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JUNE 2013

AEROSPACE TESTING INTERNATIONAL

Reaction engines

The three largest commercial engine manufacturers discuss the trials, tribulations and budgets of their latest test programs

F-35 FLIGHT UPDATE

Interview: Bill Gigliotti, deputy chief test pilot, discusses everything from fan blades, to tail hooks, to displays

MISSILE DEFENSE

Exclusive: The USA's Missile Defense Agency on the largest missile test and tactical exercise ever held

SOLAR IMPULSE

The latest news from the team that put alternative power on the world map, plus an inflight interview!

MRO FOCUS • BRAZILIAN KC-390 • FUTURE PROPULSION • CANADIAN AIR FORCE CHINOOK

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Contents

Two phrases to consider: 'À vaincre sans péril, on triomphe sans gloire' and 'Le génie est une longue patience'. These mean: 'To win without risk is a triumph without glory' and 'Genius is patience'. Wonderful words of wisdom from 17th-century dramatist Corneille and 18th-century naturalist Buffon, respectively.

Both these phrases apply to the testing of aircraft. On the one hand you have the devil-may-care attitude that drives man to defeat gravity, and the other applies to the time, diligence and detail in order to do it and develop further. Why am I using romantic French phrases? Well, as we go to press the 50th Paris Air Show is concluding!

It was in 1909 that the first ever air exhibition got underway, when 100,000 visitors turned out to see 300 static exhibitors. In 2013 more than 2,000 leading players of the industry will be wheeling and dealing and showing their wares.

At time of going to press the big news was that the show may incorporate a maiden flyby of the Airbus A350 XWB on the last day – for which Singapore Airlines announced a US$7.9bn order for up to 50. Not to be outdone, and making a statement, the normally display-shy Boeing company used a 787 in Air India livery to perform in flying displays, proving that it is firmly back in the air. I managed to grab a few words from Boeing CEO James McNerney, who said. "All battery problems are behind Boeing now, although the FAA tok a long time. We now have a system so robust, it is guaranteed for years."

UAVs had a considerable presence, and, from a business angle, the word on the economic street is that ATR and Embraer will procure a number of big orders for their second-generation regional jets.

On a personal note, I was proud to be attending the Aerospace Media Awards, held at l'Aéro-Club de France. We entered the *Total Impact* article (on the controlled test crash of a 727) from December 2012 into *Best International Aviation Feature* – however, just missed out.

Heading north from Paris to the English Channel… I was intrigued with some recent news that the only known example of a World War II Dornier Do-17 aircraft has been successfully lifted from the seabed 72 years after it was shot down by a Hurricane. It was 50ft below sea level and, barring a layer of barnacles and just a hint of rust, was in remarkable condition. It will now go through a major restoration program, with the aim of exhibiting it at the RAF museum. But what truly amazed me was that this aging hulk is now the only 'surviving' example of the 'flying pencil'; 2,000 were manufactured in Germany alone.

The same can be said of the Avro Lancaster, the embodiment of the allied night bomber. Only two still fly, and yet 7,300 were built. From my own limited research there are only 12 original flying Messerschmitt 109s; 40,000 were built. No Mosquitos now fly; the last one crashed in 1996. The last airworthy Heinkel He 111 crashed in 2003; 6,500 were built. I was really expecting it to be different in the USA, but no. Out of 12,000 B-17s, I found only 17 still flying. Understandably, I can see no evidence of a single airworthy World War I aircraft. Of course, it is very important that we take into account that huge numbers were brought down either in action or accidents, which may account for more than half.

I'm writing about this here, because on the inside back page of the magazine is an uplifting story about the restoration of a Mark XVI Spitfire, which is now flying. The point of all this? Heritage. So many amazing aircraft have been scrapped, and so few are now left. However, I am being sent more and more stories about restoring and testing of historic wartime aircraft – to fly! It is essential to look forward, but tragic to scrap the aerospace past, especially as it is all so recent.

My father used to be a pilot member of the Tiger Club. The Tiger Moth, a fabric and wooden biplane that looked more like a World War I veteran than World War II trainer, was the staple training aircraft for the RAF from the early 1930s. It was all open, with separate cockpits front and rear. My father used to take me up when I was a child. As a passenger I sat in the front (complete with leather flying helmet and goggles), him aft. You couldn't speak – the configuration, huge engine noise and wind made it impossible. It was great to pretend to be the Red Baron – until of course we banked with the wind behind, and the engine would start to stall. Dad would then put the airplane into a dive, I would scream, and then he would pull a loop. Magic. The great news is that of the 9,000 built, 250 now fly around the world, and more are being restored.

