to Kane, any upgrades and new missions would seek to capitalize on the systems successes in Afghanistan, Libya, Mali and Nigeria, where it has worked effectively as part of the ISTAR constellation to bring together multiple systems to build up an intelligence picture that can be exploited by other forces. "We are the Google search engine for people who are not sure where they are going or what they are looking for," he said. "We help narrow the search."

MARITIME MODE

Paul Francis, head of business development for Raytheon UK, said the company was looking to migrate the maritime radar mode software it has already developed for other customers onto the Sentinel's radar. This would allow the RAF to better identify maritime

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AEROSPACE TESTING INTERNATIONAL EXCLUSIVE

targets, such as submarine periscopes. During the Libya conflict in 2011, the Sentinel was used to provide daily updates to coalition commanders of the distribution of Libya's naval vessels in their ports but the performance of its radar needs to be enhanced to monitor targets further out to sea.

A big part of the trials effort will be to come up with enhancements to the systems used by airborne and ground-based crews to plan missions, analyze imagery and then manipulate and distribute this to customers. Raytheon has already funded the development of the Overseer mission management system, based on open architecture computer technology, which was currently being used by 5 Squadron, with more development expected in this important area.

Francis said it was envisaged that any electro-optical sensor could be installed above the aircraft's cockpit, in the 'bulge' currently used by a line-of-sight data link. Operational experience and new communications technology mean Sentinel crews are making less use of the data link to pass products to ground stations and are increasingly employing satcoms. Aerodynamic issues involved in installing a sensor turret on the Sentinel aircraft, also made this a better solution, he said. This project has grown in importance as the 2019 out-of-service date of the RAF Tornado GR4 – the only RAF aircraft capable of carrying the Goodrich RAPTOR photographic reconnaissance pod – approaches.

The upgrade trials to the Sentinel are expected to spread across Raytheon facilities in the USA, its site at Broughton near Chester, UK and at RAF Waddington. Company representatives and the RAF are already considering how to prioritize the trials work with maintenance work required on the aircraft once the Afghanistan mission is complete.

"We are not sure if trials aircraft will remain under RAF control or be passed to the contractor to work on," said Kane. "It is too early to say. We have five aircraft but we need to do the trials work."

Once the trial work is completed a business case will be made to the Ministry of Defence to secure funding for any upgrades to be purchased and installed on the aircraft, said Kane. Priority will be given to upgrades that bring rapid benefits. "They need to be readily deployable," he added. ∎

MITSUBISHI REGIONAL JET BREAKS COVER

After the protracted development of Japan's first jet airliner, highlighted by design changes, technological challenges and management restructuring, there seems to be light at the end of the tunnel with the first prototype breaking cover and new orders announced.

On May 7, 2014, the Mitsubishi Regional Jet (MRJ) static test aircraft was transferred from the final-assembly facility of the Nagoya Aerospace Systems Works at Aichi to the strength test station to start preparations for static strength testing. In June, Mitsubishi Aircraft Corporation (MAC) took delivery of the first 78.3kN PurePower PW1217G engine and 10 days later the wings of the first flight test aircraft were mated with the fuselage. In July, MAC seized the opportunity to make several important announcements about the MRJ program at the 2014 Farnborough International Airshow, including new customers and an additional flight test program.

Speaking at the show, MAC's president, Teruaki Kawai, told *Aerospace Testing International* that the MRJ90 is going well and that the aircraft will be rolled out in late Q3 this year. The first flight is scheduled for Q2 in 2015 with the first delivery in 2017. Kawai said that production could reach 10 aircraft per month in three or four years' time (2019). In the meantime, the company is talking to potential customers in Latin and Central America. In a major disclosure Kawai added that no decision has been made to develop the stretched version, the 100-seat MRJ100X, although the potential market for the 76-seat MRJ70 is being investigated. Hideyuki Kamiya, MAC's head of marketing, said that there may be some possibility of selling a variant of the MRJ to the Japanese Air Self-Defense Force at some point in the future.

SECOND OPINION

Right now the main focus is on the test program. With static testing underway and the imminent roll-out of the first test aircraft, which will be used for flight envelope expansion and system tests, the second of five flight test aircraft, which will be part of the 2,500-hour flight test program, is in final assembly. A second static test aircraft will join the program at the end of 2015.

Meanwhile Pratt & Whitney's next-generation product family vice-president, Bob Saia, has announced that development of the MRJ's PW1200G PurePower geared turbofan engine has proceeded beyond the halfway point of its certification program following delays suffered by the MRJ itself. Four test engines were running when the program was slowed to align it with the MRJ's airframe progress.

With the announcement in July of the first MRJ order from a US airline came the news that a considerable amount of the flight test program will take place in the USA. MAC has concluded a letter of intent with Aerospace Testing Engineering & Certification (AeroTEC) to undertake a series of flight tests at the Grant County International Airport at Moses Lake in Washington state. An engineering corporation based in

MARKET POSITION

The MRJ has been marketed as creating a new standard for next-generation regional jets, with its state-of-the-art geared turbofan engines, aerodynamic design and noise analysis technology, which will offer reduced fuel consumption and noise footprint, and enhanced passenger comfort.

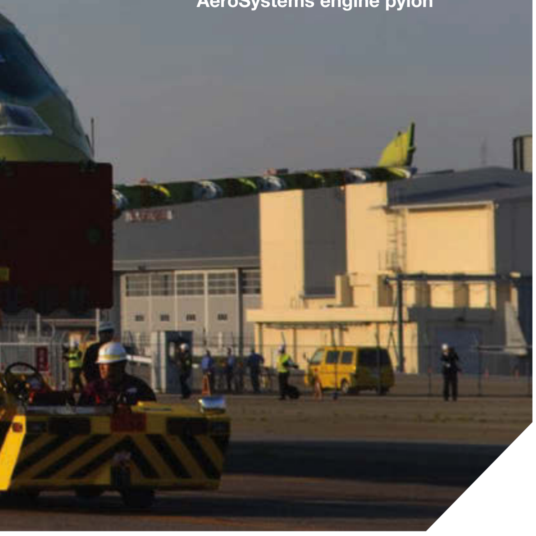
Mitsubishi Aircraft Corporation's head of marketing, Hideyuki Kamiya, believes that demand for the 70- to 90-seat class regional jet aircraft will reach more than 5,000 over the next 20 years and that the MRJ will capture 50% of that market.

The first MRJ90 static test airframe was completed in May 2014 and moved to the Aichi static test hangar

BELOW: Assembly of the first MRJ90 test aircraft has been completed, ready for its roll-out later this year
All photos: Mitsubishi Aircraft Corporation

ABOVE: The first MRJ90 airframe installed in the static test rig

ABOVE: The first PW1200G PurePower geared turbofan engine was delivered to MAC in June 2014 and mounted on the first MRJ90 test aircraft's Spirit AeroSystems engine pylon



Seattle, Washington, AeroTEC was founded in 2001 to provide turnkey flight testing, data analysis and FAA certification services for aircraft OEMs and modifiers. The company's core team comprises 17 aerospace engineers, technicians and mechanics and it is able to expand its staff as required with specialist consultants. AeroTEC is well versed in planning, testing and certification requirements of performance, stability and control, flight simulators, powerplant, structures, systems and equipment, as well as FAR Part 36 Noise including FAR Part 25 and 23, CAA and JAA regulatory requirements.

AeroTEC's president, Lee Human, told *Aerospace Testing International* that the company will be providing comprehensive flight test services to MAC to support the development and certification of the MRJ family of aircraft. These services will include test pilots, flight test engineers, instrumentation technicians, flight operations support, maintenance support and FAA coordination.

"We are expanding our existing Moses Lake flight test center to accommodate the program, and the expansion includes a new 65,000ft^2 hangar, which will be completed by September 2015, office facilities and other test support systems," said Human. "Although I'm not at liberty to discuss the details regarding flight hours or timeline, as this is MITAC information, I can confirm that substantial support will be provided by AeroTEC."

MAC's Kawai revealed that 50 to 60 Japanese engineers and technicians will be based at Moses Lake for at least a year, and a smaller number will stay for three or more years as follow-on variants of the MRJ are tested. Three MRJ90 test aircraft will be tested in the USA at the same time as two in Japan.

MAC selected Grant County International Airport at Moses Lake, which is only few miles from where Clyde Pangborn and Hugh Herndon landed their Bellanca J-300 after completing the first non-stop 41-hour transpacific flight from Japan in 1931, due to the large aerospace industry cluster in Washington, the birthplace of the Boeing Company. The airport, a US Air Force base until 1966, satisfied all its requirements for a flight test center, including 13,500ft runways, which are necessary for specific flight tests, flexibility for take-off and landings due to there being no regular transport services, and a great chance of good weather. The MRJ test program also renews another link between Japan and Moses Lake, which was used for 40 years until 2008 by Japan Airlines (JAL) to train more than 10,000 of its aircrew to fly its Boeing 747-400s.

With aircraft now coming off the assembly line, static testing underway and a comprehensive flight test program initiated in Japan and the USA, MAC is able to concentrate on increasing its share of an increasingly competitive market that includes Canada's Bombardier CSeries, China's Comac ARJ21-700 and Brazil's Embraer E2.

To date, 191 MRJ90s are on order, with options for another 184 aircraft from five airlines. All Nippon Airways has 15 aircraft ordered plus 10 options, Air Mandalay has six plus four options, Eastern Air Lines has 20 plus 20, Trans States Holdings has 50 plus 50, and SkyWest has 100 plus 100. MAC must now live up to its claim to be able deliver aircraft that live up to their projected high standards, on schedule and at a price to prove that it will be a viable competitor to the established US, European and Brazilian commercial aerospace giants. ▮

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GARNET RIDGWAY

IVORY TOWER OR SHOP FLOOR?

The aerospace testing community is made up of individuals from a diverse range of backgrounds, but does formal education offer an advantage over on-the-job training?

SOPHIE ROBINSON

There is clearly a place for both formal and on-the-job education and training in the aerospace testing world – but there are some unique advantages to the former.

The first point to note is that in the 21st century, 'formal' education in engineering-related subjects is no longer the entirely academic, abstract entity of the preceding centuries. Even the highest of university qualifications will generally contain vocational elements and transferable skills such as project management, problem-based learning and industrial collaboration, thus militating against the traditional disadvantage of such qualifications being considered irrelevant to the 'real world'.

Garnet Ridgway has a PhD from the University of Liverpool. He has designed cockpit instruments for Airbus and currently works for a leading UK-based aircraft test and evaluation organization

Recruiting university graduates is vital to maintaining the innovative edge of a testing organization. If every new recruit to the organization were trained entirely in-house, how would new ideas or ways of thinking ever be expected to prosper? While it's arguably the case that graduates have a higher initial training burden associated with them than those who have moved up from junior positions within the organization, this is far outweighed by the benefits of fresh thinking. Rather than simply working through an assigned task, a graduate is more likely to wonder: "Is this really the best way to do this?" Such an approach is critical to sustaining the long-term health of a testing organization in a competitive market.

An increasingly common feature of modern aerospace testing programs is that they are collaborative, spanning a number of organizations with various responsibilities. For this reason, the concept of SQEP (suitably qualified and experienced personnel) is something that must be universal among the stakeholders; the SQEP criteria of each organization may not be recognized by the others. Formal qualifications, such as university degrees, provide just such an independent SQEP criterion.

Formal higher education has received some criticism in the past for being irrelevant to real-world applications. However, a combination of relatively recent changes to typical course content and the advantages that can only be gained from employing graduates means that there is certainly still a place for formal education in the aerospace testing community. Most crucially, the transferable, problem-based skills that graduates bring are vital to equipping organizations to survive and thrive in a changing market.

While academic qualifications bring prestige and a string of letters after your name, the average new English university graduate can now also expect to have more than £30,000 (US$48,000) of debt. For many this is too large a disincentive, and as a consequence the engineering industry loses a large portion of the available talent to more traditional vocational careers. This is an untenable position – but our industry seems to be realizing this, and focusing increasingly on offering more on-the-job training to attract the best and the brightest young engineers.

For once I agree with my sparring partner to the left – formal higher education has received criticism for being irrelevant to real-world applications – and rightly so. Rote learning and a focus on grades and classifications can stifle the spirit of innovation and creativity so sorely needed within the engineering community.

It also takes more than just a university degree to qualify as SQEP in today's test and evaluation environment. Companies offering on-the-job training can tailor their training programs to accelerate their trainees and give them the required skills to become SQEP in their roles much faster than the more generalist approach taken in a typical degree course. This is also by far the most efficient and effective way to spend a training budget – start with employees with evident potential, develop them, and your business will gain employees with the required skills to excel in their roles. This is doubly beneficial in test and evaluation, where the required skills are difficult to teach in an academic environment and there are few opportunities to gain practical experience.

Sophie Robinson is currently finishing her PhD as part of the Flight Science and Technology Research Group within the Centre for Engineering Dynamics at the University of Liverpool. In the course of her research, Sophie regularly works with test pilots

Businesses can also use on-the-job training to ensure that skills crucial to their company aren't lost if a specific member of the team leaves or retires – something of paramount importance in test and evaluation, which can be a very niche field.

On-the-job training and academic qualifications aren't mutually exclusive either; the modern apprentice often has both. As the value of vocational training is becoming more widely recognized and the training itself is becoming more formalized, many apprentices and trainees go on to convert their experience into higher qualifications and degrees. Now if only I could recycle the bit of my brain that can still remember how to derive the Maxwell-Faraday equation from first principles and use it for something of more practical benefit…

Ship shape

After more than a decade in service, BAE Systems Warton's F-35/Queen Elizabeth class simulator has gained an LSO position – with plans for six further flight control staff in place for First of Class flight trials in 2018

BY PAUL E EDEN

In 2017 the Royal Navy expects to begin sea trials of HMS Queen Elizabeth, the first of two Queen Elizabeth class (QEC) ships designed specifically to embark the Lockheed Martin F-35B Lighting II. All being well, the first of the 48 Lightning IIs that the UK has on order should begin operating from the ship in 2018, beginning with a first deck landing that will be much more a validation of simulator experience than a trip into the unknown.

Pete 'Kos' Kosogorin, a BAE Systems F-35B experimental test pilot, recently visited HMS Queen Elizabeth, under construction at Rosyth, Fife. Standing in the ship's flying control center (FLYCO) he commented: "It's really exciting because it looks so familiar. I can see how vast, how wide and how long the deck is, and it looks familiar because of the simulator work we've been doing at Warton, in terms of integrating the F-35 into the ship using the shipborne rolling landing technique, the normal vertical landing and short take-off operations. That simulation work is part of a wider carrier integration effort at Samlesbury and Warton that has allowed us to find efficiency and savings in the design of the carrier, its deck, the array and the systems that assist the pilot in approach and landing."

A member of the F-35 Integrated Task Force at Naval Air Station Patuxent River, Maryland, for the past four years, Kosogorin explains more about the simulator's role: "The sim work hasn't just been about developing the flight controls software in the aircraft, it's also about finding out how to fly and carry out certain maneuvers, and working out various flying techniques, such as shipborne rolling vertical landing. We've brought together a cross-section of individuals to do that, from very experienced Harrier pilots to US Navy conventional F-18 pilots, and also Royal Navy and other air force pilots who have no shipborne or STOVL [short take-off/vertical landing] experience, to ensure the design is optimized for all levels of ability and all levels of scale."

HARRIER LEGACY

Comparisons are frequently made between the F-35B and the Harrier; they are usually misleading. But in the case of BAE Systems' F-35/carrier flight simulator, earlier work with the legacy jet and Invincible class ships has helped lay the foundations for Warton's 21st century simulator design. As David Atkinson, F-35 Carrier Integration Lead at BAE Systems, explains, the result is a flexible system with capabilities beyond F-35B: "We've been conducting flight simulation at Warton for over 50 years for many projects, including simulating Harriers operating from the recently retired Invincible CVS class. The F-35/carrier flight simulator has been developed to support the integration of the F-35 to the QE class ships. It is, however, capable of simulating F-35C to aircraft carriers with catapults and arrestor gear, and has been used for assessment of various flight control developments for F-35C to CVN and, while the UK was considering a CV-converted QE class ship, for F-35C to QE."

Unlike the more familiar full mission simulator, the F-35/carrier sim focuses on the near-ship environment, primarily for the assessment of launch and recovery operations, including circuits around the ship. It uses a Lockheed Martin F-35 six-degrees-of-freedom mathematical model validated against extensive flight test data; a QEC ship motion model provided by the Aircraft Carrier Alliance (ACA),

The simulator in action for a carrier approach

8	Number of personnel to be integrated into the F-35/QEC flight simulator
40	Maximum QEC F-35B complement (20 on deck, 20 below)
300	Take-off run in feet from QEC for lightly loaded F-35B
800	Take-off run in feet from QEC for fully loaded F-35B

ABOVE: Looking on from the simulator facility at F-35 testing

based on tank test data; and a computational fluid dynamics (CFD) ship-airwake flowfield that is being further developed and validated by the University of Liverpool.

Realism has been further enhanced by the recent addition of a landing signal officer's (LSO) station. The LSO's role will be similar to that aboard an Invincible class ship, but according to Atkinson there will be "a larger workstation and more sophisticated situational awareness aids and information displays".

Describing the simulator's design and how the LSO station is integrated, Atkinson continues: "From a physical point of view it has a hydraulic motion platform within a dome and uses motion-cueing algorithms to enable the pilot to feel aircraft motion in a very realistic way, despite remaining very firmly on the ground. High-specification projectors are used, with a very high-resolution projector for the pilot's forward field of view. It has a second projected screen display to represent part of the FLYCO – the LSO workstation, at which a pilot can operate as an LSO, interacting with the pilot flying the simulator, while watching the aircraft maneuver in real time. The combined motion simulator and FLYCO representation have proved very valuable while developing maneuvers, operating procedures and display layouts."

SIMULATOR AMBITION

Allowing pilots to fly F-35B approaches in cooperation with an LSO, as they will on the real carrier at sea, is already delivering immense value to the program, but Atkinson says that the simulator is scheduled for much greater capability. "Our ambition is for the simulator to be used for wider purposes than pilot and LSO interactions. We already have provision for hosting the tower controller, who is the air traffic controller in the FLYCO. Longer term we would like to expand the FLYCO representation to include all FLYCO personnel, for a total of seven personnel working closely together. We already use the simulator for experiments taxiing the aircraft around the flight deck, exploring options for siting cameras and understanding the effects of different flight deck marking schemes. It is a hugely flexible tool for a wide range of purposes."

And while deck markings may seem a rather prosaic thing to test in a multi-million pound simulator, Kosogorin says, "What we've done in the simulator is incredibly important because the results of those trials have fed into the design of the deck – to influence its markings, lighting and systems."

The F-35's complex, software-driven systems interface with the pilot via a large head-down display and a helmet display. This next-generation functionality is built into the simulator, as Atkinson describes: "We can use the simulator with a representative helmet-mounted display and the cockpit has training-standard fitments for the left and right inceptors (throttle and stick in legacy aircraft) and cockpit displays. As ever, we continually seek to improve the fidelity of the test environment for the pilots and we will be upgrading the simulator soon to provide an even more representative cockpit and FLYCO."

As well as being used for prediction and validation, there is also a very clear role for the simulator in defining the flight test program that should begin in 2018, leading to service entry in 2020. BAE Systems calls the initial at-sea F-35B/QEC proving work 'First of Class Flight Trials', and Atkinson explains the simulator's role in this crucial phase: "We expect to use the simulator to help develop the test points that need to be flown for real on First of Class Flight Trials. We also expect the test pilots to 'fly' each of the test points in the simulator before they deploy to the ship. Just as important as the pilot training and de-risking aspects of this, we will obtain predictions for key parameters from the simulator that we will use to assess the flight test results and create a basis on which test progression can be agreed during flight trials."

SIMULATOR STATUS

Warton's F-35/carrier simulator is a busy facility and already Royal Air Force, Royal Navy and US Navy pilots have flown it, as have BAE Systems and Lockheed Martin test pilots. As Atkinson notes, the reasons behind this extensive exposure are manifold: "The benefits to the program are that we always seek an input of experience from the widest possible test pilot community to ensure that nothing major has been missed in the assessments, to gain the benefit of the immense pool of experience available in the findings and recommendations from the trials, to allow pilots to discuss thoughts and ideas between themselves, and also to allow pilots to help us communicate the cutting edge way in which we are developing the F-35-to-QEC aviation interface."

BELOW: View from the cockpit

Work to date has driven modification and refinement in carrier flight deck design, aircraft design and operational procedures. "We've conducted a number of trials to develop the F-35B to QEC vertical landing, ski-jump launch and shipborne rolling vertical landing maneuvers and the supporting systems; visual landing aids (flight deck lights, glidepath indicators), F-35B helmet mounted display symbology, LSO situational awareness aids and standard operating procedures.

"We've helped the MoD and the ACA optimize and gain confidence in their designs and likewise for some changes we've made to the F-35B, to allow shipborne rolling vertical landings to be conducted. These are unique to the QE class and involve a rolling vertical landing onto the ship's 'runway' with 30 to 40kt of overtake, allowing increased bring-back weight performance for the aircraft, which should pay dividends on operations," says Atkinson. The next phase of testing will more overtly inform the flight trials that are now just four years away, generating additional evidence for aircraft load assessments, safety assessments and flight test clearances.

Of course, the simulator is the right place to discover problems as well as to test and expand capability. Over more than a decade of work, Warton's F-35/carrier simulator has identified and helped fix various issues, as well as facilitating the safe expansion of the operating envelope. "The QE class has an immense flight deck with state-of-the-art visual landing aids," says Atkinson. "The F-35 is a hugely capable 5th generation aircraft that pilots find easy to fly to a ship and we believe that there are lots of good ways to operate the F-35B to a ship the size of the QE, with our role being to optimize the designs and procedures to maximize performance. We've identified a few issues and concerns through the simulation work, but thankfully it also provides an ideal environment to visualize problems, explain them and rapidly show how potential solutions would work. Between the MoD, ACA and ourselves we have identified and resolved a number of issues over the 10 plus years that we've been working together using the Warton simulator."

INFORMING THE FUTURE

There will be no two-seat F-35 for training purposes and fairly quickly into the UK F-35B's operational service, pilots will begin coming to the aircraft direct from advanced fast jet training on the RAF's BAE Systems Hawk T.Mk 2. According to Kosogorin, who has handled a Harrier at sea, they will discover an aircraft of hitherto inconceivable capability: "The control and handling it has at slow speeds in STOVL mode 4 is exceptional. I've landed at night on a ship in the Harrier and that's a really exciting – but also scary – event. You are probably the most aroused you will ever be as a pilot in terms of focused concentration, but that doesn't mean you can't make a mistake. When a pilot is working really hard he's using up a high proportion of his capacity, so his ability to spot things and to cope with things is affected. In the Harrier, you could easily miss an aspect of your technique, miss a problem with the aircraft, or not hear a radio call, so it was easy to lose track of what was going on. But this aircraft works really well for you, so the extra capacity that allows you is a big bonus. It means a pilot can deal with an emergency more effectively, or follow a particular technique better, so the execution of your approach and landing on a ship is going to be way more efficient."