Much as I love aviation history, I can't ignore the industry's future. Read the exclusive interview with the amazing Solar Impulse co-founder and pilot, André Borschberg, starting on page 52. I hope you're as excited about it as I am.

Christopher Hounsfield, editor

PRODUCTS & SERVICES

REGULARS

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WORLD TEST UPDATE

HONDAJET: Honda Aircraft Company has announced that its fifth FAA conforming HondaJet, equipped with a production interior matching the final customer aircraft, has been successfully completed. Passing the milestone, the HondaJet program approaches the final phase of flight testing as the company advances toward FAA aircraft certification of the world's most advanced light jet.
Greensboro, North Carolina

F-35 ITF: The F-35 Integrated Test Force is concluding a series of night flights, which are testing the aircraft's capability when flying in instrument meteorological conditions. It is a necessary step in delivering a core competency to the warfighter – the ability to fly the jet safely when there are no external visibility references for the pilot. When the ITF completes the night flights, a variety of capabilities will have been tested including ground operations and the pilot's ability to maneuver the aircraft without becoming disoriented.
Edwards AFB, California

747-8 PERFORMANCE: A Boeing 747-8 Intercontinental has successfully completed its first test flight with a package of performance improvements including enhanced GE engines. This package is designed to improve the fuel efficiency of the jetliner. The airplane performance improvement package includes improvements to the GEnx-2B engines and flight management computer software.
Everett, Washington

IDENTIFICATION SYSTEM: BAE Systems has been awarded a US$34m contract to provide the US Air Force with its Mode 5 Advanced Identification Friend or Foe (AIFF) system, used to identify and track military aircraft for the F-16. The system, which was developed as an enhancement to older, less capable IFF technology, increases identification capability through the use of secure message and data transmission formats.
Arlington, Virginia

DREAM CHASER: Sierra Nevada Corporation's Dream Chaser Space System flight vehicle has arrived at NASA's Dryden Flight Research Center in California to begin tests of its flight and runway landing systems. The tests are part of pre-negotiated, paid-for-performance milestones with NASA's Commercial Crew Program, which is facilitating US-led companies' development of spacecraft and rockets that can launch from American soil.
Dryden, California

PARACHUTE TRIAL: The USA's Airborne and Special Operations Test Directorate conducted a rigorous operational test recently on the new Military Free Fall Advanced Ram-Air Parachute System, a non-developmental item that is about to replace the nearly 20-year-old MC-4 parachute system for all service branches, according to the test officer.
Yuma, Arizona

STANDARD MISSILE-6: Raytheon's new state-of-the-art missile factory in Huntsville, Alabama, has delivered its first Standard Missile-6, a ship defense weapon that will soon be able to attack ballistic missiles as well. The US Navy took delivery of the SM-6 round at the new US$75m, 70,000ft^2 facility. The Standard Missile-6 defends naval vessels against fixed- and rotary-wing aircraft, unmanned aerial vehicles and cruise missiles. By 2015, Raytheon plans to upgrade the SM-6 to also provide protection against ballistic missiles in their final phase of flight.
Hunstville. Alabama

LEGACY AVIONICS: Embraer Executive Jets has received certification for its latest avionics functions, including: Required Navigation Performance (RNP), Vertical Navigation (VNAV), Future Air Navigation System (FANS) and Localizer Performance with Vertical Guidance (LPV) as installed on both the Legacy 600 and Legacy 650 aircraft.
São José dos Campos, Brazil

A319: Airbus has received European Aviation Safety Agency certification for Sharklet-equipped A319 jetliners fitted with CFM International CFM56 powerplants. This milestone is an important step for the planned service entry later this year of the shortened-fuselage A320 family member with these fuel-saving wing-tip devices.
Toulouse, France

WAKE VORTICES: For the first time, researchers at the German Aerospace Center (DLR) have tested – under real flight conditions – a process that can break down potentially dangerous wake vortices over a runway significantly faster. To do this, they used a patented configuration of parallel ground plates, as well as a laser-based wake vortex measurement system. A modified Gulfstream G550 flew just 22m above a row of plates during the measurement campaign. Using smoke, the researchers could demonstrate how the otherwise invisible wake vortices weakened faster over the plates in the test area.
Cologne, Germany

SU-34 BOMBER: The first in a batch of Su-34 production frontline bombers to be delivered in 2013 to the Russian Air Force under this year's State Defense Order has been dispatched by the Sukhoi Company. Following the handover ceremony at the airfield of the Novosibirsk-based VP Chkalov aviation plant run by Sukhoi, the aircraft departed for its assigned home base. Several more Su-34 bombers will be delivered to the Russian Air Force later in the year.
Novosibirsk, Russia

CHALLENGER 350: Bombardier Aerospace has announced that it has expanded its leading Challenger family of business jets with the addition of the new Challenger 350 aircraft. The Challenger 350 jet was launched, with private aviation company NetJets as the worldwide launch partner, at a special event at the European Business Aviation Conference and Exhibition (EBACE) in Geneva, Switzerland. Deliveries of the aircraft are expected to begin in 2014.
Geneva, Switzerland

ELECTRIC ENGINE: Japan Aerospace Exploration Agency (JAXA) is part of a team that has successfully developed a motor coil that can maintain its maximum power more than two times longer than a conventional model, by using thermal conductive, heat-resistant insulating material. Technology to extend the time duration of a motor's maximum power is imperative for the practical use of an electric aircraft. JAXA has been engaging in research and development of an electric aircraft as one of the most promising aviation technologies for future aircraft.
Tokyo, Japan

SECOND A400M: The second production Airbus Military A400M has successfully completed its first engine runs as it begins final preparation for its maiden flight later this month. The aircraft, known as MSN8, is now undergoing taxiing trials outside the A400M final assembly line in Seville, Spain. Airbus Military expects to complete four A400M aircraft in 2013 and will deliver MSN8 to the French Air Force in the third quarter of the year.
Seville, Spain

X^3 BREAKS HELICOPTER SPEED RECORD: The Eurocopter X^3 hybrid helicopter has opened the frontiers of aviation by attaining a speed milestone of 255 kts (472 km/hr) in level flight on June 7, 2013. Several days before this accomplishment, the X^3 reached a speed of 263kts (487km/h) during a descent. With this, the X^3 surpasses the unofficial speed record for a helicopter.
Marignane, France

CRYOGENIC ENGINES: The manufacturing facilities for integrated cryogenic engines will be set up at HAL's Aerospace Division in Bangalore, according to Dr K Radhakrishnan, chairman, Indian Space Research Organisation (ISRO). He said that HAL will continue to play an important role in the future programs of ISRO.
Bangalore, India

GRANDFATHER CLOCK KEEPS TICKING

WHAT DOES 'GRANDFATHERING' MEAN?

In the Aircrew Regulation, 'grandfathering' designates the legal recognition and acceptance of certificates issued by national authorities prior to the entry into force of the Aircrew Regulation.

Grandfathering measures are included in the 'Cover Regulation' to assist 'member states' in the transition from national rules to unified EU rules. In the case of aircrew licensing, provisions on grandfathering consider some national certificates issued in compliance with given regulations, and by a certain date, as being in compliance with the new Aircrew Regulation. A 'transition measure' is a means of allowing a gradual change to the new rules. This is the official statement.

As Bob Moreau says, "Grandfathering is a term used to describe a situation where persons, or organizations, do not have to meet the explicit provisions of a new rule based on their previous experience. In other words, the persons, or organizations, are granted the status of the new rule without having to do anything additional.

"In the case detailed here, it would be impossible for anyone to meet the training requirements of the new test pilot rule as no approved training exists at the moment and it would make no sense to ground all test pilots until they went through the new training requirements from an approved source once they did exist."

With the European Aviation Safety Agency (EASA) decision to implement a new scheme of licensing for test pilots (and proposed for flight test engineers) from April 2015, members of the Society of Experimental Test Pilots (SETP) and the Society of Flight Test Engineers (SFTE), both within Europe and outside of it, continue to raise concerns. As with any new sweep of broad regulatory changes, questions outnumber answers by a wide margin. And, as many aspects of the new rules remain a work in progress, the question-to-answer ratio remains a fluid one. The questions being asked by SETP and SFTE members can be grouped into three broad areas: 'grandfathering' during the transition; post-transition training of test pilots and flight test engineers (FTEs); and day-to-day flight test operational issues.