Nevertheless, the leap from the Hawk to the stealthy, supersonic, sensor-fused Lightning II will be a big one and much of the training burden that creates will be satisfied in the simulator. The potential of Warton's F-35/carrier simulator to begin the definition of a future training syllabus even as its test work continues is obvious and Atkinson confirms its role, not only in pilot training, but also for flight deck crew: "We have already used the simulator to inform the training syllabuses and help our customers understand the benefits of immersive simulation to their training processes for the pilot and LSO. What is abundantly clear is that simulation technology is here to stay and continues to increase its role in development and training based on cost-effectiveness and an ever-increasing ability to emulate the real world." ∎

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

BELOW: **Inside the F-35/carrier simulator 'control room'**

Waiting for the 'bus

By involving test engineers and pilots earlier in new airliner development programs, Airbus believes it can shorten the airworthiness approval (or certification) process, while providing a more reliable product more quickly

BY IAN GOOLD

AIRBUS PROGRAM DEVELOPMENT TRENDS

Model	Certification time
A300	1974 – 17 months
A320	1988 – 12 months (1,200 flight hours)
A340	1992 – 14 months (2,000 flight hours)
A330	1993 – 12 months (1,800 flight hours)
A380	2007 – 20 months (2,500 flight hours)
A350	2014 – 15 months (2,500 flight hours)

The new Airbus A350 jetliner, which should receive European airworthiness approval (or certification) during September, has been the manufacturer's first test of an evolved development program that could see improved aircraft entering service more quickly, says flight and integration tests senior vice president Fernando Alonso. Having seen ever-lengthening certification periods, Airbus decided to introduce accelerated test procedures that also aimed to increase customer satisfaction from the outset through delivery of more mature machines.

In the 1980s, flight test programs had grown longer, from a year through 14-16 months to 20 months, according to Alonso, while regulations were becoming more sophisticated and technical. But no development served to act as a catalyst to change certification procedures or pace. Accordingly, his solution was to introduce flight test involvement "upstream, to be more involved earlier; there was no justification not to change things". He says the exercise involved "huge" investment to set up the related ground test facility.

"There has been a continuing deterioration in certification times," according to Alonso. He says one objective in development of the A350, which completed certification flying in mid-August, is to try to reduce the lead time while also improving safety. Accordingly, as the giant A380 double-decker quadjet entered service in 2007, the company established a new flight and integration tests center (F&ITC) that has seen pilots also participating in systems ground testing.

Aiming to "excel in testing and test for excellence", Alonso wanted "to involve pilots as far upstream as possible" in a search for, as it were, flight development holism. The philosophy has become: "Look at the aircraft as if you are the first customer, not the designer. Remember, it is going to be flown by people to carry people," says the Airbus official.

The trend toward longer certification periods will be reversed by beginning tests earlier, Alonso pointing out that the A350 campaign – about 15 months long – contrasted with the 20 months devoted to the A380 quadjet (see table, opposite). He believes the relatively greater speed with which the A350 approval program has been completed is very much a product of the new Airbus approach.

Asked just how quickly it might become possible to certificate future

LEFT: MSN004 traveled through troughs containing at least 22mm of water depth, at a variety of speeds, starting at 60kts, and successively increasing to around 140kts, during recent water ingestion testing

MSN001 COMPLETES MERTO TEST

Airbus successfully performed the 'maximum energy rejected take-off' (MERTO) test with the A350 MSN001 on the morning of Saturday, July 19, at Istres Air Force Base in France. MERTO, which follows on from the previous 'high energy rejected take-off' (HERTO) preparation test conducted by MSN001 in May, is a part of the mandatory series of tests for certification.

This latest test is to confirm the braking system's ability to safely stop the aircraft following a rejected take-off at high speed and high weight – using a set of worn-out brakes. As these brakes absorb the kinetic energy of the aircraft, they glow bright orange and reach a temperature of around 1,400°C by the time the aircraft has safely come to a standstill, whereupon the tires are deflated by special fuses.

According to certification requirements, the aircraft then has to stay put for five minutes unassisted, after which firefighters are allowed to spray the wheels and brakes to cool them. The Airbus test team received full support from the DGA (Délégation Générale pour l'Armement) – Essais en vols, which played a key role in facilitating the test.

MERTO was the A350 XWB program's final major test before MSN005, one of two cabin-equipped development aircraft, embarked on 'route proving' in July. By the end of that month, the program had achieved more than 2,250 flight hours in around 540 flights, and is on track for certification in Q3 and first delivery to Qatar Airways in Q4 of this year.

new aircraft, Alonso foresees the day when nine months' calendar time might be sufficient. For the moment, however, he says that the company's primary aim has been to show that the trend toward increasing airworthiness-approval time can be reversed.

Alonso explains that before 2002 (when Airbus was already heavily engaged in development of the A380, launched two years earlier following long project studies), the manufacturer had separate flight and ground testing sections with the drawing office including both design and testing of systems. By 2007 when the A380 entered service, the test organization involved two distinct sections, one looking after systems and cabin testing and the other overseeing development and production testing of new aircraft. Alonso's concern since then has been to establish continuity "so that the same guys who test on the ground should also do it in the air".

The Airbus flight and integration tests chief is passionate about the need for such change: "To reduce certification periods, you must start testing earlier, on the ground. So much can be done with test rigs with adequate investment and more representative equipment but, of course, there is also so much that you can see only in the air." Since developing the A380, Airbus has had the opportunity to evolve the translation from drawing board (or, rather, computer screen) to the production aircraft, concludes Alonso.

Saying that engineers "love to see how the air moves over the wing", Alonso provides an example of evolving technology: testing and measuring aerodynamics, a development he dubs "wings of change". Historically, wing surfaces carried myriad static-pressure test points linked by bundles of tubes to a blowing system, multiple sensors, a plenum chamber, metallic 'gloves' and a leak detector; on the new A350 many multipressure sensors were taped to the wing surface and fed a single cable.

BIG DATA

Aerospace, of course, has been a leading applicant of digital technology, and Alonso says the past quarter-century has seen exponential growth in the volume of test information that can be captured for analysis under what he terms a "big data project". Since the A320 single-aisle twinjet first flew in 1987, "The number of parameters recorded has increased by a factor of 50, leading to the opportunity to improve maturity through analysis of the data collected." (See table, left.)

Alonso lists three factors contributing to the data increase: available technology to record behavior of increasingly interactive and complex aircraft systems, more-demanding airworthiness requirements, and customers' expectation of more-mature aircraft at entry into service.

Before first flight, virtual testing enables Airbus to capture better

ABOVE: Maximum wing bending test – at ultimate load, the A350 XWB wingtip deflection exceeded 5m

AIRBUS BIG DATA PROJECT

Model	First flight	Parameters monitored*	Data archived**
A320	1987	12,000	8.5TB
A340	1991	14,000	12.8TB
A380	2005	320,000	57.0TB
A350	2013	670,000	53.0TB

**Per flight-hour **Flight test campaigns continuing*

knowledge of the aircraft and to optimize flight tests. On the A350, the flight testers were first engaged on the systems integration testbed, involving many simulators and rigs, in an effort to check "as much as possible, as soon as possible, and to reduce flight-test time to a minimum". For example, under the new F&ITC regime, the A350 flight crew involved in ground tests were able for the first time to demonstrate operation of landing-gear retraction on ground test rigs two years before the aircraft flew.

One obvious advantage of the integrated operation is that knowledge can be shared more readily among all parties. Under previous practice, there had been occasions when it became clear that things discovered in the air had previously been uncovered by ground test engineers without information reaching flight test personnel.

This stimulated motives to improve procedures and results through better communication between test disciplines. "To avoid a loss of information at the interface, it is best to have no interface," says Alonso, explaining that the current F&ITC structure was adopted only after the A380's development, which provided "a fresh reminder that there could be a better way".

WHAT NEXT?

With A350 certification complete, the F&ITC remains engaged in a "very significant" volume of activity: "There will always be aircraft modifications and upgrades." For example, Alonso's team is currently flying 22 test aircraft involved in six major or continuing development programs (see table, above right). Next year, there will be 16 machines in the test fleet and 19 in 2016.

The F&ITC must also test 600+ production aircraft this year, the whole activity employing more than 110 pilots, flight test and test flight engineers, and 35 ground test engineers. Meanwhile, Alonso hopes his organization can "stay small to remain reactive, very agile and close to the product".

On the degree to which airworthiness clearance can be credited for a new model's commonality with earlier variants (so-called 'grandfather' rights), the Airbus official says that the advent of new standards has introduced differences between successive models. This leads to negotiation with regulators: "It's a big problem, as airworthiness authorities are more and more allowing less and less," with health and safety being among considerations that make regulators averse to taking perceived risks.

Alonso wanted to use the A350 program to check whether it might be possible to reverse the trend toward increasingly long flight test periods: "Clearly, the answer is 'Yes'." He is not sure that future certification could be achieved in as few as nine months – Airbus is considering such a period, especially as its next program is the A320neo, a re-engining of an approved design – but believes it should be possible for the complete certification campaign of a clean sheet design.

With Airbus preparing to fly the new A320neo variant in September, Alonso is satisfied that the accelerated test campaign adopted for the new A350 will prove to have established a baseline for the future. "We can do many things with virtual means, but real flight tests will always be necessary. There will always be a need to fly aircraft." If Airbus can confirm its ideas with results from the A350 test campaign, then, says Alonso, "We will know we are doing the right thing."

Ian Goold is a UK-based freelance writer specializing in the aviation industry

AIRBUS FLIGHT TEST DEVELOPMENT FLEET

Date	Test fleet	Models under current and continuing development: Major	Continuing
2014	22 aircraft	A350-900, A320neo	A380, A340, A330, A320, A400M
2015	16 aircraft	A350-900, A320neo	A380, A350, A340, A330, A320
2016	19 aircraft	A350-1000, A320neo, A330neo (?)	A380, A350, A340, A330, A320

ABOVE: **MSN003 undergoing lightning strike testing**

BELOW: **Hot fuel certification testing during the A350 XWB's first landing in the UK**

350	Number of parameters monitored by the flight test station on board MSN005
84,000 lb	Thrust rating of MSN005's Rolls-Royce Trent XWB engines
43,000ft	The maximum altitude reached during A350 testing so far (approximately 8 miles)
685mph	The maximum speed flown during testing has been clocked at Mach 0.9 (685mph)

View finder

Synthetic vision systems have made the transition from revolutionary to routine in a remarkably short time – now their manufacturers are pushing the technology to do more

BY BERNARD FITZSIMONS

Avionics that simply enhance safety are not an easy sell. Professionally operated aircraft hardly ever crash, so how much safer do they need to be, and how can the return on investment be calculated? But enhancing operational integrity at the same time, for example by making it possible to land at an otherwise inaccessible airport and avoid an expensive diversion, can save money on a big enough scale and in a short enough timeframe that even airlines might be tempted to invest.

Enhanced vision systems, typically using an infrared camera with the imagery projected on a head-up display (HUD), have been used to achieve lower decision heights – the height above the runway where pilots must execute a missed approach if they cannot see the runway lights. Synthetic vision systems, which use databases to generate a stylized picture of the outside world, enhance situational awareness and can reduce workload. Now avionics vendors are pushing either to combine the two, or to achieve lower minimums using standalone synthetic vision enhanced with HUD symbology.

Rockwell Collins, which has delivered more than 5,000 head-up guidance systems, is developing a head-up vision system that will combine synthetic and enhanced vision on a HUD.

"We are confident that our head-up vision system will enable even lower landing minima in the future, creating greater access to airports during low-visibility conditions," said Jeff Standerski, the company's vice president and general manager, business and regional systems, at last year's NBAA convention.

Initial test flights in 2011 using a Bombardier Global 5000 compared varying combinations of flight guidance symbology, with and without synthetic vision, on both the HUD and the head-down display during instrument landing system (ILS) approaches. Preliminary results indicated that ILS tracking accuracy

MAIN IMAGE: Honeywell's SmartView combined vision system in the company's AW139 test helicopter

INSET: SmartView combines flight symbology and 3D terrain on the Primary Flight Display (PFD)

improved 70% laterally and 25% vertically when synthetic vision imagery was displayed on the HUD. Tracking on the head-down display also improved when synthetic vision was added.

Honeywell, meanwhile, has certified its SmartView synthetic vision as part of the primary flight display on multiple Gulfstream models and on Dassault Falcons with its EASy II cockpit. Now the company is looking to achieve lower approach minimums by combining the synthetic terrain imagery with HUD symbology on a head-down display.

MIND'S EYE

"What we try to do is design for the mind's eye," says Aaron Gannon, a staff scientist with Honeywell's human centered systems team, who specializes in flight deck design. "We can design for software and we can design for hardware." But the hardware and software he is talking about are those in the human brain.

"Hardware tends to be the things you were born with, your visual cortex, the onboard processing that is already there," he explains. "It's your way of perceiving the world without a lot of training." The software, on the other hand, "tends to be the side that we have to train". That requires a lot of time, exemplified by the substantial amounts of initial and recurrent training involved in teaching pilots how to use systems. So the idea behind the SmartView primary flight display is, "first of all do things in hardware; don't require a lot of training".

Gannon traces the history of SmartView back to the Sperry artificial horizon that Jimmy Doolittle used for his pioneering 'blind' flight in 1929. And just like Doolittle when the hood went up and occluded the outside world, he says, pilots flying on instruments are "trying to re-imagine what the view looks like out the window from the readings on their instruments".

That involves three basic tasks. "First of all they have to scan the instruments, the attitude indicator, which is the centerpiece, the airspeed indicator and the altimeter." Then they have to interpret: "put that into some kind of context that makes sense". After that comes aircraft control.

"Those three basics – scan, interpret, aircraft control – have not really changed until we developed three-dimensional SmartView technology," says Gannon. SmartView tends to reduce workload at the same

MAIN IMAGE: Rockwell Collins' EVS-3000 offers an uncooled solution that can detect all runway lighting, including new LED systems

ABOVE: Rockwell Collins' HGS-3500 enhances situational awareness and safety during all flight phases

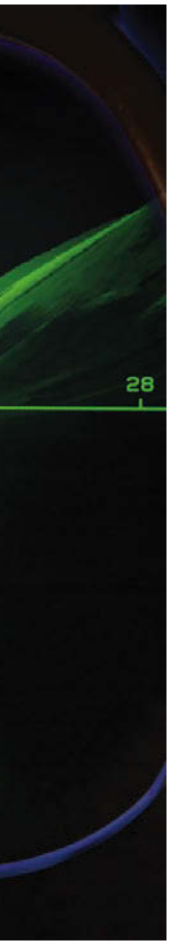
time as it increases situational awareness. "Now the pilot has a context in which the scan, interpret and control can take place."

Honeywell embarked on the SmartView program in 2002 and achieved its first certification in 2008. Certifying a brand new primary flight display technology in such a short timeframe, Gannon says, "really had to do with the process that we employ, which has always been a human-centered design process". Now that process is part of the Honeywell User Experience (HUE) approach, which the company introduced early this year.

That process has three basic steps – analyze, design and evaluate – but Gannon prefers to use other terminology. Analysis, he says, is really about understanding: "You go out into the environment, you really have skin in the game, and you are spending time on the jump seat in the real operation trying to decide what the real design requirement is." That is helped by what he describes as "a very close association with our flight test operations group".

Their contribution goes beyond testing, he says. "It's really flight test and design in my mind. Most of the pilots we have are not just there doing tests; they are doing creative design early in the design process. The design work is really a collaboration with a diversity of team members, including flight test, systems engineers and software engineers."

SmartView started as an exploration of the benefits that might result from adding terrain from Honeywell's enhanced ground proximity warning system (EGPWS) to the primary flight display. "We had the EGPWS database,



"WE ARE CONFIDENT THAT OUR HEAD-UP VISION SYSTEM WILL ENABLE EVEN LOWER LANDING MINIMA IN THE FUTURE, CREATING GREATER ACCESS TO AIRPORTS DURING LOW-VISIBILITY CONDITIONS"

which has more than 900 million flight hours on it," he recalls. "We knew that this database had the level of integrity that we needed to go onto a primary flight display, so we were really interested in what are the benefits of terrain awareness."

The response from the flight test operations group, he says, was, "we want head-up display symbology and we want to bring it heads down." So SmartView marries the high integrity ground prox symbology with HUD symbology: "That was the time that we had these two schools of thought coming together."

CREATIVE PROCESS

The next step in HUE is the design phase, or as Gannon likes to consider it, the creation phase: "Even though we call it flight test, it really is this creative process we did together."

The process starts with low-fidelity and desktop simulation, which can then be matured into an integrated simulation. Honeywell has a motion simulator at its Deer Valley campus in Phoenix, Arizona, but a fixed-base simulator is used for much of the software development.

"We run pilots through, we get quantitative feedback, we get qualitative feedback on what they think about things," says Gannon. "Then we can take that same software build we developed on the simulator and put it in one of our flight test aircraft. We keep half of the aircraft in certified mode and then the other half is a working prototype. And the first step of that prototyping process really is getting it in front of our own crew members, who have this very broad design background, and getting their early judgments on it."

Evaluate is the third stage of HUE, but Gannon prefers the term 'judge'. "We collect quantitative feedback – flight technical error, what was the dispersion in the touchdown zone for this crew – but the other thing that we want to tap into is the expertise and the experience of the crew." Their diverse expertise helps to determine the right direction in which to take a prototype, he says.

The two elements of SmartView – HUD symbology and the representation of terrain – are not meant to be separate layers on the display, Gannon stresses: "We have a principle we developed called conformality. The idea is that anything that is in the background of the scene, such as the terrain and the runway approach indicator, you can interpret directly with the flight path marker in the foreground.

"The flight path marker is telling us exactly where we're going, and when we are on the glide path on the localizer and we put that flight path marker right in the touchdown zone, that is the place that we are going to."

Why head-down? "Our pilots tend to be very thoughtful about their users," says Gannon. "What they were recognizing first of all is that not every aircraft has a HUD, but every aircraft did have a primary flight display."

Another factor is that most aircraft have a pilot flying and a pilot monitoring, and where only the pilot flying has a HUD, the pilot monitoring can have the context of the synthetic vision picture and the flight path marker. "They get more insight into what the captain is experiencing."

STANDARDS DEVELOPMENT

New capabilities such as SmartView demand new standards. FAA advisory circular 25-11 gives guidance on the design, installation, integration and approval of electronic flight deck displays, but "when you have new

EXTERNAL VISION

NASA has carried out multiple rounds of flight testing on an external vision system (XVS) for use on future supersonic transport aircraft whose sonic boom-reducing needle noses would severely limit the outside view from the flight deck.

The first series, in 1995/1996, involved a NASA Boeing 737 with a windowless research cockpit in the passenger cabin and a Westinghouse BAC 1-11 avionics test aircraft. The 20 test flights included about 90 approaches and landings flown from the research cockpit. Further tests in 1997 using the 737 with an XVS display in the forward cockpit gathered data on ambient lighting and the detection of other aircraft and objects on the ground, including the use of X-band weather radar to detect other aircraft in the air.

In 2008, NASA and Gulfstream collaborated on a series of trials in which a Gulfstream pilot in the rear cockpit of an F-18B flew the aircraft using the output from a high-definition video camera; a NASA safety pilot was in the front seat. The flights tested the video system's effectiveness in replacing normal forward visibility and investigated minimum display resolution requirements using various camera and display resolution configurations.

More recently, a NASA Beechcraft UC-12 was equipped with an XVS display in the cabin to explore the ability of a pilot using XVS to see and avoid or see and follow other aircraft – for the trials these were a Cessna 206, Cirrus SR-2 and Beech 200 King Air.

Future tests are expected to evaluate custom camera options that create high pixel density, very high dynamic range, locally adjustable exposure and contrast in image subsections, and minimal latency.

"SYNTHETIC VISION IS VERY CLEAN, IT COMES FROM A DATABASE, THE PILOT DOESN'T HAVE TO INTERPRET IT"

technology like this, you really are developing those new standards in concert with the certification authorities". Early engagement with the certification authorities is a Honeywell philosophy, says Gannon, and the relationship of the company's test pilots with the test and evaluation pilots in the certification agencies helps to get their feedback and evaluation of the system. "Sometimes we have specifications or requirements or regulations that drive us," he adds. "In other cases we have high-level philosophies that are guiding us as well. Rule number one going into this was that first and foremost this is a primary flight display, and whatever we add to it can in no way take away from this as my primary attitude instrument."

As requirements are developed in the human-centered design process, "we try out things on the ground, we try them in our integrated simulation facility, and from there we test them in the real world. That helps us to develop the requirement as to what the system should be".

The synthetic vision for lower minimums (SVLM) project aims to get operational credit for using SmartView technology, with an initial target of approval for a Category 1 equipped aircraft and crew to fly unrestricted ILS or localizer performance with vertical guidance (LPV) approaches to a decision height of 150ft in visibility as low as 1,400ft runway visual range.

Honeywell is also looking at a combined vision system that would add input from a sensor such as an infrared camera to the synthetic terrain. "They are complementary to each other," Gannon comments. "Synthetic vision is very clean, it comes from a database, the pilot doesn't have to interpret it. The problem is I would like some augmentation for the real lights that are out there, or I would like to know if there's an object on the runway and SmartView obviously can't provide that."

The good things about a sensor, he says, "are it's real world and I can now validate the runway lights or the approach lights. But the pilot has to interpret the picture, sort out the signal from the noise. So Honeywell's approach has been to combine these two technologies where you get the best from the sensor side and the best from the database side as well".

RIGHT: **Honeywell's SmartView installed on a Gulfstream – the avionics supplier was the first to certify synthetic vision in Part 25 aircraft**

BELOW: **LPV approach as seen in SmartView**

PROOF OF CONCEPT

"We opened up a proof of concept with the certification authorities," says Gannon of SVLM. "Then as part of that proof of concept we go out and we fly sorties with them, and from those we develop what is the requirement that this system needs to have."

Testing so far has included the full motion simulator with a range of pilots representing different experience levels, collecting data on flight technical error and dispersion within the runway touchdown zone. It has also involved Honeywell's Dassault Falcon 900 with its EASy II cockpit, half replaced by the SVLM prototype, and a range of pilots, including from certification authorities.

Honeywell describes SVLM as an inertial reference system (IRS)-monitored LPV instrument approach navigation engine that monitors runway data integrity, delta position, approach deviation and altitude.

"One of the things that we're interested in is alerting for the crew," Gannon says. "Have we provided the crew with enough awareness of their ability to use a synthetic vision approach for lower minimums? Are they actually allowed to go to the lower minimums or are we in some degraded mode? So we worked out some of those symbology elements as well during the proof of concept. It's not just the flying and the supplemental navigation elements, it also has to do with the flight deck alerting and the level of service that is available to the crew."

SVLM is now ready to make the transition from proof of concept to product and then certification. Gannon expects that to involve both more bench-level testing and a further series of flight tests: "We've had the proof of concept flight tests and we've collected quantitative data, we've got the pilots' qualitative feedback. But moving into certification, I would expect another round of flight tests, again using the same tools that we have with our flight test operations group, really focusing on getting the right design and getting the design right." ∎

Bernard Fitzsimons is an aerospace journalist specializing in air transport business, technology and operations

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Local knowledge

Testing the F-35 – an Australian perspective

BY NIGEL PITTAWAY

The roll-out of the first two F-35A Lightning II combat jets for the Royal Australian Air Force in July marked an important milestone in Australia's New Air Combat Capability (NACC) program being delivered by Project Air 6000. Although the two aircraft won't fly until later this year and won't be delivered to the international Joint Strike Fighter training establishment at Luke Air Force Base in Arizona until early 2015, Australia has identified the first two pilots to fly them and has recently signed a memorandum of understanding (MoU) with the US government to participate in the F-35 test program.

The RAAF is also developing its plans to conduct an initial period of operational test and evaluation (OT&E) in Australia, when the first two aircraft arrive in the country at the end of 2018, or early in 2019.

The first Australian aircraft formed part of low-rate initial production (LRIP) Lot 6 and as such will use the next main iteration of software, known as Block 3I.

The flight testing of software has recently been focused on certification of Block 2B software, which is required to support US Marine Corps IOC in July 2015. Although 2B and 3I offer the same level of functionality, they are hosted on different processors and the Australian jets, along with the other LRIP 6 aircraft, are awaiting certification of the latter later this year.

Block 3I software is also required to support the latest Generation 3 flight helmet, which will rectify shortcomings discovered with the earlier helmet during flight testing. Because modifications are also required to the cockpit, which will be made from LRIP 7 onward, the first two RAAF aircraft will require retrofitting once flight test of the helmet is completed.

Flight testing has also been affected by the recent fleet grounding, following the destruction of an engine and subsequent aft fuselage fire experienced by an F-35A at Eglin Air Force Base. "We're just starting with (Block) 3I testing and with the little bit of hiatus we had with the grounding, we're just getting back into the testing. We'll really test with 3I probably in the September timeframe," explains Lockheed Martin's F-35 chief test pilot Al Norman. "Right now, AF-3 is the test jet loaded with 3I. We'll have more jets loaded with 3I and when we do, the [Generation 3] helmets will be compatible with those. The Gen 3 break in to the LRIP jet is LRIP 7, which is next [northern] spring time."

Norman adds that the current F-35 test force is divided between integrated (defense and contractor) test teams at

Edwards Air Force Base in California and Patuxent River in Maryland, and the group at the Lockheed Martin facility in Fort Worth.

"I'm in charge of the test pilots at all three sites. The test force at Edwards is made up of six A model airplanes, two B model and one C model. Patuxent River has five B and four C models and we do the primary STOVL and carrier work out there," he says. "We're primarily heavy on US Air Force-type military test pilots at Edwards. Contractor-wise we have a mix. Then heavy on the Navy/Marine Corps pilots at Pax River. For the contractor test pilot corps, for example, I have a US Air Force background and Giggs [Bill Gigliotti] has a US Navy background. Out at Edwards, we have three US Air Force background guys and a Canadian Forces background guy."

The recent MoU signed between Australia and the US will see at least four RAAF personnel added to the team at Edwards.

FIFTH GENERATION

When asked if, as a '5th generation' jet, the F-35 flight test process is any different to legacy programs, Norman says the discipline of flight test carries through the tenets and the precepts of good flight testing, regardless of the aircraft: "I had the benefit of being one of the initial test pilots on the F-22 – I flew that for 12 years. There are some things that these 5th-generation airplanes do a little differently," he replies. "Each airplane has its own little unique things about it, but I think the discipline of how we go about preparing for a test – designing an airplane, determining what we need to test, designing the test to measure those things and/or determine where we are along the way, and then actually going out and flying them, remains the same."

Accordingly, flight testing is broken down into two separate programs: flight science and mission systems testing.

Flight Science testing is involved with envelope expansion, and for the F-35A is about 95% complete with Block 2B software and about 60% on aggregate when the total F-35 program is considered. "There's a little bit of high alpha to do for the A model, a little bit of STOVL work and high alpha work left to do for the B, which is really important for the US Marine Corps IOC," reveals Norman.

Mission system testing is, as the name implies, primarily concerned with the development of the F-35 as a weapons system, including stealth characteristics.

AT A GLANCE

The F-35 Lightning II will provide the RAAF with a transformational '5th generation' fighter capability and provides major benefits to the Australian aerospace industry, with more than US$412m already contracted and up to US$6bn in expected manufacturing orders over the life of the program. "It's fitting that in the year Australia commemorates 100 years of military aviation, we also mark the arrival of the most advanced fighter ever developed," said Marillyn Hewson, Lockheed Martin chairman, president and CEO, during a ceremony held at Lockheed Martin to commemorate the official roll-out of the first two F-35 Lightning II aircraft for the RAAF, back in July. "The F-35 Lightning II will lay the foundation for the next century of Australia's military air power."

The aircraft, known as AU-1 and AU-2, are scheduled to undergo functional fuel system checks before being transported to the flight line for ground and flight tests in the coming months. The jets are scheduled to be delivered to the RAAF later this year, and will be based at Luke Air Force Base, Arizona, where they will be used for Australian and partner country pilot training.

Al Norman describes a typical day in flight test: "Taking Edwards, for example, we take a week to two-week look ahead where pilots prepare with their (flight test) engineers. We work in integrated teams in the sense that it's transparent between government and contractor as to how we work," he says. "Test cards are prepared for us and we then determine if these tests are even possible and, if so, we'll go to the simulator and practice, either for mission systems or we'll practice for envelope expansion-type flying, and then we'll go fly. And then when we come back, one of the most important things is debriefing what we saw, how it compared to what we expected to see, and then where we move on from here. It's the old adage of timing and preparation – when those two things come together, we're on our way."

AUSTRALIA'S CONTRIBUTION

Australia has joined the F-35 initial operational test evaluation program, albeit as a non-flying participant. The primary objective is to support and gain insight into the US program and thereby de-risk Australia's own OT&E program to meet the planned 2020 IOC, which is represented by the first fighter squadron and an operational conversion unit standing up.

Four RAAF personnel will be based at Edwards as a result of the MoU, covering operational, engineering, logistics and maintenance aspects of the program, and will include a qualified test pilot and flight test engineer.

"We'll now be far more actively engaged and we'll be doing that in the capacity of a partner in that test and evaluation program," explains Air Vice Marshal Chris Deeble, head of Australia's F-35 program. "There will be things that we'll be able to clearly bring back into the Australian context, but we'll also be privy to other things that will have broader application and may have some level of classification associated with them."

Although the Australian effort will not be controlled by the RAAF's test unit, the Aircraft Research and Development Unit (ARDU), the organization will have some involvement in testing in the USA: "The reality is most of the people that

BELOW: **The F-35 will provide the Royal Australian Air Force with a transformational '5th generation' fighter capability**

we have deployed will have ARDU backgrounds, so to that extent they're not necessarily working in an ARDU guise, they're program representatives, but to a large extent they are bringing the expertise and knowledge of ARDU with them to be able to inform ARDU's consideration of test and evaluation in the main," explains AVM Deeble. "ARDU clearly has a role to play in terms of signing off on test and evaluation aspects, for airworthiness and otherwise, but they're not necessary going to be labeled as ARDU personnel."

Australia is however contributing to F-35 testing locally, with the construction of a full-size F-35 model known as the Iron Bird, to study electromagnetic effects such as telecommunications transmissions, radar and lightning strikes on the aircraft. The Iron Bird test rig has been constructed by the Defence Science & Technology Organisation (DSTO) at RAAF Edinburgh in South Australia and was unveiled in early July.

"The United States Joint Strike Fighter Program Office asked the DSTO to undertake this research, based on its world-class experience in investigating electromagnetic environmental effects," said Australia's Defence Minister, Senator David Johnston, at the unveiling.

"WE HOPE TO LEVERAGE AS MUCH AS WE CAN FROM A TACTICS AND TECHNIQUES PERSPECTIVE OUT OF THE US TEST AND EVALUATION PROGRAM"

TOP: First Australian F-35A Lightning II, pictured during its recent roll-out ceremony in Fort Worth, Texas

The research undertaken by DSTO will support the verification for compliance and airworthiness certification for the F-35.

LOCAL OT&E

Air Vice Marshal Deeble considers the biggest challenge to Australia's F-35 program now centers upon local infrastructure and he says that two aircraft will be brought to Australia in 2018-19 to begin a series of testing.

The aircraft will carry out some weapons testing on Australian ranges, but their primary objective will be to validate facilities at RAAF Williamtown in New South Wales and Tindal in the Northern Territory, as the two main operating bases. Other RAAF airfields and forward operating locations will also require some form of validation, as will the Australian iteration of the Autonomic Logistics Information System (ALIS), required for day-to-day operations and sustainment.

"The US will be predominantly managing the risk of the airframe and the airframe capability, so I believe the biggest risk that we have will be integrating the JSF capability into our broader systems here in Australia," says AVM Deeble. "So with infrastructure, it will have to look at communications and other aspects. In the OT&E program, we will be flying missions and measuring the end-to-end mission efficiency associated with using those systems in the Australian context."

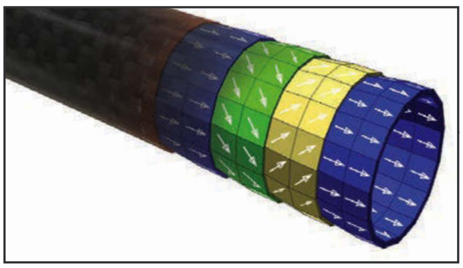
Australian OT&E will also exercise RAAF maintenance processes, such as weapons loading, and also how the F-35 will integrate into the broader system of systems. Such testing will include datalink environments and interoperability with other Australian Defence Force platforms such as the E-7A Wedgetail AEW&C and KC-30A tanker.

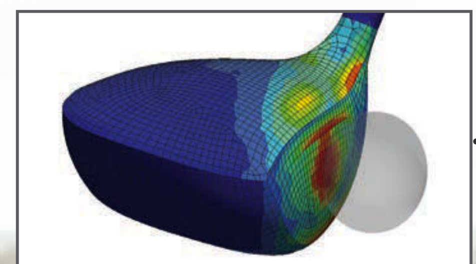
"We hope to leverage as much as we can from a tactics and techniques perspective out of the US test and evaluation program, then we will continue to try and be smart in making it work effectively in Australia. We will make sure it's interoperable with the systems we have here, from an IT, infrastructure, sustainment and a broader air defense capability perspective. These will be critical aspects of what we do," concludes Deeble.

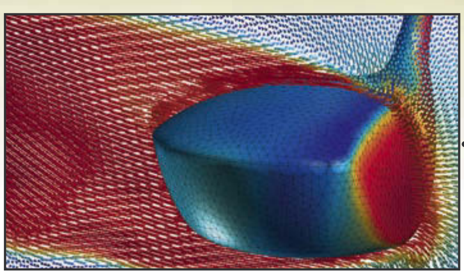
"Having engagement in the US test program clearly gives us some insight and understanding. The reality is, we don't want to do that effort again unless we really have to. So the areas that we'll be specifically focusing on without duplicating everything that's already been undertaken will be those interfaces to our systems. An example will be the testing of our facilities at Tindal and arguably when we deploy aircraft for exercises like Pitch Black, where we will have more than just a single squadron of F-35As deployed, we're going to have to exercise that system as well." ∎

Nigel Pittaway is a freelance aviation and defense journalist based in Australia

72	Australia has committed to 72 F-35A aircraft – comprising three operational squadrons – two at RAAF Base Williamtown and one at RAAF Base Tindal. In addition, a training squadron will be based at RAAF Base Williamtown
2018	The first F-35 aircraft will arrive in Australia in 2018 and the first squadron, Number 3 Squadron, will be operational in 2021. All 72 aircraft are expected to be fully operational by 2023
US$85m	An F-35A purchased in 2018 and delivered in 2020 will cost US$85m, which is the equivalent of US$75m in today's dollars
US$11.5 billion	The total capital cost for the RAAF's acquisition of 72 jets, which includes the cost of associated facilities, weapons and training







Dream departure

Boeing reveals the meticulous steps behind preparing the 787-9 Dreamliner for flight testing

BY JOHN BRADFORD

When the first Boeing 787-9 Dreamliner lifted off on its inaugural flight from Paine Field in Everett, Washington, USA, last September, it began a nine-month period of flight testing that went as smoothly and successfully as any in the company's history. That success didn't happen by chance. It came as the result of years of planning and design work. Furthermore, that success didn't just mean the airplane was certified; it also demonstrated that the Dreamliner had transitioned from a technological leap to a stable platform.

Before Boeing gives the green light for a first flight and the start of flight test activities, the team undertakes an arduous process of ensuring the airplane is flightworthy, with years of design iterations, laboratory tests, extensive analysis, and detailed planning across numerous organizations.

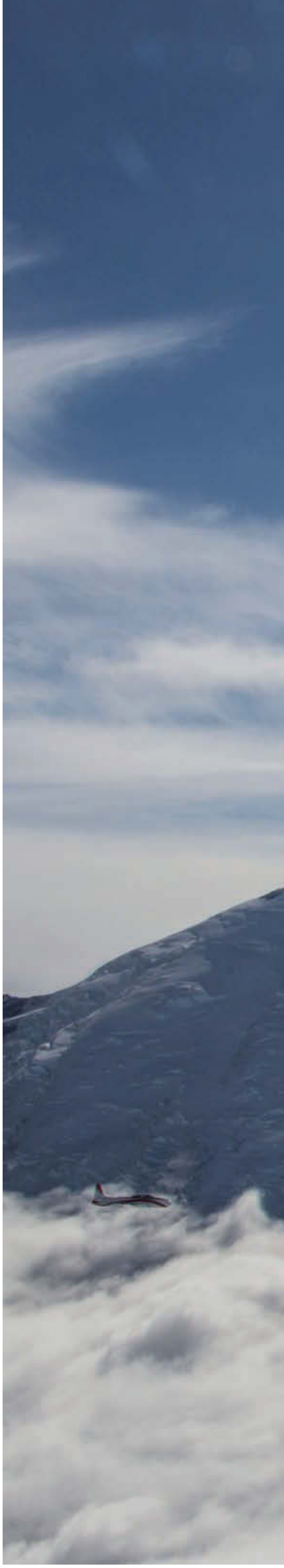
These steps leading up to a first flight are common across all of Boeing's major programs. Development of a new airplane, whether it is an all-new platform or a derivative, is guided by a series of gates, each associated with specific criteria to ensure that design objectives and safety and regulatory requirements are satisfied. The decision to offer a new airplane comes from a detailed understanding of the market's needs, which is among the earliest of gates in the development process. Design refinements, reviews and the finalization of the design comprise the next steps. Finally, production and test readiness and delivery evaluation are completed.

As the program transitions through these phases, design and project planning details narrow in scope from concept to a focused plan. Before passing through each milestone, all outstanding issues and risks are cataloged and assigned closure plans according to program timelines and requirements. In the period between each gate review, status checks serve to ensure that plans are progressing as expected.

And while start of production and approval for flight testing are among the last gates, the work required to pass through them begins to take shape in the earliest stages of the program and evolves as the program passes its design milestones.

FLIGHT TEST PLAN

Developing the detailed flight test plan occurs in collaboration between design and test engineers and program leadership. The plan includes a wide range of considerations, from the



The 787-9 Dreamliner's first flight, flying by Mount Rainier in Washington state, September 17, 2013

SUMMARY OF MAJOR 787-9 CHANGES AND TESTING

787-9 CHANGE	MAJOR TESTING REQUIRED
6m (20ft) stretch and structural enhancements	· Environmental control system (flow balance, smoke, noise) · Hydraulic and electrical system testing · Flutter/modal stability · Air data system · Take-off/landing and high-speed performance · Stability and control (including natural ice, crosswind performance, control system malfunctions) · Autopilot tuning · External lights · Flight control system · Extended operations (ETOPS)
Additional take-off flap detents	· Take-off/climb performance · Low-speed performance · Stability and control · Flight control system
Larger gear, wheels, tires, brakes and wheel wells	· Landing performance · Brake performance tuning · Rejected take-off performance and maximum brake energy evaluation · Wheel well thermal testing
Avionics systems updates	· Specific systems tests · ETOPS
Flight control surface and actuator design improvements	· Flight control system · Flutter/modal stability · Stability and control
Thrust increase	· Thrust rating validation · Engine control system testing · Take-off/landing and high-speed performance · Stability and control · Flight control system · Autopilot/autoland/flight director · ETOPS
Fuselage and wing structural changes enhancements	· Flutter/modal stability testing

highest level of deciding how many airplanes will be part of the testing effort, to the detailed definition of test requirements, specific missions, instrumentation definition and installation, critical path network development to determine the order of testing, test part procurement, and spare-parts planning and procurement. Many contingency plans are developed to address geographic considerations for weather and seasons, as well as test facility availability and personnel planning.

As the airplane design becomes more focused, so do the plans of the flight test program. Fleet size, specific missions and sequencing, configuration, program footprint and test requirements can all change as program priorities evolve. Scenario planning exercises, wherein alternate test program options are devised and evaluated, are often used to determine the best course of action. Proposals to utilize new testing methods or alternatives are welcomed and often pursued.

One example of a change made to the 787-9 testing plan was the decision to use 787-8 test airplanes in the flight test inventory to conduct a portion of 787-9 testing not explicitly requiring that airframe. This meant more testing could occur early and simultaneously, enabling the team to be more efficient.

Additionally, after initial consideration of conducting extreme weather conditioning at international locations, the McKinley Climatic

ABOVE: **One of three 787-9s dedicated to the test program**

BELOW: **ZB002 in Alice Springs, Australia, where it performed hot weather testing**

Laboratory at Eglin Air Force Base was used for the simulation of extremely hot and humid conditions. This enabled the team to address the seasonal limitations that could have extended the time it took to complete tests. The team focuses on designing a test program that satisfies all requirements as efficiently and safely as possible, and much effort is applied during these early planning phases and gate reviews to ensure that this occurs.

The specific layout of a flight test program varies according to the airplane design. Flight testing of a new component or software version on an established platform, such as an upgrade to an in-flight entertainment system, occurs regularly, and typically does not require extensive planning and reviews. At the other end of the spectrum is the testing required to certify an entirely new airplane. The 787-9, as a derivative, came in further down the spectrum, but not at the extreme end. The most visible change with the 787-9 is a 6m (20ft) increase in length, which provides additional cabin layout flexibility and cargo capacity. The change in length drove other accommodations such as adjustments to the main landing gear, and structural and systems changes. The flight test program thus focused on these elements of differentiation from the 787-8.

Other design enhancements also required testing, such as hybrid laminar flow control, an industry first that reduces drag around the horizontal and vertical tail, thereby saving fuel and reducing emissions.

"ONE EXAMPLE OF A CHANGE MADE TO THE 787-9 TESTING PLAN WAS THE DECISION TO USE 787-8 TEST AIRPLANES IN THE FLIGHT TEST INVENTORY TO CONDUCT A PORTION OF 787-9 TESTING NOT EXPLICITLY REQUIRING THAT AIRFRAME"

ORGANIZATIONAL STRUCTURE

All facets of test program development and execution are the responsibility of Boeing Test & Evaluation (BT&E), in conjunction with the airplane program. An organization within Boeing's Engineering, Operations & Technology branch, BT&E is engaged in airplane and laboratory test programs before and following every major program. Experts from Flight Test Engineering, Data Systems & Technology, Flight Operations and Flight Test Manufacturing are involved early in test program coordination and provide inputs into those aspects of the design process that directly affect the test program structure.

These include: test fleet layout and individual airplane mission development; test fleet build configuration and integration into the manufacturing process; test requirement collaboration with design engineering; instrumentation definition, allocation and integration; and representation of flight test considerations in all program discussions and reviews.

Within BT&E, specific groups contribute unique elements of the testing and evaluation disciplines. The Data Systems & Technology team specializes in the design, manufacture and operation of onboard and ground-based data acquisition, analysis and display systems. Flight Test Program Management integrates BT&E groups and interfaces with program leadership. Flight Operations includes pilots and other specialized flight deck system experts. Flight Test Engineering includes operations, analysis, instrumentation installation and configuration, atmospheric sciences for meteorological analysis and photo/video services. Flight Test Manufacturing, Quality Assurance and Flight Analysts maintains and modifies the flight test airplanes, including installing instrumentation and support equipment and quality control. The Lab Test & Evaluation team provides an array of test and analysis capabilities for testing better suited to the ground or before an airplane is available, ranging from individual components to integrated, full-up system testing. Metrology provides calibration and certification for test assets. Finally, the Test Operations Center & Logistics team offers visibility of organizational readiness and assets, and provides logistics and facility support for coordinating local and remote testing.

In the case of the 787-9, BT&E worked closely with the 787-9 program, part of Boeing Commercial Airplane's Airplane Development team. Members of BT&E were collocated with the program team, served on the leadership team and were fully integrated to ensure a common understanding of priorities and plans.

> "THIS COMBINATION OF TEST AIRPLANE ASSETS PROVIDED THE ABILITY TO LAY OUT THE TESTING EFFICIENTLY AND MINIMIZE DOWNTIME WITHIN THE FLEET"

TESTING ASSIGNMENTS

The 787-9 test program, like all major test efforts, saw many incarnations. One element that remained consistent was the decision to use three primary test airplanes with staggered first flights. These three airplanes, ZB001, ZB002 and ZB021, received extensive instrumentation packages; two other airplanes, ZB197 and ZB167, were production airplanes and thus contained minimal flight test installations. Of the five 787-9s involved in testing, three were configured with Rolls-Royce engines (ZB001, ZB002 and ZB197); and two were outfitted with GE engines (ZB021 and ZB167).

This combination of test airplane assets provided the ability to lay out the testing efficiently and minimize downtime within the fleet. If one category of testing encountered an issue or a test part was not ready, testing could be reallocated to keep the fleet in the air and the program progressing. Some test phases, such as flutter, were tied to a specific airplane: ZB001 for Rolls-Royce engines; and ZB021 for GE engines. Likewise, the team defined portions of testing that could be moved between test airplanes to respond to program priorities, program status and airplane readiness, including tests for stability and control, aero performance, autoflight and flight controls.

And while the team was able to be flexible in assigning much of the testing, each airplane was outfitted with some unique instrumentation that drove its primary missions.

ZB001, the first 787-9 to fly, was outfitted with full instrumentation racks; water barrels with load banks; a flight test tailskid; a trailing cone; a load monitoring system; a telemetry system; a display system to visualize test parameters on additional displays in the flight deck; and systems to generate modifications for test scenarios (altering control laws, introducing intentional faults, and so forth).

This airplane focused on flutter, aero performance, stability and control, flight controls, autopilot and brake tuning, as well as demonstration activities for international regulators.