Bob Moreau, a senior test pilot and fellow of SETP and SFTE, explains the predicament: "Given the rather detailed and explicit requirements for the issuance of the new test pilot rating in accordance with FCL Section 280, the subject of grandfathering is a starting point for questions. What grandfather criteria wouldn't require additional training by an EASA-based test pilot currently conducting flight test activity? If some amount of additional training is deemed necessary and no instructor is EASA approved, how would this be accomplished? Might this differ from place to place? Who would be authorized to make the decisions?

"For non-EASA-licensed pilots currently conducting test activity within a European member state, will there be any type of grandfathering, such as exchange

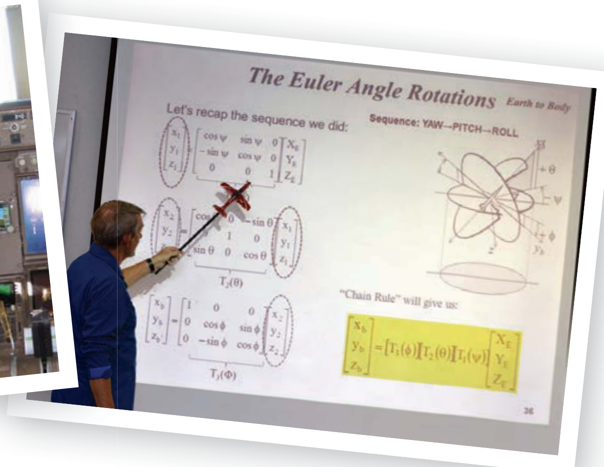
test pilots from the US Force attending Empire Test Pilots School (ETPS) or EPNER TPS?

"Some of these answers are already known. A test pilot flying a Joint Aviation Authorities (JAA) registered aircraft will need to have a JAA license with a test pilot rating. A test pilot flying a non-EU registered aircraft in Europe would not need to be grandfathered, because the regulation would not apply. A US exchange pilot at ETPS needing to fly any aircraft can do so as long as the activity remains within a 'military' frame (taking off and landing from an RAF base) for which the regulation does not apply either. However, a US exchange pilot needing to ferry an experimental aircraft from Boscombe Down, UK, to an airshow at any JAA airport would need to have a JAA license with a test pilot rating.

"There is a large number of possible permutations that are not being addressed officially. These are not trivial questions because once the rules go into effect, and the grandfathering period ends, the possibility exists of having flight testers on the outside of the system looking in, faced with no recourse but to abide by the very long requirements of FCL.280. Cases can be very complicated, and the answer for non-JAA-licensed pilots to be grandfathered is that most likely they may not.

"The issue of grandfathering also extends to the various TPSs. Currently, once the full rules are implemented, only approved air training organizations (ATOs), of which a TPS is defined as being a type of ATO, that meet specific EASA training requirements, are to be granted approval. What, if any, are the specific grandfathering criteria applied to the various test pilot schools? For example, the German civil authority (the LBA) explicitly approved the National Test Pilot School (NTPS) in California to give training leading to German test pilot licenses, Class I and Class II. Does that entitle the NTPS to be grandfathered for EASA Category I and II TP licenses?

"It is safe to assume that both the ETPS and EPNER will adjust their TPS curricula to meet any EASA-defined requirements. But what about the other TPSs, which are predominately military orientated, such as the US military TPS? Both have a long history of including slots for exchange students from other countries.



INSET LEFT: **An associate Fellow of the Society of Experimental Test Pilots, Captain Bob Moreau is a FedEx Experimental Flight Test/Strategic Projects and FAA Test Pilot DER**

LEFT: **Are the equations of motion or the new EASA test pilot licensing requirements easier for test pilots to understand?**

What would be the logic by which a TPS student from Europe would opt to attend either of these knowing that, upon return to the EU, their hard-learned skills would not be recognized to conduct any type of EASA flight testing? A graduate of any such school processes the same basic knowledge and skills to properly flight test an aircraft. Therefore, there should be some path by which graduates may be subject to some short amount of additional EASA-specific certification training that would equal the EASA test pilot licensing requirements. This could take the form of embedded EASA content within the overall TPS course. Or, it could take the form of an EASA approved short course.

"Put simply, if the aircraft is EU-registered, and the program is an EU product validation, the rules apply. However, an EU member state can accept a non-EU-licensed test pilot who holds the appropriate qualification issued under ICAO Annex 1, and is employed by an aircraft manufacturer for the purposes of flight tests. Would this same allowance be made for FAA TPs or FAA DER test pilots? The answer should be yes, but no answer has yet been written."