The second 787-9, ZB002, included elements of the production interior and the associated data systems. It also had a removable trailing cone and an oxygen analysis system. Primary test objectives for this airplane included systems validation, the environmental control system, autopilot tuning, avionics, and propulsion and fuel systems.

ZB021, the third 787-9 and the only airplane in the primary flight test fleet with GE engines, was outfitted similar to ZB001 with a focus on flutter, aero performance, stability and control, flight controls, and brake tuning and performance.

By design, the two production airplanes (ZB197 and ZB167) had very little flight test unique monitoring equipment as they were used for functionality and reliability testing, extended operations (ETOPS) validation and testing of selected systems and avionics.

FLIGHT TEST RESULTS

The entire 787-9 test program proceeded largely as the first flight had – smoothly and as planned, with few surprises. The team capitalized on the stability of the airplane design, its maturity and its reliability, which meant the airplanes were available and ready to fly as scheduled. A major contributing factor was the maturity of airplane systems, which were fully qualified and tested before first flight. With more than 550 flights in more than 30 locations around the globe, the team was able to shift testing as needed to accommodate hardware and software updates, or in some cases, to take advantage of test modules completed ahead of schedule. Nimble responses to changes of scope or schedule were feasible. Successes such as these went a long way to sustaining momentum throughout the project, a particularly important achievement in any test program.

The 787-9 provided Boeing with an opportunity to demonstrate that the 787 design and technologies are well established and that the model fulfills its design objectives. Time and again, flight after flight, the airplanes delivered throughout the test program. Much of that success was clear evidence of the rigor of the development, design and build processes; and the talent and efforts of those who support them.

Perhaps most important, it proved that Boeing had succeeded in leveraging and extending 787 technology to produce the 787-9, which, as chief 787 pilot Capt. Randy Neville described after the "no squawk" first flight, "did exactly as we expected", leading to on-time certification and delivery of the 787-9 in June 2014. ▮

5	Number of aircraft in the 787-9 flight test fleet: three (ZB001, ZB002 and ZB021) received extensive instrumentation packages; two (ZB197 and ZB167) were production airplanes with minimal flight test installations
206ft	Overall length of the 787-9 (63m), which makes it 20ft (6m) longer than the 787-8
15,000	The number of hours of wind tunnel tests conducted across the whole 787 program
800,000	The number of hours of computing time, using Cray supercomputers, required by the whole 787 program

ABOVE: **20ft (6m) longer than the 787-8, the 787-9 extends the family in capacity and range**

John Bradford is a test director/test operations engineer based within Boeing Test & Evaluation's Flight Test Engineering group. Bradford was a principal contributor to the 787-9 test program development and later an Operations team lead on ZB001, the first Boeing 787-9 Dreamliner

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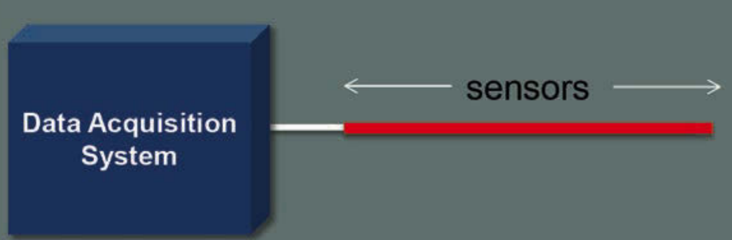

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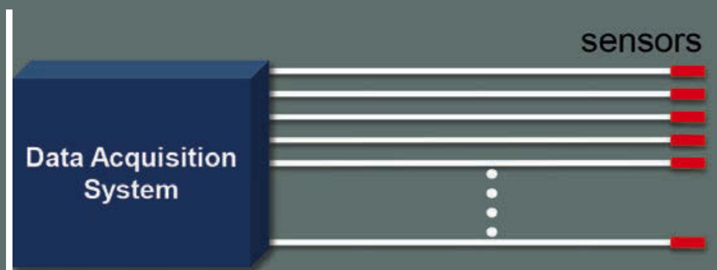

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INVESTIGATION: TEST SITE

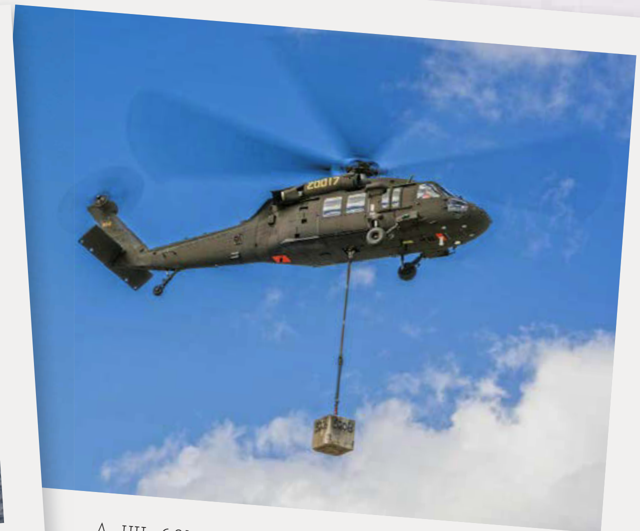
In this third installment of our in-depth look at test sites, *Aerospace Testing International* gains exclusive access to helicopter test sites. Our reporters look at some of the leading rotorcraft test locations around the world and talk to those that run them, including: Airbus Helicopters, the US Navy, AgustaWestland and Sikorsky.

A US Navy MH-60S Seahawk helicopter trialing biofuels

X2 Technology high-speed demonstrator (with S-76)

Merlin HMA2 upgrade line at Yeovil

A US Navy AH-1Z takes off from USS Wasp



A UH-60M Upgrade Black Hawk demonstrates hands-off cargo delivery

- The two prime Airbus Helicopters facilities have a total of 25 helicopter landing slots each

- The US NAVY HX-21 base has laboratories, overwater ranges, E3 (electromagnetic environmental effects) facilities, and many other testing assets

- Just over 600 engineers and 3,200 permanent staff work at Yeovil, UK, covering all 28 skill sets needed to develop and build military helicopters from a clean-sheet design

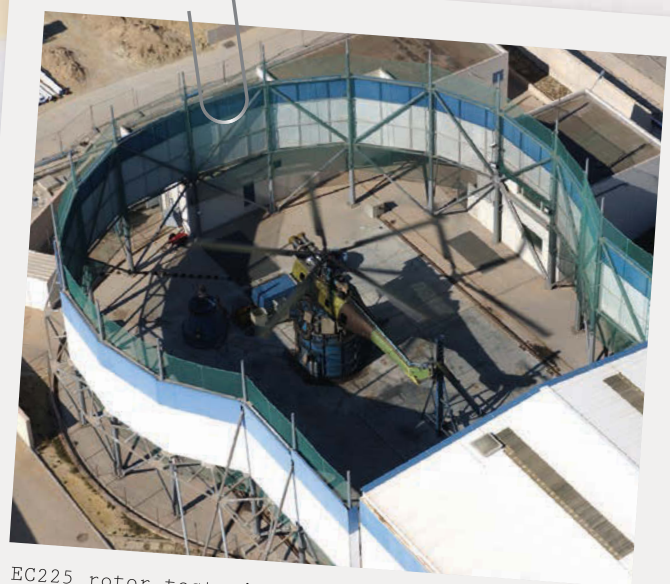
- Sikorsky's DFC has 300,000ft^2 of hangar and 80,000ft^2 of office space allocated to programs including the US Army UH-60M Black Hawk and Canadian CH148 Cyclone

- For high-altitude test work, Airbus Helicopters operates from Leadville, Colorado, at an elevation of over 3,000m, the highest city in the USA

AEROSPACE TESTING INTERNATIONAL EXCLUSIVE

Airbus Helicopters
Location: Donauwörth, Germany

Coordinates
Latitude: 48.719
Longitude: 10.778
Elevation: 411m


EC225 rotor tests in Marignane (Photos: Airbus Helicopters/Patrick Penna)

Previously known as Eurocopter, Airbus Helicopters operates as a fully owned subsidiary of the Airbus Group, and traces its lineage back to the 1992 merger of the rotorcraft divisions of Aérospatiale of France and Deutsche Aerospace of Germany. The world's largest helicopter producer in terms of revenues (€6.3 billion in 2013), Airbus Helicopters comprises three entities: parent company Airbus Helicopters, German subsidiary Airbus Helicopters Deutschland, and Spanish subsidiary Airbus Helicopters España.

The company's key test sites are in its major production centers: Marignane outside Marseille in France, and Donauwörth north of Augsburg in southern Germany. Donauwörth has a heli-lane with a length of 500m and Marignane offers 3,500m and 2,370m runways. However, the Marignane runways are part of the adjacent international airport and not devoted to helicopters. Each facility also has a total of 25 helicopter landing slots.

The test facilities at each site are set up to be as similar as possible. Both are capable of supporting the full range of test activities and are appropriately equipped with rigs, simulators and flight-test equipment. Patrick Brémond, Airbus Helicopters' vice president for flight test and engineering, explains that the ethos ensures that Marignane and Donauwörth have "exactly the same organization, methods and way of working".

The flight test divisions at each location are divided into two teams, one responsible for production aircraft as they come off the manufacturing line and the other for development testing. The development test team consists of test pilots, flight test engineers and ground test engineers. A dedicated sub-team is provided for each active program, headed by a project pilot and a project flight test engineer. For each helicopter line, this pairing acts as a "focal point and a voice of flight test", according to Brémond.

All told, Airbus Helicopters has a cadre of 70 flight test aircrew divided between the two sites. While test pilots and flight test engineers are typically assigned to a family of products, there is additional capacity that can be assigned to a project if required. Supporting these aircrew is a much larger team of ground engineers and analysts for recording the results of tests and sharing the data.

The Airbus Helicopters flight test fleet includes a number of company aircraft, but remains flexible, as Brémond explains: "Generally we have several prototypes at the beginning of a program, but when we attain 'cruise mode', we will retain one or two company aircraft to support continued development, to improve the product and to respond to any problems or customer requirements."

Inflight and ground-based test instrumentation is responsible for gathering data on hundreds of parameters during each test flight, and the process of recording is entirely digital. "Our first responsibility is to process the data," says Brémond, "to check that everything corresponds and that no mistakes have been made." The company typically has a flight test engineer on board the helicopter during each test flight to monitor the data as it is gathered. When required, however, capacity allows a ground engineer to monitor telemetry data from a dedicated ground station.

A considerable amount of flight test work is conducted outside these two main facilities, including at locations in the USA, Brazil, Spain, Singapore and elsewhere. For instance, high-altitude, high-temperature, low-temperature and icing tests are all conducted in suitable environments around the world. For high-altitude test work, the company operates from Leadville, Colorado, the highest city in the USA at an elevation of over 3,000m.

Brémond highlights two particular flight test projects that have been undertaken in recent months. At Donauwörth, the flight test team saw the successful certification of the EC145T2 four-ton-class lightweight twin in the first quarter of the year, leading up to the first customer deliveries in July. At approximately the same time, the EC175 medium-sized twin received its certification at Marignane. In both cases, following initial certification during a test campaign in early 2014, the test team moved to Canada for cold weather trials at temperatures of around -40°C. In the summer the EC175 additionally went to the USA for a series of high-temperature trials in Nevada and high-altitude trials in Colorado. The process was typical of the company's step-by-step approach to expanding the envelope through flight test and subsequent certification.

A different situation exists for pure research programs, such as the X3 high-speed compound helicopter. "Normally the target is to get initial certification and then deliver to the customer," Brémond continues. "For the X3 our role was only

EC225 rain testing in Marignane

“Flight testing for military programs is conducted along lines similar to those for the company’s civilian rotorcraft”

to build the helicopter, examine the potential for this very new concept and identify the elements that could be interesting for the future.” While the X3 program involved a dedicated test team, project test pilot, flight test engineer and ground test engineers, there was no need to fulfill the requirements for certification. “It represented a different way of thinking,” says Brémond, “but the actual flight tests were conducted in the same way.”

Flight testing for military programs, meanwhile, is conducted along lines similar to those for the company’s civilian rotorcraft. “For the past 15 to 20 years,” says Brémond, “all military programs have referred to civil regulations.” For military helicopters, however, it is not unusual for a given customer to accept certain parts of the civilian certification while considering others superfluous for a particular mission. On the other hand, military operators will generally have a range of additional requirements that have to be flight tested prior to acceptance. They might be provided by the military authority in the particular country, or by the specific customer. “We try to complete all the qualifications ourselves, undertaking the full developmental testing,” says Brémond. “Very often we will need to go to other military installations, for example for weapons testing.” Recent locations for military flight testing have included Belgium, Sweden and Spain. Selection of an appropriate test area for a military-specific test item is based on a combination of mission type, availability and, importantly, cost considerations.

The two facilities share English as a common language and the setup is designed to allow exchange between sites when required. For example, the chief test pilot at Marignane was previously a test pilot in Germany. On other occasions it has been known for flight test engineers to move between sites. This is aided by the company’s efforts to increase standardization between ‘French’ and ‘German’ products. Notably the EC145T2 and EC175 share the same avionics, cockpit layouts and even flight controls. Brémond attributes this “complete man-machine interface family concept” to work completed in cooperation between the two locations. “My target,” he reveals, “is not that everyone does the same thing, but that we concentrate on harmonizing our functions in the areas where it makes sense.”

For the years ahead, Brémond admits that the challenges facing the flight test team at Airbus Helicopters are much the same as those facing every other manufacturer: “We have to improve our ability to develop items faster and get them to market quicker. The development cycle for helicopters is a long one, but we are working on solutions that encompass all available engineering means.” ▮

HELICOPTER ZERO

In the future, Airbus Helicopters will make use of a new development test concept known as Helicopter Zero. Brémond describes this concept as “a kind of prototype, representative but not dedicated to flight test”. The simulation rig will be available one year to 18 months ahead of the first flight of the helicopter. “The idea is to speed things up. It will look like the prototype and will feature everything you will find on the prototype, except for a few items such as doors. It will include all the wiring harnesses and a complete cockpit, connected to sensors or simulators.”

Helicopter Zero will be provided in two discrete versions to aid different parts of the test program. Real engines won’t be fitted to the basic rig, which is designated System Helicopter Zero, but they can be simulated and all systems can be tested working together. While System Helicopter Zero will be dedicated to global system integration, Dynamic Helicopter Zero will be outfitted with a powerplant, complete with gearbox and rotors. It too will be a non-flying test article but will be capable of conducting ground runs to gather test data prior to the prototype taking to the air.

The Helicopter Zero concept is already being put to work on the X4 family of helicopters, which will eventually replace the Dauphin. “We will build a Helicopter Zero for every new program,” Brémond confirms.

A mixed test fleet of French and German helicopters out of Marignane

Sikorsky Aircraft Development Flight Center

Location: West Palm Beach, Florida, USA

Coordinates
Latitude: 26.907
Longitude: -80.325
Elevation: 9m

A UH-60M Upgrade Black Hawk demonstrated hands-off cargo delivery in April 2014

About 20 miles inland from Florida's Gold Coast, the busy Sikorsky Development Flight Center (DFC) is dedicated to rotary-wing breakthroughs. It was the test site for the fly-by-wire Comanche scout-attack helicopter, home to the X2 Technology high-speed demonstrator, and this April hosted hands-off cargo deliveries by an optionally manned Black Hawk helicopter. Upcoming efforts include the CH-53K Heavy Lift Replacement helicopter, S-97 Raider, and a new US Air Force Combat Rescue Helicopter. The Sikorsky campus typically logs 1,500 to 1,600 test hours a year. "That is not engineering flight testing or production flight testing," explains DFC general manager John Fischetti. "This is purely high-risk developmental flight testing."

The DFC tests aircraft for engineering teams headquartered in Stratford, Connecticut. According to Fischetti, "The history of the flight center here in Florida is kind of remarkable. It correlates to the late 1970s and early 1980s when the Black Hawk started to take off."

Development and production flight testing of Sikorsky helicopters long shared airspace around the Connecticut plant. "We were developing aircraft in Stratford and producing them in small lots," recalls Fischetti. "Not until the Black Hawk did we enter the realm of competing for priorities. We made a decision to segregate the two."

Florida testing started in March 1977 on land long used by United Technologies Corporation (UTC) sister company Pratt & Whitney to test rocket engines. Fischetti explains, "They wanted privacy, so they went to the swamps of Florida." The location protected testers from noise complaints and promised Sikorsky testing freedom. "That's something we lost in Stratford where the urban environment grew up around the plant."

Sikorsky first moved its commercial S-76A helicopter program to Florida. "We were probably a third of the size then that we are now," says Fischetti. "We had a 7,000ft runway because UTC was using it as a landing strip shuttling people to Hartford, Connecticut. We had a hangar. We started slowly growing it into a flight test center for development aircraft." He adds, "Since 1977, every new Sikorsky product has come through the Development Flight Center here in West Palm Beach." Among those products was the latest S-76D.

Today, the DFC has a dozen buildings with 300,000ft² of hangar and 80,000ft² of office space allocated to programs including the US Army UH-60M Black Hawk and the Canadian Forces CH-148 Cyclone. "In 2012 we put in a brand new 60,000ft² hangar. That was all about the CH-53K. We're going to have four flight test aircraft. They're large. They consume the test center's largest hangar." The renovated UTC terminal now belongs to Sikorsky Innovations, the rapid prototyping shop that will roll out the Raider this October.

The DFC tested the S-92 commercial helicopter and later its autonomous oil rig approach software. "The weather is ideal," says Fischetti. "For a flight load survey, we need to null out biases, and the biases are usually wind. Early in the morning, we usually have a couple of hours of very low wind. We did all the X2 flight testing before eight or nine in the morning to take wind out of the equation." Florida nevertheless has one shortcoming. "We don't get cold weather, we chase icing… In the past few years, we've taken our products to Colorado, Alaska and northern New York, to chase blowing snow."

The DFC runway has a slope landing facility and an ADS-33 handling qualities course. Other aids include a tethered hover stand, compass rose, and external stores jettison range. Sikorsky controllers operate an Eagle flight-following radar system. "It allows the pilot in the aircraft to stay within the aircraft watching gauges, reading flight cards, and the radar system puts eyes in the control tower looking out over surrounding airspace."

Fischetti notes, "We have three telemetry rooms that allow us to talk to aircraft as they're flying." He adds, "We have our own software group. We buy equipment off-the-shelf, but the systems integration work is unique to what our needs are." Two telemetry vans support field testing. ∎

The X2 Technology demonstrator achieved 250kts cruising speed and provided the basis for the S-97 Raider

Air Test and Evaluation HX-21, US Navy

Location: Naval Air Station, Patuxent River, USA

Coordinates
Latitude: 38.2382
Longitude: -76.416
Elevation: 5m

Image: Google Maps

Within the Naval Air Warfare Center Aircraft Division (NAWCAD) at Patuxent River, Maryland, Air Test and Evaluation Squadron Two One (HX-21) conducts developmental flight test and evaluation of all US Navy and Marine Corps helicopters and tiltrotors. As squadron commander and former chief test pilot Marine Lt Col. John Neville explains, "Developmental Test has a multidisciplinary team of fleet pilots, structural and systems engineers, instrumentation experts and the like.

"When we do our developmental testing, we're verifying specifications, identifying mission-relatable capabilities and deficiencies, and forecasting operational impacts for fleet employment. Our test pilots are board-selected from the operating forces to bring an appropriate level of operational and mission-specific insight. We facilitate maturing a system in preparation for operational test and fielding to the fleet."

HX-21 has operated under different names since 1949. In recent years the dedicated rotary-wing test unit has flown the multi-sensor/multi-role MH-60R and MH-60S Seahawks, upgraded UH-1Y utility and AH-1Z attack helicopters, and the high-speed/long-range MV-22 tiltrotor, all now in fleet squadrons. Efforts have begun for the CH-53K Heavy Lift Replacement Helicopter, expected to be operational in 2019, and a presidential helicopter replacement based on the civil-certified S-92 aims for initial operational capability in 2020.

HX-21 technical director Joseph Carbonaro says, "One way to frame that is both the Navy and Marine Corps, from the late 1990s to current time, are replacing all aircraft. We're finishing up with the '53K and presidential programs. Once we're done, we will have recapitalized all our naval rotary-wing capabilities from the past."

PAY AS THEY GO

HX-21 reports through the Naval Air Test Wing Atlantic, and its customers are the Naval Air Systems Command (NAVAIR) program offices (PMAs) that buy and support aviation systems. Neville says, "We provide the reporting of our test results funded and tasked by the program offices to help them make informed and accurate decisions for their continued program efforts, whether it's procurement or future development efforts."

Carbonaro adds, "It's like pay-as-you-go. The PMA essentially pays for what it uses." In addition to NAVAIR programs, HX-21 sometimes supports outside users. Boeing and the Canadian government tested the CH147F Chinook ADS-33 handling qualities at Patuxent River, and Sikorsky and Canada will borrow HX-21 hangar space for CH148 Cyclone stores separation tests. "We task-organize for the particular testing that's ongoing," notes Neville. HX-21 has 39 experimental test pilots, including nine civilians. All are graduates of the Navy Test Pilot School, also at Patuxent River.

About 150 contract support personnel are augmented by government engineers. "We're a competency-aligned organization," says Carbonaro. "The squadron doesn't own the engineers – they come from the competencies." In addition to structural, systems integration and other areas, HX-21 draws on an Air Vehicle Modification and Instrumentation group. "They are government people with the exception of the V-22," explains Carbonaro. "We still have one of the engineering and manufacturing development aircraft. We have a small group of Bell Boeing people who maintain the instrumentation that's been on that aircraft for the past seven or eight years."

The HX-21 fleet includes nearly all Navy and Marine Corps rotary-wing types. MH-60S Seahawks, for example, are testing rocket pods for the advanced precision-kill weapons system. While the legacy AH-1W undergoes tests with a digital map and linkless cannon feed, the new AH-1Z is near approval with the T700-GE-401C engine. Neville observes, "The H-3 we have was the one that used to fly President Nixon, but it's been modified to be a test platform."

Presidential, V-22, and other test aircraft are scattered in three hangars, but all have access to unique Pax River resources. "The NAWC pretty much has a full spectrum of engineering capability," says Neville. It has laboratories, overwater ranges, electromagnetic environmental effects facilities, and other testing assets. An upgraded ADS-33 course will support the CH-53K and other rotary wing/tiltrotor platforms and the Test Pilot School.

Carbonaro notes, "We have the ability to link multiple labs to stimulate and simulate the aircraft and transmit the data to the ship combat direction system software and hardware. You can hang an H-60 in our anechoic chamber and stimulate it with threat emitters so that it thinks it's flying in a theater of war."

For HX-21 testers, the H-60 and other Navy and Marine aircraft are software-intensive systems. According to Neville, "You're either addressing obsolescence or other deficiencies or improvements and adding capabilities." Carbonaro concludes, "You're never really done."

AH1Zs and UH-1Ys underwent software regression and envelope expansion testing in 2010

AgustaWestland, UK Test Centre

Location: Yeovil, Somerset, UK

Coordinates
Latitude: 50.942
Longitude: -2.6333
Elevation: 55m

Image: Google Earth

As one of Europe's 'big two' helicopter manufacturers, AgustaWestland invests considerably in research and development of new rotorcraft. The company has extensive test and evaluation facilities spread across its sites in Italy and the UK.

Its site at Yeovil in Somerset is one of the most technologically advanced helicopter design, flight test and manufacturing facilities in the world. The company's pedigree in helicopter development is unprecedented, dating back to the 1950s. In 2000, the UK's Westland Helicopters joined its Italian counterpart Agusta to form AgustaWestland. Four years later, Agusta's parent, the state-owned defence company Finmeccanica, took a controlling interest in the UK-Italian helicopter manufacturer.

Westland Aircraft was founded in 1935, and during World War II, the company produced several iconic military aircraft, including the Lysander, the Whirlwind and the Welkin.

After the war, the company began to build helicopters under a licensing agreement with Sikorsky. From the mid-1950s it increasingly concentrated on helicopters. Production started with the Sikorsky S-51, which became the Westland Dragonfly, flying for the first time in 1948, and entering service with the Royal Navy and Royal Air Force in 1953.

In the 1960s and 1970s, the company's Yeovil and Weston-super-Mare sites were preoccupied with the design and development of helicopters in cooperation with France's Aerospatiale. This collaboration led to the birth of the famous Puma, Lynx and Gazelle helicopters. In the 1980s, Westland and Agusta teamed up to produce the 101 or Merlin helicopter. The famous Lynx and Merlins made their first flights at Yeovil.

Development work was split across Yeovil and Agusta's site at Vergiate in northern Italy. The manufacturing was split as well, with work on key components divided between Italy and the UK to avoid duplication. There were eventually two final assembly lines to complete UK- and Italy-specific variants, although a single supply chain fed into them. Today, Yeovil's main focus is on work for the UK Ministry of Defence, but the company has diversification efforts underway to reduce reliance on a projected downturn in British military work.

The company has the personnel and equipment to conduct end-to-end design, development, flight test and manufacture of military helicopters, including machines intended to operate from warships at sea. More than 600 engineers work at Yeovil, covering all the 28 skill-sets needed to clean-sheet design and build a military helicopter.

To deliver this, the company has a core project management and design team at Yeovil, as well as the specialist departments to translate their intentions into reality. These include engine and transmission integration, avionics, weapons, mission systems, manufacturing, flight test and supply chain departments. Like much of the aerospace industry, the company has increasingly outsourced its component manufacturing and assembly, which has led to reductions in the workforce at Yeovil to the current 3,200 full-time staff and 1,500 subcontractors.

Yeovil's workload today shows its range of activity. Final assembly of the AW159 Wildcat light helicopter for the British Army and Royal Navy, and flight testing of finished products, is well underway. This is expected to continue for two years, although export orders from South Korea will extend Wildcat activity. The Merlin also remains a major focus, with upgrade work underway to bring the Royal Navy anti-submarine Merlins, in cooperation with Lockheed Martin, up to the new Mk2 standard. Designers have begun the first phase of work on converting RAF Merlin transport helicopters to operate from warships, including fitting folding rotor blades and tails.

The next major UK military product is expected to be a project to extend the life of the British Army's Apache attack helicopters, which will involve the adaptation of the latest US variant of the gunship to incorporate British technology and systems.

In 2012, Yeovil began work to design and develop a search-and-rescue variant of the AW189 helicopter being purchased for the UK Maritime and Coastguard Agency's service provider, Bristow Helicopters. This was followed by some £90m (US$145m) investment, from the company and the UK government, to support the design and development in the UK of advanced technologies in the field of tiltrotor systems integration and for increasing the performance of tiltrotors.

AgustaWestland chairman Graham Cole earlier this year stressed to his staff at Yeovil that they were working in a highly competitive global marketplace, saying, "One of the messages we give to our employees is that we live in a lovely part of the world here in south Somerset, but when you come through the gates you're in a tough world of helicopters, and there are people around the world fighting you, and looking for your business." ■

Merlin HMA2 upgrade line at Yeovil (Lockheed Martin)

Black. magic

How do you test composites? More than just 'black metal', these new materials require, and deserve, a whole new approach that takes into account their unique properties

BY SAUL WORDSWORTH

The rise and rise of composites is one of the stories of the last decade. Initially confined to the military due to their cost and perceived risk, the use of composite materials is now firmly entrenched within the commercial arena. In 10 years, Boeing has leapt from 12% composite weight in the 777 to 50% in the 787. In an industry where environmental issues, the price of oil and an increasingly competitive market are all paramount, the high strength-to-weight ratio of dual materials is seen as irresistible.

"Introducing a new solution into an industry as conservative as aerospace takes a very long time," says Faye Smith, director of Avalon, a UK-based composites consultancy, which includes BAE Systems and Saint-Gobain among its clients. "We are in phase one at the moment, where there is a lot of direct substitution. We call it black metal, where the design replaces the metal part with composites but with only minor modification. Though not the best way to use composites, this had to happen in such a conservative sector as aerospace. Since the parts look the same, the industry is happy. The next phase will be a complete redesign such that you're using composites in the optimum way. The best thing about composites is that you can create different properties within the same section, enabling a completely alternative kind of design."

Although the process of redesign continues to be a slow one, the current benefits of composites are still clear to see: fatigue and corrosion resistance, lower pressure tooling, lightness, the possibility of complex shapes and the ability to tailor a part to your own specifications. These generally offset the higher cost and damage tolerance associated with these low-density stiff materials. The question remains, however: what are the key differences when testing composites as compared with standard isotropic materials?

SATELLITE SOLUTION

Slade Gardner is a Fellow at Lockheed Martin (LM) Space Systems Company. He is the man behind Apex, an LM-developed thermoplastic nanocomposite consisting of a short fiber and nanofiber-reinforced blend of ultrapolymer. It is produced using injection molding and extrusion and is being implemented on the next generation of LM's A2100 satellite buses. It is also earmarked for future designs of its missile defense products such as THAAD.

"We've developed a very significant design database for the Apex material system and this was created through extensive mechanical and physical testing," says Gardner. "All the typical laboratory tests you might think of, we have done – tension, compression, sheer, impact, flexure, fatigue – along with all the physical properties you

FUEL FOR THOUGHT

Engineers at NASA's Marshall Space Flight Center in Huntsville, Alabama, recently began the first in a series of tests of one of the largest composite cryotanks ever built. The 18ft-diameter (5.5m) cylinder-shaped tank was lowered into a structural test stand at the Marshall Center.

To check tank and test stand operations, the first tests are being conducted at an ambient temperature with gaseous nitrogen. Further tests will be with liquid hydrogen cooled to super cold, or cryogenic, temperatures. The orange ends of the tank are made of metal and attach to the test stand so that structural loads can be applied similarly to those the tank would experience during a rocket launch.

The composite cryotank is part of NASA's Game Changing Development Program and Space Technology Mission Directorate, which are innovating, developing, testing and flying hardware for use in NASA's future missions. NASA focused on this technology because composite tanks promise a 30% weight reduction and a 25% cost savings over the best metal tanks used today.

The tank was manufactured with new materials and processes at the Boeing Developmental Center in Tukwila, Washington.

RIGHT: NASA's composite cryotank is lowered into a structural test stand at the Marshall Space Flight Center

NASA Photo/David Olive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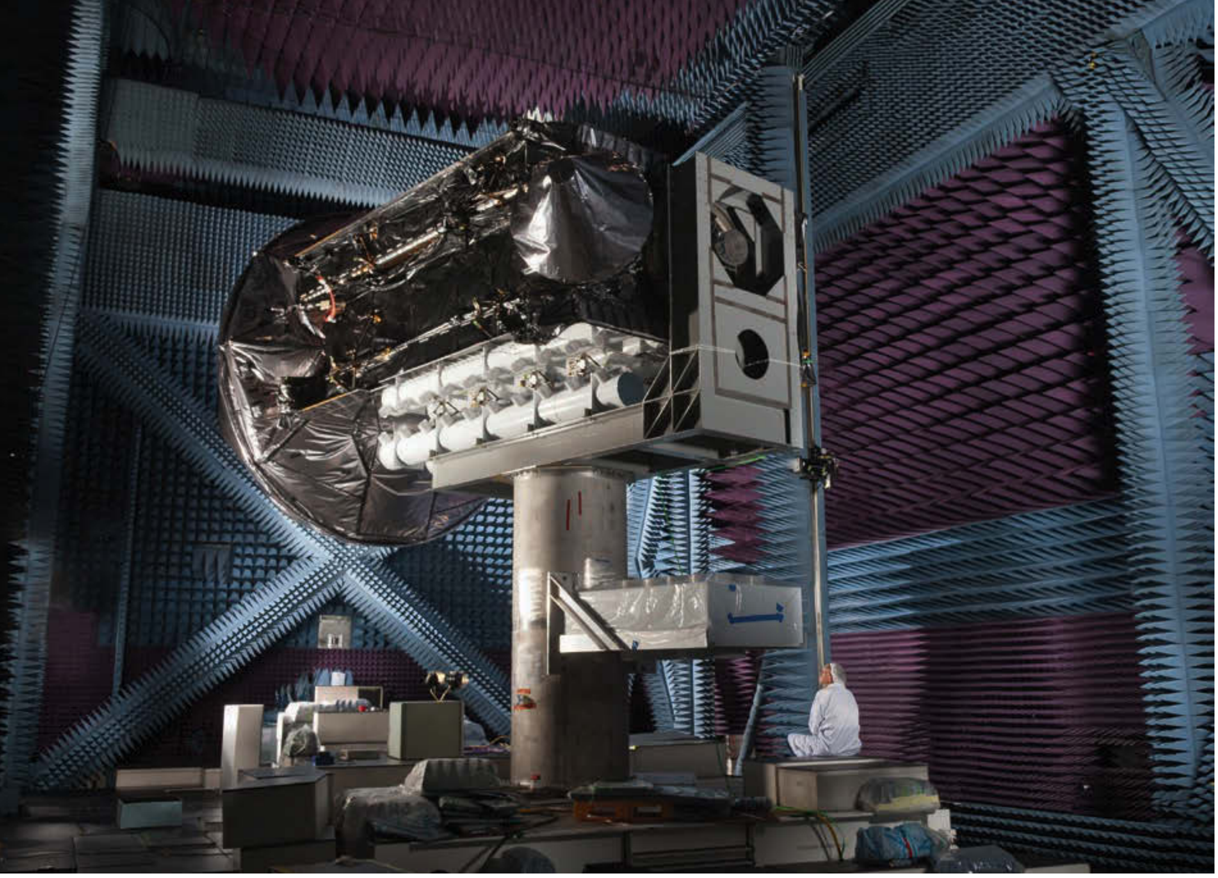

ABOVE: An MUOS satellite undergoing testing – the Lockheed Martin A2100-class satellite uses composites in its solar arrays, reflectors and payload decks

would consider, such as galvanic corrosion, thermal expansion, electrical and thermal conductivity, and density. All that testing feeds into a database that we offer to our program customers in order to build implementation articles. Sometimes our customers tell us there is a gap in the database for their particular design needs. They may ask for very high temperature mechanical test data, in which case we will return to the lab and generate the data for that customer. The tests we do on composites are the same as their aluminum equivalent, but with different results."

With both the A2100 satellites and missile defense products, Apex is used for secondary internal structures such as clips, brackets and cable trays. As Apex is a new material, Gardner and his colleagues are starting out with secondary structures to build their competence base before embarking upon higher load case conditions. For the A2100 satellite, they are deploying over 1000 clips that stabilize the craft's main structure, while for missile interceptors they are considering a handful of composite components internal to the missile, such as brackets, clips and cable trays.

"We test the components in different ways," says Gardner. "For satellite clips, they are bonded in place then connected using a fastener. When we test those in a simulated environment, we bond them into test hardware that simulates the bonded condition then test that adhesive bond as well as the mechanical integrity of the clips. For the missile application, the test requires mechanical testing at higher temperatures and different vibration regimes so those parts are tested for mechanical rather than a bonded installation."

TEST EXPERIENCE

Bill Hooper is manager of Composite Research and Development at ATK, a leading aerospace manufacturer. His focus varies from orbit vehicles to military and commercial aircraft.

"Fundamentally, the biggest thing to understand about composites is that you've designed your material, and designed it to have some sort of mechanical response," he says. "Composites are anisotropic – they possess very different properties in each direction. This drives the way you get data, and the data you get. With composites, there are enormous benefits but also more degrees of flexibility that you have to understand."

According to Hooper, much of the actual equipment used is essentially the same as that used for testing metal components: tensile test machines or sheer tests or compression tests. What varies is the type of test specimen used: "There are a lot of standard test specimens defined for tensile testing," he says. "Another common test is open hole compression. These are industry test techniques, so everyone is generating data that is comparable, regardless of who does it. From a test machine standpoint, it is essentially the same sort of technology and equipment you'd use with other materials. The main difference is that you often have bigger load cells and bigger actuators."

"OVERALL WITH COMPOSITES, YOU HAVE TO UNDERSTAND YOUR RESPONSE AND STRESS-STRAIN LEVELS"

It is the mix of different properties in different directions that drives the complex testing. As a result, characterization programs for composite materials can become very expensive. According to Hooper, it is not uncommon for someone making branded parts, for instance for a hinter stage on a rocket, to spend upward of US$3 million on testing. Rocket motor case materials are tested at the fiber and resin level to provide design input properties. ATK also does subscale cylinder and bottle winding, with tests on coupons or burst tests of the subscale bottles to verify their design input properties. All its full-scale rocket motor cases have a pressurized 'proof test' to verify they will perform in operational conditions.

"We do not have rocket motor cases fail from the composite failing because we have proof tested them all," says Hooper. "Overall, with composites you have to understand your response and stress-strain levels. That's why you have to do the test and that comes at a cost. Metals have more standard, established data design. Composites vary depending on how you choose to lay them up. That's really the trade-off you get there – added cost versus customized response. The pay-off comes back by reduced weight."

RESEARCH ANALYSIS

"Composites have a much more complex structure involving a lot of potentially weak interfaces," says Dr Dan Kells, research manager at the National Composites Centre in the UK. "Although metals can have a very complex microstructure, there is less variation. In addition, environmental testing can be completely different. Thus testing against hot, wet conditions and various chemicals and oils, such as Skydrol, is usually carried out, whereas metals would be tested against corrosion."

According to Kells, the main challenge when testing composites is the number of variations and stages in manufacture. In order to be able to fly, the material must pass tests at all levels: starting with an assessment of the fiber/resin matrix and interface between them, moving through the testing as coupon laminates to structural elements and then full structures. In order to change material, it is necessary to go through the entire pyramid again, at a cost of several million pounds. This means that aircraft are not always designed on the latest resin/fiber combination. Metals are not immune from this hierarchy but it is much less complex.

"Composites can be very sensitive to specimen configuration, such as notch sensitivity, or sensitivity to changes in thickness," he says. "In addition, specimen preparation is much more difficult and the tests themselves are much less consistent. This of course means that more tests are needed. Furthermore, in service a large amount of sub-surface damage can be caused by relatively minor impact and this needs to be detected."

LESSONS LEARNED

"What we find is there's a level of detail and precision with subscale coupons that you need to consider," says Bill Hooper, manager of composite research and development at ATK. "If you are not careful, you will bias your results. Therefore you have to pay close attention that there are no flaws in your test sample when you make them, and whether your alignment is correct. Sometimes your data can drift and you find the machine has an alignment issue. Another common problem is that some of these standard test samples have some bond endcaps on them or grips for the machine to hold onto. You can run into difficulties with the glue. Though this doesn't have anything to do with the composites, you need to get the endcaps glued on well."

50%	The Boeing 787 Dreamliner has an airframe comprising nearly 50% carbon fiber reinforced plastic and other composites. This approach offers weight savings on average of 20% compared to aluminum designs
50,000	The use of composites on the 787 is estimated to save 50,000 rivets per aircraft
88,185 lb	Average amount of composites consumed by Airbus per day (40 metric tonnes)
US$4.5 billion	The aerospace composites market is anticipated to grow to 101,800,000 lb (46,175 metric tons), valued at US$4.5bn by 2022

TECHNOLOGIES USED

For aircraft structures, the most common method is ultrasonic c-scan, Kells explains. This allows large structures to be fully assessed and will identify voids or other visible structural defects.

"This is accurate and accepted but it is relatively slow and requires water coupling between the probe and the specimen just like a pregnancy scan," he says. "X-rays are also used which are faster but not so good for large areas. In the field, various 'coin tapping' techniques are often used to detect delamination damage. Two other techniques are eddy current testing, based on the conducting properties of carbon fiber, and thermography. In the lab, similar mechanical testing will be done for composites and metals but the jig and fixtures are often different. One of the developing areas is the incorporation of sensors into composite structures to sense internal damage of loss of performance. This is often referred to as Structural Health Monitoring and is most commonly based on incorporating fiber-optic sensors into the structure during manufacture. This has been shown not to adversely affect the structural performance."

CERTIFICATION

Most aerospace certification is historical. As a result, current standards are often based on years of understanding of how metal performs. Some within the industry have pointed out that certification requirements now need to be rewritten to account for, and take advantage of, the unique properties of composites.

"This is happening," says Hooper. "NASA has a clear set of requirements to qualify composite structures for use in rocket launches. They have very specific requirements for going through a proof test cycle due to the importance of safety with astronauts on board. There will be extensive non-destructive evaluation of parts before proof test and after, plus a qualification requirement. That's how the rocket people do it. For aircraft it is different. Subscale parts will be tested, and some structure assemblies, but they certify a lot more based on analysis of that data. For instance, it is not practical to take the airplane and break a wing off, as compared to NASA requiring a failure test of a perfectly good interstage."

"There is less standardization in basic materials," says Kells. "Thus, aluminum alloys have a detailed alloy classification and theoretically anyone could reproduce, say, 7050 aircraft alloy. In composites, each resin and fiber combination will be proprietary to a manufacturer and it would be virtually impossible for anyone else to reproduce it. The starting point in most industries has been the metal standards. So, for example, aircraft standards have been designed around the most common aircraft material, aluminum, which is particularly vulnerable to creep. This has meant that design of composite aircraft components has been unnecessarily conservative. Although this is changing, it has been a matter of catching up." ∎

Saul Wordsworth is a freelance aerospace journalist for Aerospace Testing International

BELOW: **Composite rocket nose fairings, made from Lockheed Martin's APEX material**

Rules of engagement

UK UAV trials continue to make progress, with senior figures suggesting UAVs will be a common sight in just over a decade

BY TIM RIPLEY

Unmanned aerial vehicle (UAV) operations in visual flight rules (VFR) airspace is not expected until the end of 2018, and they will have evolved to complete maturity and unquestioning acceptance by 2028, according to the director of the UK's effort to integrate UAV flights into civilian airspace.

Speaking at July's Farnborough International Airshow, Simon Jewell, chairman of the cross-industry research steering group ASTRAEA (Autonomous System Technology Related Airborne Evaluation and Assessment), said the program has now reached the stage where the technology is ready, and industry has to work with the regulators to define the parameters and guidelines within which UAVs will be allowed to operate freely in various airspace categories.

"Initial operations under the more ordered instrument flight rules in controlled airspace are expected to be carried out next year," he said. He added that the initial period of UAV operation felt like the "early days of motoring", when cars were required to have a man walking ahead of them waving a red flag.

The current phase of the ASTRAEA program, known as 3A, will be complete in mid-2015, at which time the final phase – 3B – will start. That phase will mainly be about proving systems integrity and gathering performance data to support regulatory decisions. Important issues include the reliability and integrity of the ground-air piloting datalink, and the ability of the UAV itself to operate autonomously among other traffic if the datalink fails, even momentarily.

The goal for UAVs is to be allowed to operate in uncontrolled VFR

A glimpse of the future? UAVs will eventually become commonplace

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LEFT: BAE Systems' Jetstream aircraft known as 'The Flying Test Bed', which can fly as if it were an Uninhabited Air Vehicle (UAV), has undergone a series of flight trials

airspace where other traffic is autonomous and not flight-planned.

The ASTRAEA program partner companies – Airbus Defense and Space, AOS, BAE Systems, Cobham, QinetiQ, Rolls-Royce and Thales – and more than 100 universities and small-medium enterprises, have spent more than £30 million (US$48 million) over the past eight years, including funding live flight trials.

Lambert Dopping-Hepenstal, ASTRAEA's technology director, speaking during the same Farnborough briefing, said that the sense-and-avoid technology perfected during this phase will also translate usefully into manned aircraft, particularly general aviation types operating in uncontrolled VFR airspace, because pilots can be made aware of potential conflicts.

SIDE ISSUE

For all these benefits, it is neither reasonable nor economical to partition existing airspace to accommodate UAVs. Instead, Dopping-Hepenstal said ways had to be found to introduce UAVs alongside piloted aircraft so that they fly under the same rules and regulations. All the basic technologies to make this possible exist. The main challenge is their application and integration to allow vehicles to be certified to share airspace with other piloted craft.

In a report on ASTRAEA's progress to date, seen by *Aerospace Testing International*, Dopping-Hepenstal says that a major issue with the current generation of UAVs is that they are generally designed for military uses in segregated airspace rather than operations in civilian or general airspace.

"WITH THE PILOT REMOTE FROM THE AIRCRAFT, HOWEVER, THE AIR VEHICLE WILL ITSELF HAVE TO TAKE ON SOME RESPONSIBILITIES"

"In the UK, commercial unmanned operations are currently limited to very small aircraft, generally weighing no more than 5kg, flown within direct line-of-sight of a ground 'pilot'," he says. "These UAVs have to operate below 400ft (120m) and no closer than 50m from people and structures. While these limitations are manageable for small operations in agriculture, surveying, or inspection of hazardous areas, they are too restrictive for many potential applications."

Even with the technology being examined by ASTRAEA, Dopping-Hepenstal says it was still envisaged that for all UAVs a human pilot will always be ultimately responsible for the safe conduct of the flight. "With the pilot remote from the aircraft, however, the air vehicle will itself have to take on some responsibilities," he notes. "The pilot of a modern commercial aircraft can use both intuitive and primary sensing – such as seeing, hearing, feeling and smelling – to generate informed reactions. The pilot also has access to a huge amount of information from cockpit display systems. An unmanned aircraft not only has to replicate the pilot's own senses but must also encode all of this information in a form suitable for sending down to the ground pilot."

COLLISION AVOIDANCE

The most recent phases of ASTRAEA have moved into demonstration of the key subsystems and enabling technologies. These include numerous flights using surrogate aircraft to explore and test collision avoidance

TWIN APPROACH

The ASTRAEA program consists of two separate projects.

The first is Separation Assurance & Control, which is focused on the particular technologies required to control the flying vehicle from the ground control station; the spectrum, security and integrity of the communication system; and the vehicle's sense-and-avoid system.

The second project – Autonomy & Decision Making – will focus on providing intelligence in the vehicle through a variable autonomy system that shares decision making for the mission and contingency management with the human operator.