UK UAV EXPERIMENT WRAPS UP

Unmanned aerial vehicles (UAV) flights in non-segregated airspace (general airspace regulated by the UK CAA) were successfully demonstrated during the culmination of a seven-year UK experimental project, according to participants in the £62m (US$93m) effort.

The ASTRAEA (Autonomous Systems Technology Related Airborne Evaluation & Assessment) project ended in May following 45 test flights of a BAE Jetstream surrogate UAV testbed aircraft (pictured), and the consortium running the project is considering engaging with international partners to extend its work.

A consortium of UK industry, academia and the government's Technology Strategy Board (TSB) launched the ASTRAEA project in 2006 to examine the technologies, systems, facilities, procedures and regulations that will allow autonomous vehicles to operate safely and routinely in civil airspace over the UK. Major UK-based companies involved included AOS, BAE Systems, Cassidian, Cobham, QinetiQ, Rolls-Royce and Thales.

"We demonstrated that UAV can break out of segregated airspace," said Dr Carl Loller, BAE Systems director of future capability and engineering integrated solutions.

"We believe the ASTRAEA showcase culmination flights are a world first for flights of a large UAV [which just happened to be a 'surrogate UAV' in this particular ASTRAEA case] in non-segregated civil airspace and fully integrated with national ATC. The set of ASTRAEA showcase flights in March/April this year successfully demonstrated this was now possible, including meeting the safety requirements of the regulators and putting the UK in a strong technical and regulatory leadership position in this key area of UAV development."

The ASTRAEA effort culminated with 150 hours of flight testing by the Jetstream surrogate from BAE Systems' Warton site, which ultimately involved the aircraft flying to Inverness Airport in Scotland under the control of a ground station via a satellite communications link.

Human pilots were at the controls during landing and take-off, before they handed over to the ground-based pilot at Warton. The aircraft was fitted with sense-and-avoid health monitoring and autonomous decision-making systems to assist the pilot, as well as an avionics architecture to link the elements together, said Loller.

During the culmination flights the project team introduced deliberate malfunctions to test the robustness of the system. The sense-and-avoid systems from Thales provided the ground-based pilot with visual clues of bad weather, and also tracked intruder aircraft in its airspace. "It was better than human pilots in certain circumstances," Loller said. The communications links used on the ASTRAEA surrogate had a three- to four-second latency, but better antenna and more satellite bandwidth could improve this and enable future UAVs to operate in heavily congested airspace, such as around major hub airports. A key element of the project was the production of what Loller termed a suite of "virtual certification" documentation for the UK CAA, which could be the basis of certification of future UAVs. "We didn't certify ASTRAEA, it was not appropriate," he said. "We could have if it had been a product."

This experience could be at the heart of the next phase of ASTRAEA, which could see the UK engaging with European and other international partners. "There might be phase 3, it is under discussion. ASTRAEA3 could be built around the brand," said Loller. "It would be less about maturing technology. All our partners are now in a prominent position to use the ASTRAEA brand to engage and influence regulators in Europe and in the US as well. We should celebrate that we have mastered this."

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SCALEXIO

DREAMLINER NIGHTMARE OVER?

Boeing has dispatched teams of engineers to Dreamliner customers based around the world to begin installing improved battery systems on the troubled 787 airliners.

New batteries and installation kits needed for the new battery system, billed as putting a stop to the fires that plagued Boeing's newest airliner earlier this year, are being prepared for shipment. The teams have been assigned to customer locations to install the new systems. Boeing said the aircraft will be modified in approximately the order in which they were delivered.

The move follows approval of battery system improvements for the 787 Dreamliner by the US FAA on April 19, which cleared the way for Boeing and its customers to make the modifications. This will lead to a return to service and resumption of new production deliveries. "FAA approval clears the way for us and the airlines to begin the process of returning the 787 to flight with continued confidence in the safety and reliability of this game-changing new airplane," said Boeing chairman, president and CEO Jim McNerney. "The promise of the 787 and the benefits it provides to airlines and their passengers remain fully intact as we take this important step forward with our customers and program partners."

The FAA said the action will permit the return to service of 787s in the USA upon installation of the improvements. For 787s based and modified outside the USA, local regulatory authorities will have to provide final approval on return to service.