The program was created in 2006 to research and demonstrate how an unmanned aircraft could safely integrate itself into airspace shared with other aircraft. It is unique in its holistic approach to the problem, addressing the human side of the equation (legislation and the operational control of unmanned aircraft), not just the technical challenges. Indeed, it is likely that many emerging technologies could be used to make current manned aircraft operations even safer.

"LIMITATIONS ON THE AMOUNT OF DATA THAT CAN BE HANDLED THROUGH SATELLITE LINKS, AND SIGNAL-PATH DELAYS, COULD COMPROMISE SAFETY... A LAPSE OF JUST A FEW SECONDS IS UNACCEPTABLE, PARTICULARLY IN AREAS OF HIGH-DENSITY AIR TRAFFIC SUCH AS THE APPROACHES TO HEATHROW AIRPORT"

systems both for other airspace users and for adverse weather, and also small UAVs flying from the West Wales UAV Centre, to simulate security missions in support of a major sporting event.

DETECT AND AVOID

"One area of technology in which ASTRAEA has made good progress is with 'detect-and-avoid'," says Dopping-Hepenstal. "This is the unmanned aircraft equivalent of how the pilot of a manned aircraft avoids other air traffic, the ground, obstacles and dangerous weather."

Simple aircraft-mounted video cameras, linked to extensive algorithm sets, have been demonstrated to match a pilot's ability. They can detect small unidentified aircraft or other objects that are not equipped with traffic collision avoidance systems, even when set against difficult backgrounds such as urban conurbations.

"Improvements in optical processing techniques owe much to the work being undertaken in adjacent sectors such as cell phone development and gaming," says Dopping-Hepenstal. "The ASTRAEA partners have undertaken extensive flight trials to verify fused sensing performance using numerous encounter scenarios. The detect-and-avoid performance results have been further optimized in the laboratory, and a prototype system is currently being reconfigured for installation and test within a UAV."

Detect-and-avoid cameras have been fitted in the nose of a Metroliner Flying Test Bed aircraft. This non-cooperative system relies on electro-optical sensors – video cameras – to spot aircraft on a potential collision course quickly enough to undertake evasive maneuvers. This has to be achieved against complex terrain or urban backgrounds where there is great potential for false alarms.

ASTRAEA has also made good progress in a second key area – communications networks: "The networks need to maintain links reliably with UAVs that might be flying at high speeds, many thousands of kilometers from the ground-based pilot," says Dopping-Hepenstal. "These links need to be secure and fast, with as little latency [time lag] as possible to ensure rapid decisions and reactions."

An obvious solution would be to use a satellite-based radio communications network to link the ground-based pilot, air traffic control and the unmanned aircraft. "This is not a complete solution, as limitations on the amount of data that can be handled through satellite links, and signal-path delays, could compromise safety," he says. "A lapse of just a few seconds is unacceptable, particularly in areas of high-density air traffic such as the approaches to Heathrow Airport. However, a solution that the project is developing is ad hoc networking," he says. "This exploits the communications equipment on other aircraft, manned and unmanned, that are within radio line-of-sight, to create a large, connected airborne communication network. These feature security measures such as encryption to both incoming and outgoing messages."

Dopping-Hepenstal is cautious about some of the more futuristic uses being envisaged for UAVs. "The delivery of takeaway meals or books in crowded urban environments may be a challenge too demanding for the near future," he says. "A hub-to-hub concept may be more achievable. For example, the rapid airborne delivery of transplant organs or blood supplies between hospitals may well be realistic within the next five years." ∎

Tim Ripley is an international aviation journalist and freelance writer

BELOW: Thales Watchkeeper's first flight (April 2010) – the UAV took off from dedicated facilities at Parc Aberporth in West Wales for a 20-minute flight

Jump to it

Inside the KTV – the flight test office responsible for evaluating all new equipment and modifications for the Royal Netherlands Air Force (RNLAF) F-16 fleet

BY THOMAS NEWDICK

Located at Leeuwarden in the northern Dutch province of Friesland, the Kantoor Testvliegen (KTV, or flight test office) may be a small unit, but it has an important role within NATO. Flying a single, specially equipped Lockheed Martin F-16 Fighting Falcon, the KTV is responsible for evaluating all new equipment and modifications for the Royal Netherlands Air Force (RNLAF) F-16 fleet. The unit is also responsible for testing new software updates for use across the European Participating Air Forces (EPAF), which comprises fellow F-16 operators Belgium, Denmark, Norway and Portugal.

At the time of writing, the KTV operates as a branch of an F-16 squadron, 323 TACTESS (Tactical Training, Evaluation and Standardization Squadron), one of two on the base. A unique unit, 323 TACTESS is divided into four separate departments, or flights, the first two of which carry out standard operational duties in common with other Dutch F-16 units. As such, 323 is also an 'ordinary' Dutch F-16 unit, with regular operational commitments to the NATO Response Force (NRF), including in Afghanistan.

The second flight is additionally charged with organizing the Frisian Flag international large-scale fighter exercise. A third flight is responsible for standardization within the RNLAF, and also provides the Fighter Weapons Instructor Training (FWIT) course for the EPAF. The fourth department of 323 TACTESS is the operational test and evaluation (OT&E) flight. The fifth and final element is also the smallest: the KTV.

The flight test office holds a special position within 323 TACTESS, as chief test pilot Major Ralf 'Lucky' Lukkien, explains: "The flight test office is supported by 323 TACTESS; however, I directly report to the squadron commander and directly to the materiel command flight test department. I rely on the squadron commander for support, but my tasks come direct from the materiel command."

MAIN: Serial J-066 or the Orange Jumper – the RNLAF's unique F-16BM instrumented testbed


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RIGHT: **'Viagra Boom' extended pitot**
BELOW: **'Lucky' checks out the F-16's orange wiring and new Programmable Master Unit (PMU) in the flight test office hangar**

"WE DO SEE A SLIGHT DROP OFF IN THE TESTING OF NEW CAPABILITIES FOR THE F-16... [BUT] WE ARE SEEING MORE AND MORE SUSTAINABILITY FLIGHT TESTING"

280+	There are over 280 standard parameters available for real-time examination in the backseat HUD of the Orange Jumper
4,500	To date, Lockheed Martin has produced more than 4,500 F-16s and developed upgrade programs for 11 countries
1,400m	The approxmiate length (14km) of the orange (test-related) wiring in the Orange Jumper
US$24,000	The estimated cost per flying hour of an RNLAF F-35A – roughly 10% higher than the cost per flying hour of the F-16 it will replace

The unit is headed by Lukkien, a USAF Test Pilot School graduate with more than 2,400 hours on the F-16, including around 1,500 combat hours over the former Yugoslavia and Afghanistan. The KTV comprises a staff of two test pilots, one flight test engineer and a dedicated technical engineer for support of electronic systems. "We are a small unit," Lukkien admits, "but we have all the rest of the base for engineering and support and the National Aerospace Laboratory of the Netherlands (NLR), which helps out with analysis of data."

SELF SUFFICIENT

The KTV carries out its work from its own building next to 323 Squadron headquarters, and also maintains its own workshop and mission planning and briefing facilities. "We have computers for analysis on-site," says Lukkien. "In the workshop we can modify and adjust as needed for certain projects, but we do not have much in the way of specialized testing facilities."

As well as operations from the Leeuwarden headquarters, the KTV also makes use of locations run by the NLR, with which it has a close relationship. Two NLR test sites in Amsterdam and Northeast Polder are, for example, available for radar trials and electromagnetic interference (EMI) testing. "If we need to drop smart weapons, with a huge footprint, then we deploy to other bases," explains Lukkien. Recent deployment locations for weapons tests include the Vidsel range in Sweden and Bodø in Norway.

The main role of KTV is to test all new configurations of the Dutch F-16 fleet at a cost-effective price. The primary tool for this work is the unique F-16BM instrumented testbed, serial J-066, known as the Orange Jumper. This two-seat F-16 remains fully mission capable, and is therefore unique in the world. "Normal flight testbeds lack certain operational systems in order to accommodate all the flight test equipment," Lukkien continues. "My F-16 is fully mission capable and still has all the operational systems in it. It is also used for day-to-day training missions by the normal squadron."

Any new equipment for the Dutch F-16 will first be evaluated by the KTV, using the Orange Jumper. The flight test office will examine how any new addition affects the existing external load configurations: this might involve a new device or software patch.

The KTV also works closely with the US Air Force's 416th Flight Test Squadron located at Edwards Air Force Base, California. The major software upgrades for the EPAF operators are currently first evaluated and tested at Edwards. However, J-066 is also used to evaluate the software tape during early operational assessments. Its unique fully operational status and recording capabilities help to find, determine and fix problems encountered at an early stage.

Beyond EPAF duties, the KTV also occasionally conducts some work on behalf of the US F-16 Special Project

Office. “Last year we also did Advanced Interrogation Friend or Foe (AIFF) Mode 5 tests that will benefit not only the EPAF but also the US F-16 community,” says Lukkien.

The Orange Jumper name is derived from the fact that all additional test equipment and wiring in the aircraft are colored orange for ease of identification by maintainers. This F-16 can carry external high-speed cameras on multiple stations for safe-separation testing, and is also fitted with an extended red and white ‘Viagra Boom’ pitot tube to measure angle of attack, side slip and environmental data. “The special thing we have in our F-16 is that we normally fly with our flight test engineer in the back seat. He or she has a display where he can monitor all parameters required for the testing. For load testing, for example, he can pull up a screen with graphs displaying specific frequency diagrams for the oscillation and can monitor it in real time. We don’t use a control room on the ground, instead we have our flight test engineer with us in the back seat.”

The flight test office is currently working on a range of initiatives, among them integration of the GBU-49 precision-guided bomb, beyond-line-of-sight communication and SATCOM testing, integration of new night vision goggles (as worn by Lucky, above) and night vision compatible displays.

Projects now also include work to pave the way for the introduction of the Lockheed Martin F-35 Lightning II, in the form of L-16 interoperability testing. “In the near future there is also a test project for smart simulation,” Lukkien reveals. Currently NLR and the Dutch Aerospace Group are in the bidding for the F-35 simulation programme. “The aim is to develop live virtual constructive training for the F-35, and this will probably involve our testbed for risk reduction, before migrating this to the F-35.”

Another example of the KTV’s collaborative work with the NLR is the Fighter Aircraft Robust Power Management (FARPM) project. Commissioned by the RNLAF, this has used the Orange Jumper for flying demo profiles. For FARPM, the NLR uses calculation models to study the effects of energy management and distribution on the operational deployability of new-generation fighter jets.

LUCKY BY NAME

Chief test pilot at the KTV is Major Ralf ‘Lucky’ Lukkien. After initial pilot training, Lukkien returned to 323 TACTESS at Leeuwarden in 1998, as a young wingman. In 2002 he became a weapons instructor pilot at the unit’s weapons school, before flying operationally over Kosovo and Afghanistan. One of his main jobs as a weapons instructor was operational testing and evaluation of the new software tapes and weapons for the RNLAF F-16. As such he was involved in the successive M3, M4, M5 and M6 upgrade programmes, initially as a duty officer attached to the operational test unit. In 2007 Lukkien became flight commander of the evaluation flight of 323 TACTESS, responsible for operational testing and evaluation. This role brought him into contact with the test pilot community at the squadron, who also help with operational testing. At this point ‘Lucky’ decided on a different career path, and tried out for a slot as a test pilot. In 2010 he was selected to start test pilot school and that summer he went to the US Air Force Test Pilot School at Edwards Air Force Base, California, graduating in June 2011. Returning to Leeuwarden, he became test pilot at the KTV. He became chief test pilot in August 2013.

ABOVE: The Orange Jumper with GBU-38 500 lb Joint Direct Attack Munition under port wing – introduced as part of M4 software upgrade

A CHANGE IN SIGHT

In early November, 323 TACTESS is set to disband, and as a result, the KTV will be rolled into 322 Squadron, also based at Leeuwarden. The move is part of wider cuts within the Dutch military, and also continues rationalization of the F-16 fleet as the RNLAF moves towards its final retirement and replacement by the F-35. “For the flight test office there will not be much in the way of change,” confirms Lukkien. “The only thing that will change is who we report to and who supports us.” In fact, base operations already make use of pooled aircraft, and pilots of the two squadrons have been working together for the past 12 months.

Although the F-16 is getting older, in some ways the KTV is playing an increasingly important role. The new flight test instrumentation system is intended to ensure the life of the jet until its planned withdrawal date in 2024. J-066 recently emerged from deep maintenance, including the provision of wiring for a completely new flight test instrumentation system from ACRA (a division of Curtiss-Wright Controls Avionics & Electronics). “Basically all components were replaced by a new suite,” explains Lukkien.

After six months in the hangar, successful test flights of the new configuration began this August. However, the jet will shortly go back into maintenance for a six- to eight-week period in order to receive new ARC-120 radios. Shared use of aircraft on the base means the KTV can call upon other Leeuwarden F-16s to keep flying when J-066 undergoes work, and when specialized flight test instrumentation is not required.

“We do see a slight drop off in the testing of new capabilities for the F-16,” admits Lukkien. However, the future still looks bright for the KTV. “We are seeing more and more sustainability flight testing.” This might involve testing of replacement components, for example.

Continued cost cutting also means the NLR is playing an increasingly important role in the KTV’s work. “They designed and maintain our flight test instrumentation,” Lukkien says, “and they do a lot of the data processing. Due to restricting and downsizing, a lot of the engineering capability has moved over to the NLR.”

The KTV is required to continue testing with the Orange Jumper until 2024 but if necessary could continue beyond that for one or two more years, Lukkien confirms. ▮

Thomas Newdick is an aviation and defense writer and editor based in Berlin

High-temperature vibration

Design and selection criteria of high-temperature accelerometers for aerospace propulsion

Accelerometers and pressure sensors for measurement in aerospace propulsion systems require special consideration during design and manufacturing processes. Specialized applications frequently require use of a single sensor model, which must be capable of operating over significantly wider temperature ranges, for example, -420° to +1300°F (-251° to +705°C), while providing high accuracy, stability and reliability (Figure 1). Typical applications for high-temperature aerospace propulsion sensors include measurement on gas turbine engines both in flight and in test cells, as well as rocket motors. The same sensor might be required to withstand radiation and to be used in monitoring vibration inside a nuclear power plant or space vehicle, or the cryogenic conditions of liquid propellants. These environments present a multitude of measurement challenges.

Materials and construction techniques must be optimized, not only to enhance high-temperature performance, but also to allow operation in the presence of gamma and neutron radiation without degradation. Whether used in aircraft engines, space vehicles, or power generation stations, these sensors must provide high levels of accuracy, stability and reliability. Therefore, these instruments used in extreme environments, such as cryogens and high temperatures, require special consideration during the design and manufacturing process.

The primary purpose of engine health monitoring accelerometers on gas turbine engines is to detect high vibration levels related to out-of-balance conditions; however, it is also possible to perform additional engine health monitoring with the data. The specific performance requirements associated with the desire for engine health monitoring ultimately determine the functional requirements, for example, frequency response, of the accelerometer.

For more than a decade, the Model 357D90 shear mode accelerometer with UHT-12 crystals has provided successful vibration measurements on ground-based, aero derivative turbine engines. The latest addition to this product family is a differential shear output version, Model EX611A20. There are considerable technical challenges involved with gas turbine engine vibration monitoring applications. The sensor must resolve low-amplitude, low-frequency vibration in the presence of high-amplitude, high-frequency vibration, while at high operational temperatures. Engine balance readout instrumentation will integrate acceleration to velocity or displacement. When acceleration is integrated, even low levels of distortion can produce large errors in velocity and displacement signals, easily exceeding engine balance alarm levels. There are a number of potential design criteria that can cause signal anomaly at low frequency. A more detailed look at the two characteristics of material selection and noise follows.

Piezoelectric sensors are made from both naturally piezoelectric crystals and artificially polarized polycrystalline ferroelectric ceramics. The choice of sensing material depends on environmental and performance requirements. Each material has unique features and advantages which characterize its performance in various applications. Natural crystals tend to provide the highest temperature range and the lowest (or zero) pyroelectric output. However, ferroelectric ceramics offer extended frequency range and smaller size for equivalent charge output. Table (below) organizes material types ranked by temperature and pyroelectric susceptibility, and thus their suitability for use in engine applications where thermal loading is not constant.

Single, natural crystals, such as quartz and tourmaline, are inherently piezoelectric. Most naturally occurring single crystals that are used for sensors are grown in laboratories rather than mined, resulting in consistent quality with reduced risk of supply. In addition, the man-made aspect of a natural crystal has enabled the development of new, higher performance variations. The exception is tourmaline, only available through mining, rendering its supply chain uncertain and its cost prohibitive for use in sensors.

Ferroelectric ceramic materials are not inherently piezoelectric, because upon chemical formulation, they are in a random polycrystalline orientation. For the ceramic to become piezoelectric, the individual dipoles of each crystalline structure must be aligned. The alignment process involves applying a high voltage to the material to align polar regions within the ferroelectric ceramic element. After the artificial polarization process, known as poling, is complete, the crystal may undergo a pre-aging process and then can be used in a sensor.

Ferroelectric ceramics exhibit significantly higher sensitivity or charge output per imposed unit force. A commonly used high-temperature sensor material, BiTi (bismuth titanate), has an output three to four times its natural crystal counterpart, quartz. BiTi can be used to temperatures as high as 950°F (510°C). Various compounds may be added to the ceramic material to alter sensor characteristics but high temperature ranges come at the expense of sensitivity. Drawbacks of BiTi include the need for a carefully controlled environmental condition inside the sensor, and for a perpetually stabilized partial pressure level of oxygen to preserve its operational characteristics.

The new UHT-12 crystal is stable in any atmosphere and these sensors are backfilled with inert gas such as argon or nitrogen. UHT-

Natural versus Ceramic Crystals

Material	Natural Piezoelectric Single Crystals	Ferroelectic Ceramic, Piezoceramics	Piezoelectric Coefficient pC/N	Maximum Useable Temp °C	Pyroelectric
UHT-12 shear	X		12	650	No
UHT-12 compression	X		6	650	No
Quartz shear	X		4	250	No
Quartz compression	X		2.2	200	No
Tourmaline shear	X		3.5	650	Yes
Tourmaline compression	X		1.8	650	Yes
Bismuth Titanate		X	21	500	Yes
Bismuth Titanate derivates		X	14	600	Yes

TABLE 1: **Examples of piezoelectric material**

12 crystal does not exhibit any pyroelectric output and provides for reliable operation at temperatures approaching 1,200°F (650°C). While the raw charge output of this material is not as high as commonly used BiTi, additional benefits of the material include a relatively low capacitance and higher insulation resistance at operating temperature, which results in a low noise operation when used with a differential charge amplifier.

Another comparison of BiTi and UHT-12 is the ability to use the material in a sensing element configuration in a shear orientation. Physical and process limitations prevent BiTi from operating in a shear mode and thus legacy high-temperature sensors are still manufactured with compression mode sensing elements. On the other hand, UHT-12 may be used in a shear configuration if properly prepared.

Although the traditional BiTi produces a sensitivity of 50pC/g, the UHT-12 crystal provides between 5-10pC/g and has proven suitable for turbine vibration measurements. This lower sensitivity provides a further opportunity for smaller parts, lighter weight and wider frequency response. In today's world of low-noise electronics and high dynamic range analog to digital converters, there is simply no need for a larger, higher sensitivity element. In fact, when the UHT-12 element, which has lower element capacitance and higher insulation resistance than traditional BiTi sensors, is coupled with a suitable differential charge amplifier, a standardized 25mV/g output is provided. The dynamic range is greater than 120dB, providing a measurement resolution typically better than 0.002g (broadband from 1Hz to 10,000Hz).

The noise plot (above) is noise data taken with two charge amplifiers, each having a low frequency response of 1.6Hz (-3dB). One of the amplifiers was configured to provide a 25mV/g output with the sensor, and the other was configured to provide a 25mV/g output with a traditional 50pC/g BiTi-based sensor.

Both sensor theory and actual on-engine data support the use of high-temperature shear technology as the preferred measurement solution over the legacy design of compression accelerometers. The use of commercially available, synthetic, naturally piezoelectric UHT-12 crystals has the added benefits of higher temperature operation, no pyroelectric output, higher insulation resistance, better long-term reliability and long-term commercial sourcing security.

Note that the UHT-12 material also permits the use of a shear sensing element configuration. High-temperature BiTi materials are not able to function in a shear configuration. Whether used in aircraft turbine engines, rocket motors, or power generation stations, UHT-12 accelerometers must provide high levels of accuracy, stability and reliability. Therefore these instruments used in extreme high-temperature environments require special consideration during the design and manufacturing process.

Bob Metz is director of Aerospace and Defense at PCB Piezotronics, Inc

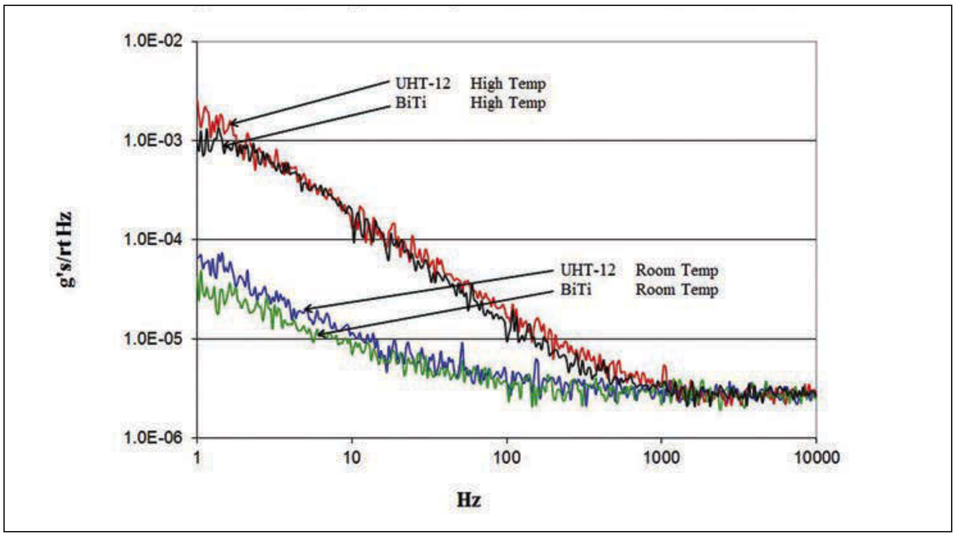
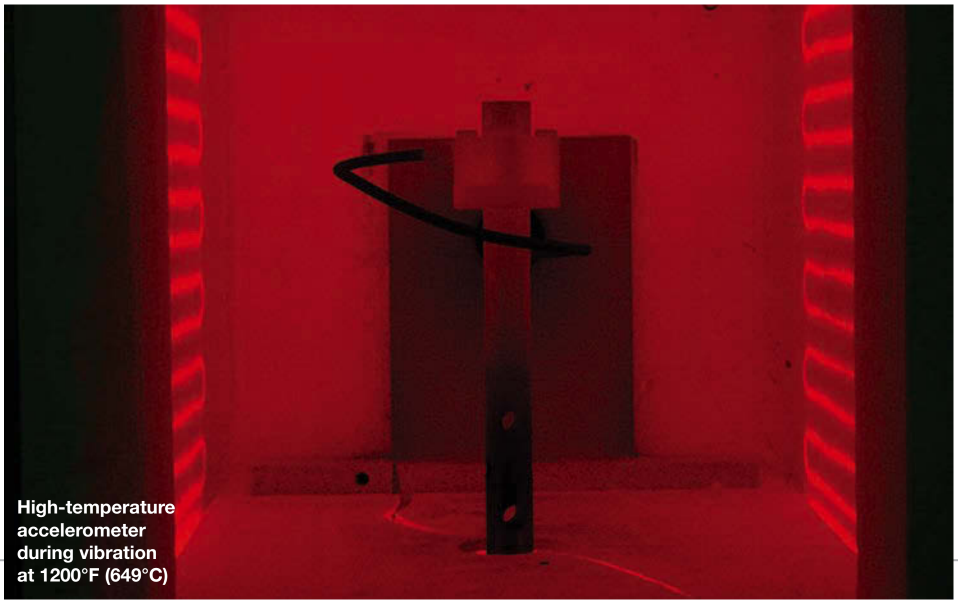


FIGURE 1: **Spectral noise of synthetic crystal vs bismuth titanate based sensors**



High-temperature accelerometer during vibration at 1200°F (649°C)

NEXT-GENERATION DATA RECORDER

Test engineers need a hassle-free and easy way to record data, while still able to view past data. Is this possible?

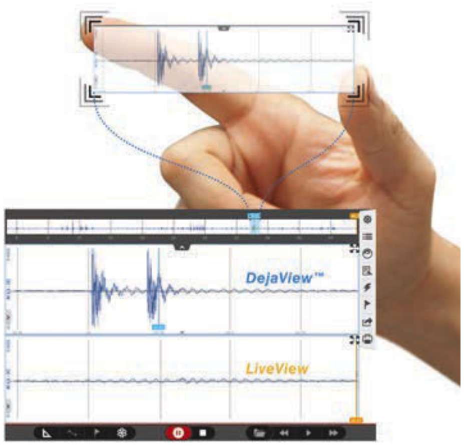
For test engineers, one of the biggest challenges in recent years has become the huge amount of testing that needs to be performed in always shorter times. Valuable test time is often spent preparing data acquisition systems for measurement. Issues that appear may be as trivial as not having the right physical input available, but more often the instrument software setup and operation is a hassle. For long-term testing, a key issue is the missing or insufficient ability to view data from the past while still recording.

Typical long-term testing applications for such recorders are engine test chambers, burn-in stations, materials production testing, HALT and HASS lifecycle testing, bench testing of satellite components, tap testing using high bandwidth accelerometers and environmental labs. For these tests, besides voltage and current inputs, a wide variety of sensors are in use, including strain gauges, accelerometers, force sensors, pressure and load sensors, and thermocouples.

This variety of sensors leads right into the issue of having the correct physical input available. Dewetron's new TrendCorder offers four slots for TRION series modules. TRION modules are available for virtually every sensor, and combine the power of simultaneous sampling ADC technology with advanced Dewetron signal conditioning. These modules can be exchanged by the user in moments, at any time. Calibration is stored on the modules, and running a self-test after installing a new module ensures proper function.

When the TrendCorder is turned on, an app loads and shows the incoming data immediately. The TrendCorder can be operated 100% by touch, including alphanumeric entry, channel setup and display configuration. Each channel has independently selectable ranges. The user can select filtering for each channel at any frequency and with up to eight orders of roll-off. The filters are done in hardware, therefore they impose no load on the computer. Users can select any filter on any channel, at any sample rate, even for the high-speed modules, which run at 2MS/s per channel.

TrendCorder brings the intuitive multi-touch operation of an app on an Apple iPad or smartphone to the data acquisition world. A single touch will start recording. Gestures that you use on your smartphone also work on the TrendCorder and make browsing and zooming your data easy. Besides simplicity, the intuitive 64bit application with multi-touch technology shows its full potential when data from the past needs to be viewed.



DEJAVIEW FEATURE

Even while the TrendCorder is streaming data continuously to disk at high rates, the user can scroll back on the recorder graph to any place in the recording and pinch/zoom on the graph to see any detail, no matter how far back in time it might be – and all without interrupting recording. This DejaView feature is very often needed by test operators conducting long-term testing, which cannot be interrupted. It is often not possible to stop recording just to enable a look back in time at previously recorded data. The TrendCorder's unique data handling architecture represents a major technical breakthrough in power and performance. ■

ABOVE: **The DejaView feature allows users to view the data from the past even during recording**

RIGHT: **TrendCorder brings the intuitive multi-touch operation of an app on an Apple iPad or smartphone to the data acquisition world**

VIBRATION TESTING

Fatigue Damage Spectrum is a new user-friendly tool to help measure a product's fatigue and calculate its lifespan, while dramatically reducing test time

The accumulated damage that a product experiences in the field due to a variety of stresses placed upon it will eventually cause a failure in the product. These failures can be replicated in the laboratory using random vibration testing.

There are a few methods that can be used to incorporate real-world data into your random vibration testing.

One of the methods introduced by Vibration Research (VR), more than 15 years ago, is Field Data Replication. This method records the data in the field and replays it on the shaker exactly as it happened in the real-world recording. This method can be a bit time-consuming but it is a very effective way to obtain and run real-life data on a system. Importing recorded data is nice for a specific product, but how can we make it random, or incorporate it into a test specification?

The next real-world method to consider is Random Import. Random Import creates a power spectral density (PSD) from recorded data while putting random peaks as average, peak hold, or somewhere in the middle. In the past we would take a recorded signal and generate a random breakpoint table for it. The question is; how long should this test be run? At what level should it be? Can the test be accelerated?

The newest method introduced by Vibration Research is Fatigue Damage Spectrum (FDS). This method uses real-world data on a shaker in an accelerated way and is a user-friendly tool which can dramatically reduce test time. FDS answers the questions about how long a test should be run and whether the test can be accelerated. This patented technique from VR incorporates real-world data, using the Henderson-Piersol method, into random testing. This method states that acceleration, velocity, and displacement may all be used to import recorded data into a PSD plot, but once any of the three is chosen to calculate FDS, that same one must be used again to generate a PSD plot.

LEFT: Thin metal beams were used to prove the accuracy of life prediction using Fatigue Damage Spectrum

BELOW: Fatigue Damage Spectrum dramatically shortens the test time on jet turbine blades, showing weaknesses in a matter of minutes rather than hours

So, gone are the days of guessing how long to run your random profile test and which profile is more realistic, or which environment will cause more damage. Over the past several years, the vibration industry has embraced Kurtosis Control – a new technique that brings about these failure modes in the laboratory in a more realistic and speedy fashion. FDS is also an effective tool that can show the damage a product will experience at a particular frequency and the effect Kurtosis Control has on the random vibration test. Kurtosis Control is a more effective method than traditional random vibration tests because it brings products to failure more quickly. FDS shows the increasing fatigue damage across all frequencies that accompany the increased Kurtosis levels, which cause the faster product failure.

In summary, by using the FDS and a total fatigue damage value, the test engineer can program a test to decrease a product's testing time and make random vibration testing all the more effective and realistic.

REAL-TIME TESTS FOR ACTUATORS

A current trend in the aviation sector is to replace hydraulic actuators with electric ones in modern actuator applications

The new technical developments in actuators have given rise to challenges such as efficient system design, the traceability of all work steps and integration testing. Some projects also require steps for the certification of an aircraft by the FAA or the EASA. The software has to comply with DO-178 to obtain certification, while the electronics hardware is subject to DO-254.

Growing system complexity also forces up the test requirements. Testing on component level alone is no longer enough to ensure that all the components will function exactly as planned when installed in the aircraft. Complex test facilities are indispensable, both for stimulating the system and for measuring the actual system responses. In addition, the entire verification and certification process has to be rigorously documented to ensure that each system is tested correctly and against the correct requirements.

TESTS WITH AUTOMATED REAL-TIME SYSTEMS

Of all the challenges mentioned above, it is system integration and system verification that have the greatest potential to benefit from using automated real-time systems. Moog uses real-time systems for three tasks: to emulate controllers when testing actuators, to emulate actuators when testing control software, and to test integrated systems by emulating system inputs and measuring system responses.

In addition, real-time systems help automate complex test runs and execute them in a deterministic fashion. This makes it possible to perform regression tests for modified systems and variants within a very short time. In particular, complete and thorough failure mode and effects testing (FMET) can also be carried out. Additionally, by simulating actuator errors, real-time systems allow actuator-specific error detection algorithms to be tested without expensive test hardware. Taken all together, these options add up to far-reaching improvements to test methods and considerable cost savings.

TEST FACILITY FOR FLIGHT CONTROL SYSTEMS

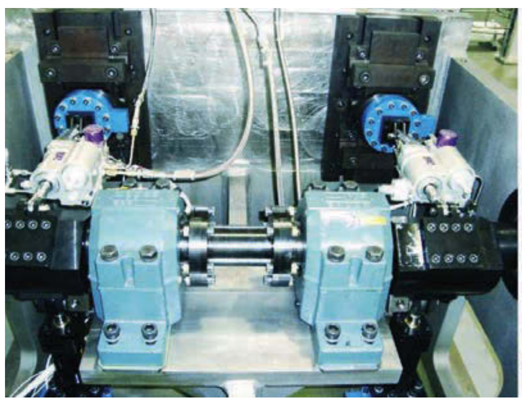
The typical actuator testing workflow can be demonstrated by an example of a test system for the flight control system of a passenger aircraft. The system can be used both for complete testing of the integrated system and for pure software verification tests. This makes it possible to integrate real components into the tests and also to simulate individual components or the entire system.

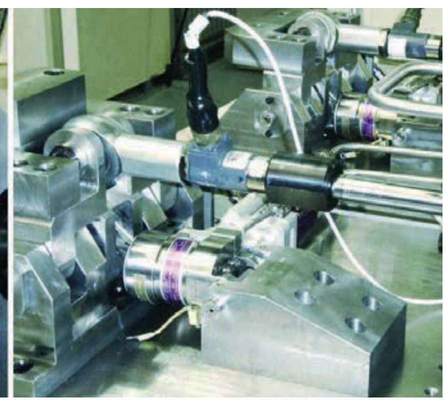
The test system includes a feature for using real pilot control inputs, or alternatively, these can be simulated, for example, to perform repeatable test runs. The test laboratory contains a wide variety of actuator hardware with associated test benches that are controlled and monitored by the test system.

The flight control system in this example also includes the control of the aircraft's high-lift flaps. The high-lift test bench consists of the hardware for one wing. The second wing is simulated by a load motor and real-time controls, so the test bench takes up less space in the laboratory. This setup can handle tests for complex fault scenarios that are very difficult to reproduce using real hardware.

The test system consists of a dSPACE multiprocessor environment, 16 ARINC 429 channels, relays for switching between the simulated and the real hardware, and almost 400 I/O channels.

The system provides numerous failure insertion options, plus the ability to use a lot of test benches either singly or as a system. Automated test runs allow software and system requirements to be formally verified. This representative closed-loop environment is a very efficient development and certification platform for the integrated system and embedded software. ∎





TOP: **Typical actuator test benches for testing passenger planes (left: rudder actuator test bench; right: spoiler actuator test bench)**

RIGHT: **Pilot workstation with realistic controls and flight control software**

THE SCARLET SCREAMER

In September 2013, the Swiss Air Racing Team became the first-ever international team to win the Reno Air Race Formula One category

History was made one Sunday last September, as the Swiss Air Racing Team's Scarlet Screamer sped over the finish line of the 2013 Reno Air Race in Nevada, USA, with every other aircraft in the Formula One category hot on its tail. Piloted by Vito Wypraechtiger and a close half-second ahead of reigning champion Steve Senegal, the Swiss Air Racing Team became the first-ever international team to win the Reno Air Race Formula One category.

The Reno Air Race has been an annual event since 1964, and is the last remaining major aircraft circuit race in the world. The five-day event is held each September at Reno-Stead Airport, which lies 15 miles (24km) north of the city, in the Nevada desert. Teams are able to compete in various categories: the original Unlimited, Formula One and Biplanes racing classes have over the years been joined by the T-6, Sport and Jets classes, in 1968, 1998 and 2002, respectively.

The exhilarating aerial race combines the very best piloting skills with outstanding aerodynamics and incredible power. More than 200,000 spectators witnessed the Swiss Air Racing Team's triumph on this, the 50th anniversary of the air race. This success is a result of the hard work and dedication of both the pilot and crew, as well as in the development of the aircraft.

THE WINNING AIRCRAFT

The Scarlet Screamer started its life as a Cassutt III-M plans-built experimental aircraft, originally featuring plywood wings and a steel, fabric-covered, tube fuselage. Recognizing the necessity of matching the capabilities of more modern rival aircraft, the Swiss Air Racing Team committed itself to improving the Scarlet Screamer with modifications that could compete with the composite monocoques and advanced aerodynamics increasingly fielded by competing teams.

IMPROVING THE AIRCRAFT'S AERODYNAMICS

To explore various options for enhancing the aircraft's performance, the team worked together with the aerodynamics department of RUAG Aviation, an established independent Swiss lifecycle solution provider for the aviation industry. Together with the other partners of the Swiss Air Racing Team, RUAG Aviation performed extensive evaluations of the aircraft to define how it could be improved. Through this, the distortions of the original fabric-covered rear fuselage and the shape of the cockpit were found to produce excessive drag under racing conditions. This resulted in the turtle deck and the cockpit area being identified as offering the most potential for aerodynamic optimization. A new shape for the upper fuselage was thus designed within the framework of the official rules set forth by the Reno Air Racing Association. CFD calculations and flight tests prior to the race demonstrated that the chosen shape significantly reduced the turtle deck's contribution to the Scarlet Screamer's overall drag. Further improvements were made through a smoother transition between the vertical stabilizer and the fuselage.

NEW COMPOSITE PARTS

To maintain the low weight and still obtain a stiff and undeformable geometry, carbon composite materials were selected for the manufacture of the new parts. Following the completion of the structural design, fabrication of the parts began in the prototype and model workshop of RUAG Aviation's aerodynamic department. First, a positive plug of the new turtle deck shape was built, upon which the negative form was laid. This mold was then used to laminate the turtle deck and provide a form to blow the new Plexiglas canopy. The new turtle deck and the new canopy were, once complete, shipped to the US where they were integrated onto the Scarlet Screamer. Subsequent test flights confirmed the benefits of the design changes, and helped set Vito Wypraechtiger and his team on the path to their outstanding achievement.

GOING FORWARD

The Swiss Air Racing Team is immensely proud of its achievement, and has already set its sights on delivering an even better performance in this year's race. Preparations have begun on all sides – within the team and with its various partners. Beyond air racing, the team's accomplishments demonstrate the significant capabilities and technical workmanship of Swiss industry. It is for these reasons that RUAG Aviation is proud to support the Swiss Air Racing Team through its aerodynamics expertise, and is pleased to continue doing so in future races. Andreas Hauser, manager of the aerodynamic department at RUAG Aviation, is firmly optimistic: "We are confident that our technical and financial cooperation with the Swiss Air Racing Team will be pivotal in the continued development and persistent successes of the team."

LEFT: The new turtle deck prior to leaving the wind tunnel composite workshop

BELOW: Vito Wypraechtiger with the victorious 2013 Scarlet Screamer. Photo: Swiss Air Racing Team

ACOUSTIC QUALITY CONTROL

A new system requiring minimal knowledge to operate can test acoustic materials and constructions in their finished state

Modern acoustic materials such as engine liners are tuned to attenuate very specific sound components – certain frequencies, for example. Such precise attenuation must be maximized inside rigid design parameters set by the engine or airframe design, without adding weight. Consequently, virtual designs must be painstakingly optimized to deliver the very best balance of performance at very specific engine settings and in relation to decided flight certification points.

But all that hard work can be quickly undone if the design specifications are not correctly translated to the finished product. Different subsuppliers can choose differing materials and manufacturing processes, and may deliver differing effective acoustic performance from the manufactured parts. Variability may occur through tolerance variations in resistive meshes, perforated hole diameters, or adhesive blockages of both. The manufacturing processes can also change over time. With all these factors, effective checks are necessary on the final product, to ensure conformity to specifications and uniformity of performance.

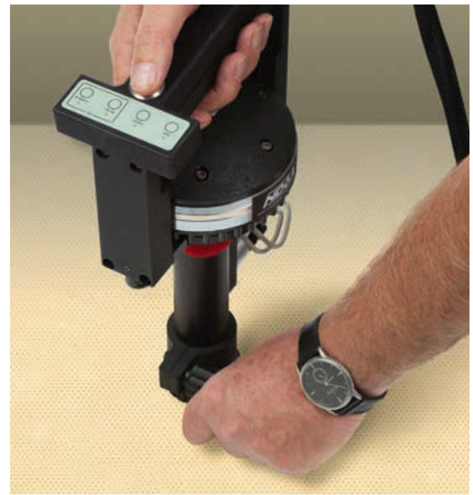
Material testing has traditionally required measuring the acoustic performance of a sample piece in a laboratory. This approach has always called for acoustic expertise to conduct, and either destroys the final construction – requiring representative, sacrificial test items – or tests the material in a flat state. But the final installation in the real world will meet non-linear acoustic resistance responses at very high sound-pressure levels. The best way of addressing this until now has been DC flow resistance measurements of manufactured panel components, but these suffer from being less representative of the final product and still requiring specific expertise.

Performing exacting acoustic quality assurance (QA) on final constructions can be vastly simplified with Brüel & Kjær's portable impedance meter. It uses high pressure sound up to 155dB to quickly spot-test acoustic materials at levels representative of those seen in aircraft engine ducts. The operator simply holds the ergonomically designed instrument in contact with the test article, and receives a clear go/no go signal from an LED. Being so straightforward to use for non-destructive tests, it can be incorporated into the production line QA routines performed on every unit. And since it tests the product in its final curved form, after all manufacturing processes have been completed, it is suitable for use on engine noise rigs, noise certification tests, and in situ engine panels on the shop floor.

Engineers can simply programme the unit with the desired acoustic specifications and tolerances, after which measurements are largely automated. External measurement factors such as humidity and temperature considerations are automatically calculated and incorporated into the acoustic measurements.

The software features a task-oriented user-interface, which is designed to intuitively guide the user through the logical steps of measurement. After testing, even reporting is automated, with an interactive impedance graph presenting all of the measured spectra and their relative performance against the specification and tolerances. The software closes the loop back to development by allowing extraction of the necessary parameters to develop and update models for acoustic impedance, such as the non-linear acoustic resistance characteristics of acoustic panels.

A number of acoustic sources can be used: broadband, pure tone, or a user-defined waveform. The latter may be used to represent an engine signature. The 29mm inner diameter tube allows measurement between 500Hz and 6,400Hz, the frequencies of primary interest for engine acoustic lining design. The meter can test at facing-sheet sound-pressure levels up to 155dB, well into the non-linear region. In addition to providing the components of impedance, it can deliver the traditional measurement of absorption coefficient, and can thus measure aircraft interior materials. It comes with a material sample holder as standard, for traditional 'closed tube' laboratory material testing.



At the gates of the airframe manufacturer, all that matters are finished products delivered on time to specification. This is best guaranteed with exacting QA of final units, after all manufacturing processes are complete. Brüel & Kjær's portable impedance meter is a complete system that can quickly ensure nothing leaves the factory with sub-par acoustic performance, by testing with the same high sound-pressure levels that panels are designed to mitigate. By providing guidance from measurement to green light to report, it helps engineers set specifications for technicians to follow on the production line. As a result of this innovation, Airbus now specifies acoustic quality control as an alternative to DC flow tests. ∎

ABOVE: The portable impedance meter tests finished constructions after all manufacturing processes have been completed

LEFT: Simple controls give clear pass/fail results to non-expert users

NON-DESTRUCTIVE TESTING

The influx of composite materials in aerostructures combined with the rising pace of programs has necessitated notable changes in the control activities

NDT EXPERT is a TESTIA (Airbus Group) subsidiary specializing in non-destructive testing in the field of aeronautics and space.

The company has more than 20 years' experience in the industry, and has worked closely with Airbus Group Innovations. With a 150-strong team made up of engineers, product marketing experts and certified technicians, NDT EXPERT/TESTIA has the capacity to meet the demands of international clients and their subcontractors. Eight overseas subsidiaries allow the company to operate worldwide.

The global offer now includes the ability to deliver a complete solution of products and services: definition and writing of customers' needs, study and design of means of control, their implementation, commissioning, training and qualification of operators, preparing regulatory requirements (service level 3 preparation NADCAP) and inspection services on-site if needed.

Where engineering services are concerned, NDT EXPERT/TESTIA specializes in semi-automatic machines (immersion or contact), special machines and robotic means. The A350 program delivers the best possible solutions, including the design and development of special machines for the control of specific geometry parts (frames, profiles, panels and so on).

A 'design to control' approach is used so that the means are tailored to the geometry of the parts, rather than the other way around. This enables optimization of investment costs, control and cycles.

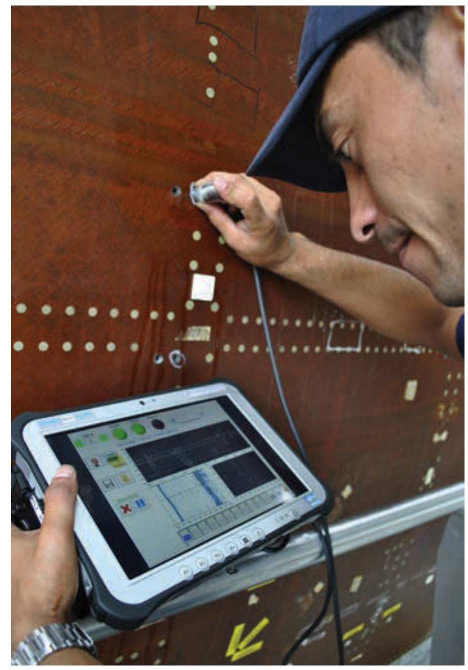
The NDT inspection guarantees the integrity of aerostructures, enhanced by further analysis.

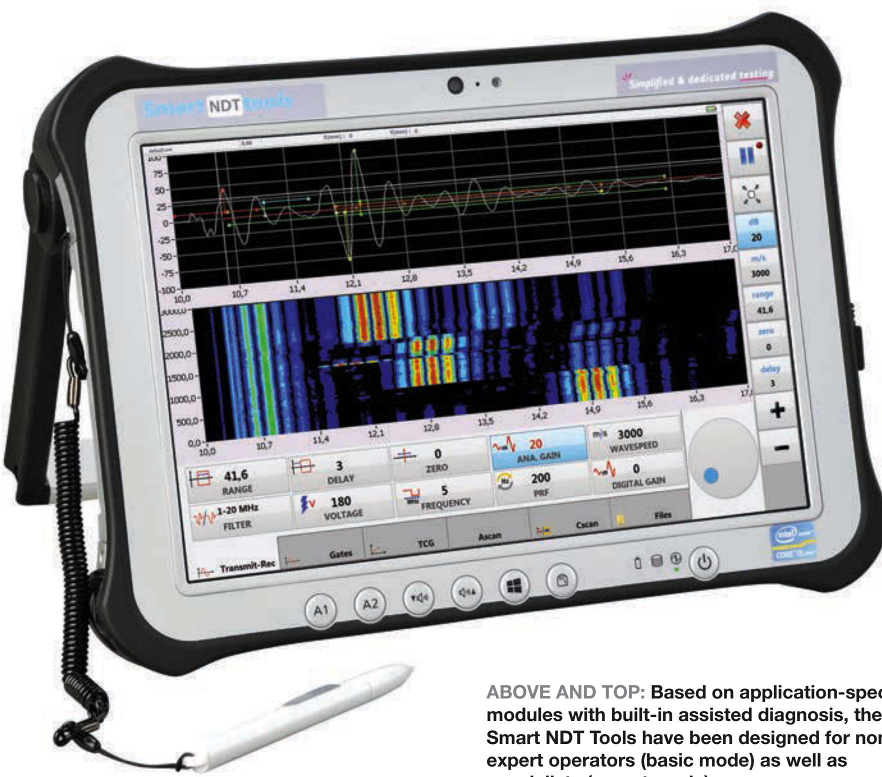
NDT EXPERT controllers have already acquired real expertise in UT-phased array monolithic composite control (pulse echo) and sandwich structures (transmission). In addition, teams are now trained to use Ultis, the software dedicated to mapping diagnostics, ultrasonics in particular.

Because of its staff's skills, knowledge and use of Ultis, the company is now able to accelerate the phases of diagnosis and reporting. Ultis Version 2 provides automatic defects detection and automated publishing inspection reports. Gains can represent 70% of analysis time. Ultis Version 3, available since July 2014, re-reads the mapping and simplifies the communication with the engineering office.

Finally, the recent arrival of the latest version of inspection equipment Smart NDT Tools perfectly illustrates the company's response to the industry's NDT needs. In both mono- and multi-element versions, these tools may ship as dedicated control applications for holes and thickness measurement, coupled with automatic report modules. This serves several types of activities: maintenance (UT, ET and resonance), production in special portable versions, and automated machines.

NDT EXPERT/TESTIA aims to provide all players in the field of aeronautics and space with the most advanced NDT technologies, guaranteeing an optimization cycle control that complies with quality requirements. ▮





ABOVE AND TOP: **Based on application-specific modules with built-in assisted diagnosis, the Smart NDT Tools have been designed for non-expert operators (basic mode) as well as specialists (expert mode)**

STRUCTURAL AND ACOUSTIC TESTING

Aircraft manufacturers need powerful acoustics and structural dynamics testing equipment to keep up with the demanding requirements of modern machines

There is continuous pressure these days to test aircraft and components in real-life circumstances and against ever-stricter deadlines. Aircraft manufacturers require more and more powerful, yet portable data acquisition systems, designed for the rigorous structural dynamics and acoustic testing. Modern testing systems need to provide easy inflight diagnostics and troubleshooting. The systems need to have simple user interfaces so that both expert and non-expert users are able to perform fast and reliable measurements. These systems must have broad functionality, combined with the autonomy and testing freedom of pocket-sized solutions.

Manufacturers who provide parts for passenger aircraft, business jets or rotorcraft need inflight cabin noise and vibration data to analyze their components' behavior. Be it for interactive troubleshooting, or for advanced acoustic comfort assessments, cabin trim suppliers or damping material suppliers rely on real-life test data to uphold and improve their products' performance.

However, usage should not be limited to inflight testing. The same systems must work on the ground to be used for operational data collection. Systems must support multichannel input and measure any combination of voltage, acceleration, and acoustic signals. The ability to collect operational data enables further test tailoring.

Siemens's new LMS SCADAS XS system meets the testing equipment requirement of today's manufacturers. This new system helps engineers in the aviation industry perform advanced structural dynamics and acoustic testing.

The LMS SCADAS XS makes noise and vibration diagnostics more accessible and cost-effective, even for remote testing. The aerospace and defense industries can profit greatly from the system's flexibility when performing inflight diagnostics, collecting operational data, and more. The extra-small and rugged design of the LMS SCADAS XS enables test engineers to perform a wide variety of in-field noise and vibration tests. The 12+ channel system with onboard signal conditioning processes all standard noise and vibration signals. Inflight or on the ground, it is the first personal testing system for NVH test engineers and technicians.

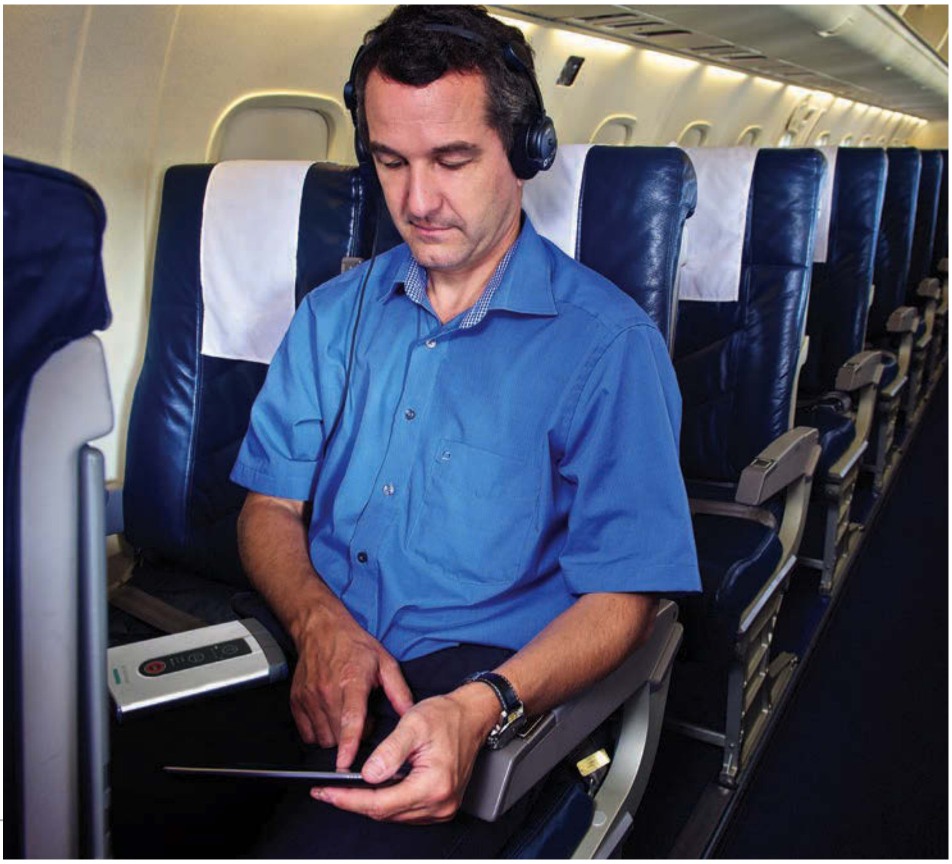
The LMS SCADAS XS literally fits in the hand. Combined with reliable onboard data storage and a full working day's battery autonomy, it gives test engineers the flexibility they need to take testing efficiency to the next level. The LMS SCADAS XS offers high channel-density capabilities and integrated signal conditioning. It can be used as a standalone recorder, with or without the enclosed tablet, or as a regular front end, connected to a PC. The tailor-made tablet application allows for easy, on-the-spot data validation, including audio replay.

The LMS SCADAS XS offers a new, battery-operated solution for recording vibration and acoustic data. Not only is it certified for inflight usage (certificate IATA-TI/IATA-DGR section II/section IB PI 965, PI 966 and PI 967), the LMS SCADAS XS's compact design also makes it a carry-on solution, easily fitting into any passenger's cabin luggage.

Equipped with a pre-configured standalone LMS SCADAS XS and an LMS SCADAS 3D Binaural Headset, even non-expert staff can record the required acoustic or vibration data in a test flight or even on a commercial flight. Test data is subsequently brought or sent home to the lab for detailed analysis.

With its compact size, the LMS SCADAS XS is also suited for the testing of very small unmanned aerial vehicles such as drones. Applications include hard landing test, shimmy testing and offline flutter testing. Test setup is very straightforward and does not require the presence of a specialized testing engineer.

Lastly, the LMS SCADAS XS's battery autonomy makes it possible to test the drones in flight for several hours. ∎



RIGHT: **The LMS SCADAS XS portable data acquisition system brings a completely new dimension to noise and vibration testing**

STRAIN AND TEMPERATURE SENSING

The need for strain temperature measurements in the testing industry is huge, but has newcomer Luna Innovations created a fiber optic measurement alternative?

Everyone in the testing world is familiar with the need for strain and temperature measurements on components as well as full-scale structures. These measurements are required for design and model validation as well as reliability determination. Standard sensors such as resistive foil gauges for strain measurements, and thermocouples for temperature, are usually readily available in test labs. While these methods are proving indispensable for system characterization, single point sensors are inherently limited in their ability to provide full-field information.

Luna Innovations (Roanoke, Virginia, USA), a relative newcomer to the sensing scene, is applying its technological advantage in the fiber optic measurement world to distributed sensing applications. Luna has developed fiber optic-based distributed sensing interrogators and sensors that provide a much more detailed view of the strain and temperature gradients within a system. The technology enables low-cost, fully distributed sensing capabilities with millimeter spatial resolution and high dynamic range. The sensors themselves are small, lightweight, immune to EMI, radiation-resistant, and can be embedded in or adhered to a material's surface. For aerospace testing, Luna's systems can be utilized in a variety of settings, from coupon material testing to larger scale subsystem tests.

FULL-FIELD WING FATIGUE BEHAVIOR

Composite materials are increasingly used in the aerospace industry as they are stronger and lighter, and offer greater corrosion resistance than structures built with traditional materials. Due to their non-homogeneity, composites require extensive physical and mechanical testing to characterize performance properties. In current testing schemas, load frames are used to measure the bulk property of a composite material, or single point sensors are placed on parts for characterization. Neither of these methods provides localized information on the non-homogeneous properties of composite materials. For larger parts, usually hundreds and thousands of single point sensors are utilized to obtain a picture of the full-field strain during tests. The logistical challenge associated with this is large, not to mention the time requirement for sensor installation, and the mass added just by the electrical leads running from each sensor. As an alternative example, with a single optical fiber, an entire composite wing can be instrumented and tested in both static and fatigue loading. The fiber sensor can be run in a grid pattern across the wing, resulting in the ability to measure strain gradients at a very high spatial resolution. This would allow weak points of potential failure to be located and monitored. This view of local strain gradients across the part during active loading could be used hand in hand with modeling data to provide invaluable insight into design decisions, and to help guide the future development of similar parts.

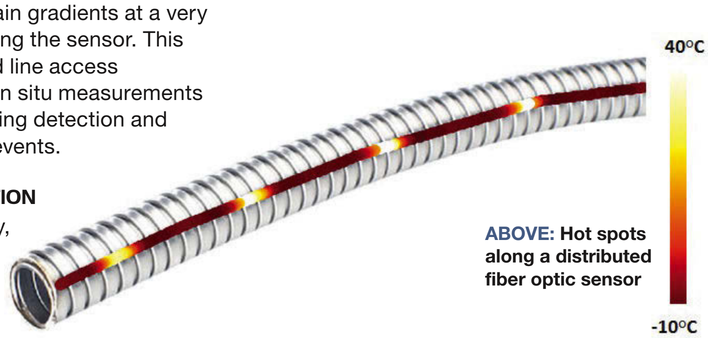
COMPOSITE PATCH REPAIR DELAMINATION

Cracks that occur due to impact damage can be repaired with a composite patch, to reduce stresses in this region and to prevent crack growth. The patch itself now needs to be measured for effectiveness, performance, and strength of the repair. This can be done easily by embedding a fiber optic sensor into the bond line, to measure strain gradients at a very high spatial resolution along the sensor. This overcomes previous bond line access limitations, and provides in situ measurements of localized strains, enabling detection and tracking of delamination events.

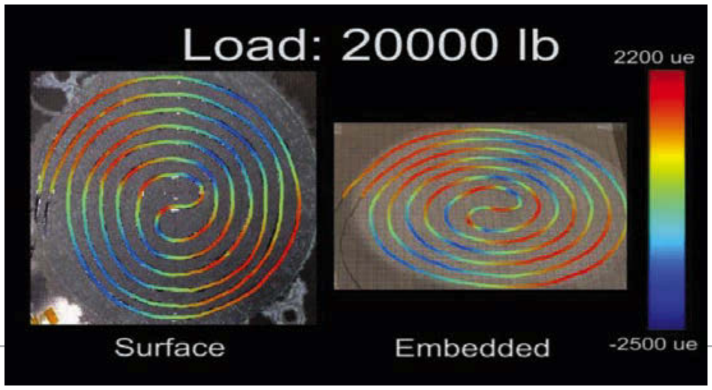
BLEED AIR LEAK DETECTION

Obtaining a high accuracy, high spatial resolution temperature profile of critical components has long been the holy grail of temperature sensing. With distributed fiber optic sensing, this goal is closer. Consider the compressed bleed air system. Compressed bleed air from the engines is used to run the propulsion system, maintain cabin pressure, and provide thermal energy for systems such as wing de-icing. Leaks in the bleed air lines can affect not only these systems, but can also cause damage to nearby components exposed to the extreme heat and pressure of the bleed air. The current solution for detecting bleed air leaks is a binary on/off alarm that has a high false-positive alarm rate and does not accurately locate the leak. With the use of distributed fiber optic sensing, long lengths of bleed air lines can be instrumented. The fine spatial resolution provided by distributed fiber optic sensing could provide full coverage, ensuring that no leak event goes undetected. When a leak occurs, the sensing system could provide information on the location, magnitude, and duration of the leak – information that is vital during damage assessment.

Information obtained from a truly distributed sensing system could provide invaluable insight into both the design and performance of parts and systems integral to the aircraft's performance.



ABOVE: Hot spots along a distributed fiber optic sensor



LEFT: Strain map of a stepped-scarfed composite patch repair. A single fiber sensor was embedded in and surface mounted on the patch repair, and measurements were taken during a shear frame load test. Collaboration with National Institute for Aviation Research

SOLUTION SEPARATES WATER FROM HYDRAULIC FLUIDS

The new Test Fuchs WSS3-20 water separation system is capable of separating free and dissolved water from hydraulic fluids down to extremely low concentrations with an innovative atomization and vacuum concept. The user-friendly, standalone unit not only separates water, it also removes gas and particles from hydraulic fluids. Traditional purification units are often connected directly to the air-con and cannot operate the aircraft's hydraulics due to low performance in pressure and flow. This leads to delays and extended service times. This provided a challenge for the experienced Test Fuchs engineers, who are always looking for possibilities to reduce time and save costs.

The purifier is connected to the hydraulic ground power unit and dehydrates the hydraulic fluid of the ground power unit reservoir. This can be done without the aircraft to save on service times. During an eight-hour operation, the water content from 200 liters of hydraulic fluid is reduced from more than 0.5% to 0.1% (1,000ppm) and even lower. After that, the aircraft is operated with nominal pressure and flow by the dehydrated hydraulic ground power unit, reducing to a minimum the water concentration of the air-con hydraulic fluid in minutes.

The benefit of this new strategy is that the service time on aircraft is reduced to practically nothing, while the water content in the moving parts such as actuators is removed by using a ground power unit.

The fully automatic purifier is operated manually via one main switch, buttons and analog indicators. An online relative humidity sensor shows the actual water concentration. As an option, an absolute humidity sensor in a range from 0ppm to 20,000ppm, and also an online particle counter according to AS4058 purity levels, are available.

The WSS3-20 water separation system can be moved by hand or by truck if needed. The stainless steel housing is resistant against any hydraulic fluid. All necessary hoses with self-sealing quick connection couplings are also part of this unit.

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INTELLIGENT, INTUITIVELY OPERATED CT SYSTEMS

Yxlon is breaking new ground in operational friendliness with the new Yxlon FF20 CT and FF35 CT systems for the non-destructive testing of materials and their measurement. Conventional computed tomography scanners on the market are complex systems involving sophisticated operation – even for experienced users. In contrast, the new Yxlon Geminy software platform supports the user intuitively and 'paves' a simpler way to achieving the best data quality in three-dimensional inspection – even for new CT users – via the platform's system intelligence.

An eye-catching feature of the new CT systems is the new 'smart-touch' operating concept with two monitors. One of them is arranged in a horizontal format, as usual, the other in a vertical format. This not only increases work ergonomics: it keenly simplifies operational workflows as well. While one monitor is used for control and input, current results can be displayed on an ongoing basis on the other. Touchscreen operation has already achieved an everyday status in private-sector applications.

The Yxlon FF35 CT combines precision with versatility. With the large inspection envelope and two different x-ray tube sources, a close critical look can be taken, even at larger objects, or to scan the details of an inspection series of smaller items with a high degree of accuracy. While doing so, the directional tube head is enhanced via the optional, new transmission tube head FXE190.61.

Operation via Yxlon Geminy differs greatly from the kind experienced in conventional computed tomography systems. This system is controlled via icons and manages almost completely without text. The intuitive operation helps to acclimatize staff quickly during initial training so that operators are able to work with the equipment productively within a short period of time. The system settings are regulated incrementally via user profiles. The individual inspection steps along with the elements of the imaging chain respectively contained within them are composed using 'smart touch' from graphic symbols in the form of a block diagram.

Unlike the situation found in conventional CT systems, the communication between Yxlon FF35 CT or Yxlon FF20 CT and users doesn't end when they literally leave the system. The operator can obtain information according to his or her needs via remote access, for example by means of a tablet, or be kept up to date automatically via push messages. This way, an inspection operator can pursue other work activities while the system implements a measurement, yet is still notified on a timely basis when a work process is concluded. In a different vein, a quality manager can receive information about the system status at all times – for example, whether results from system tests are available and if they comply with the specifications – without the manager having to perform the actual work in the CT system.

INDEX TO ADVERTISERS

Time machine

A personal account of the trials and tribulations of building a replica Sopwith Camel in time for the centennial celebration of its first flight

BY JOHN SHAW

The anniversary of the outbreak of World War I is an appropriate time to remember its famous fighter – the Sopwith Camel. Over four years ago, I started to build F-AZZC to an as original specification as possible from planks of wood, and I wanted to hopefully fly by the anniversary of the first Camel flight in December 1916. F-AZZC has been the prototype for four Camels, but I have kept F-AZZB (project for sale) up to speed as progress has been satisfactory. The plan is for the Camels to go on the French vintage register.

'Top secret' Sopwith drawings came from a 35mm film of the Sopwith schedule – original but incomplete. Replicraft drawings appear to have been redrawn from the Sopwith originals, but there are a number of inconsistencies. Fellow enthusiasts and museums have helped to fill in a few gaps, but often replicas were not necessarily built to 1917/1918 specifications. Field and factory modifications seen in old photos rarely made it back to the drawing office as official amendments.

The challenges have included sourcing the right people with the knowledge, skill and passion to interpret the plans and build the parts accurately. My skill is woodwork, but I have had to learn others such as metal splicing, metal machining, spinning and milling, pattern building for aluminum and lost wax casting, and even cane-work for the seat. We have even gone to the length of finding a supplier with original jigs for AP155 for the undercarriage, building a jig for AP121 for the wing and empennage trailing edges and a mold to make rubber for the joystick. Some of our castings are now getting used around the world by vintage specialists and museums, which has helped offset development costs.

I was lucky enough to buy an original le Clerget 9B 130hp engine for my aircraft and to find a retired engineer who could – and did – return it to working order. Even so, new rocker arms and spark connector wires have had to be made. An original propeller was borrowed and copied by an artisan (now retired) in the old fashioned way. I have an original oil tank, but for safe operation, decided to have all new tanks made to the original plans. The fuel system requires a hand pump before start-up (original borrowed and copy made); and a Rotherham pump (original owned, but may use a copy which I am building). I still need to find a Sopwith patent air pressure gauge and relief valve, WWI fuel filter, WWI tachometer, second original magneto, original 3/8 three-way valve and carburetor fittings. Please search your sheds. The engine slotted into the engine front and back plates perfectly and the plumbing (air, oil and fuel) is progressing. Currently F-AZZC is in the UK having her firewall and cowlings made.

I have many original flying instruments, but would still like to find a more appropriate WWI 0-1,800rpm gauge. The empennage has been fitted and all the control wires for rudder and elevator spliced up. It was very satisfying to see them operational. We tested a splice and, at 1 ton, the wire split and the splice stayed intact!

There are some instructions on rigging and assembly, but I have had to learn the hard way that there are some really critical complicated metal fittings for the struts and undercarriage where minor problems can only really be fully discovered at assembly. Discovery of fabrication errors meant a lot of rework. I am now happy with the undercarriage, the fit of the upper wings to the center section, and the cabane strut fit of the center section to fuselage. I have yet to test the interplane strut fit and lower wing fit to the fuselage. The aircraft has to be fully assembled for its next check by the French aviation authorities before I can start to cover it with linen and paint in the PC10 color scheme.

There is joy and heartache in vintage restoration. High levels of authenticity often come at a high price. Methodology and skills have disappeared, so recreating them is challenging, but there is great satisfaction when it works. I would be grateful for any help with my problems and 'wants' listed above; you can keep up-to-date with progress at: www.johnsshawaviation.co.uk. ∎

John Shaw, now retired, has been a carpenter and joiner, commercial diver and flying instructor at various times. His first glider flight was in 1958, aged 10, and he has had a lifelong interest in aviation, restoring many gliders and aircraft, as well as old buildings. Most of the Camel work is done in his workshop in France, but his metal workshop is in Cornwall, UK

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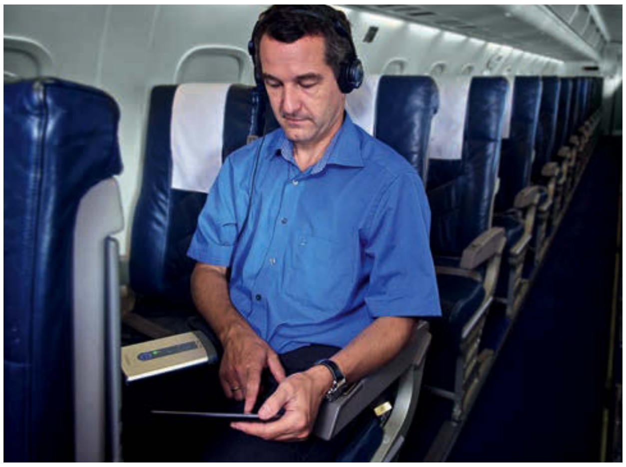

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