Approval of the improved 787 battery system was granted by the FAA after the agency conducted an extensive review of certification tests. The tests were designed to validate that individual components of the battery, as well as its integration with the charging system and a new enclosure, all performed as expected during normal operation and under failure conditions. Testing was conducted under the supervision of the FAA over a month-long period beginning in early March.

Boeing, in collaboration with its supplier partners and in support of the investigations of the National Transportation Safety Board and the Japan Transport Safety Board, conducted extensive engineering analysis and testing to develop a thorough understanding of the factors that could have caused the 787's batteries to fail and overheat in two incidents in January 2013. The team spent more than 100,000 hours developing test plans, building test rigs, conducting tests and analyzing the results to ensure the proposed solutions met all requirements, said Boeing.

The improved battery system includes design changes to prevent faults and isolate it should one occur. In addition, improved production, operating and testing processes have been implemented. The new steel enclosure system is designed to keep any level of battery overheating from affecting the airplane.

Boeing will also begin installing the changes on new airplanes at the company's two 787 final-assembly plants, with deliveries expected to resume in the weeks ahead. Despite the disruption in deliveries that began in January, Boeing expects to complete all planned 2013 deliveries by the end of the year.

UK ACCELERATES TYPHOON WEAPON INTEGRATION

Operational test and evaluation of the next package of Eurofighter Typhoon weapons upgrades is be accelerated to meet UK in-service date requirements.

Efforts to integrate the Phase 1 Enhancement B (P1E(b)) package of capabilities will involve a trial aircraft being deployed to RAF Coningsby in Lincolnshire in September 2013. RAF personnel from 41 (Reserve) Squadron, together with the test pilots from BAE Systems at Warton, will then conduct operational test and evaluation, ahead of the UK Ministry of Defence formally granting the new upgrades their military release to service (RtS) certification to allow routine use by frontline RAF Typhoon units. Previously, operational test and evaluation was conducted by the UK after RtS had been achieved.

"This parallel activity will bring better efficiency to the evaluation and testing of the Typhoon," commented Mark Bowman, BAE Systems's chief test pilot.

"Typhoon BT17 will go to Coningsby to operate at P1E(b) standard to do operational evaluation ahead of formal RtS so that the RAF can assess the weapon system suitability to meet its Strategic Defence and Security Review-defined, Interim Force 2015 (IF15) in-service date deadlines," he said.

"P1E(b) ground testing and flying testing is well on target across the partner companies, and certification for industry will be completed by the end of this year."

The P1E packages includes weapons integration of Paveway IV, GBU-48, GBU/EGBU-16, GBU-10/GBU-16, full Litening III LDP and IRIS-T phase 2. Other enhancements include improvements to MIDS (Multifunctional Information Distribution System), chaff/flare, ROVER terminal compatibility, helmet targeting for both air-to-air and air-to-ground weapons, the ability to strafe with the cannon, and concurrent multiple ground and air attack capability, including up to four targets simultaneously or six targets successively.

P1E(b) enhancements and new capabilities include a new display, GPS improvements to counter jamming, toss and dive air-to-ground attack profiles, improved helmet integration, tactical display improvement to provide more information, MIDS enhancements, PIRATE infrared tracker upgrade, radar upgrades and integration of a RAIDS instrumented training pod.

CHINESE DRONE SEEN FOR FIRST TIME

Pictures of a new Chinese unmanned combat air vehicle (UCAV) demonstrator featuring an advanced flying wing design have emerged on the internet.

The pictures, taken at an unidentified site that is believed to be the Shenyang Aircraft Corporation's (SAC) test center, shows the drone being prepared for flight. Chinese internet discussion forums are one of the main routes for information about the country's secretive aerospace industry to reach the outside world. Some sources suggest that this method of publication is tacitly approved by the authorities in Beijing. The tailless, unmanned and partially stealthy aircraft appears to be a flying testbed rather than a prototype because it features a plethora of instruments around its fuselage.

Chinese bloggers identify the aircraft as the Lijian – or 'Sharp Sword' UCAV demonstrator – calling it the product of an industrial collaboration between Hongdu, a maker of military jet trainers, and SAC, one of two major suppliers of frontline fighters to the Chinese Air Force and Navy.

The size and shape of the pictured aircraft is very similar to advanced Western designs such as the Boeing Phantom Ray, Dassault Neuron, BAE Systems Taranis, Lockheed Martin RQ-170 and Northrop Grumman X-47B.

Unlike its flying wing cousins in the West, however, the Lijian does not appear to be designed for reduced visibility to radar in all aspects: the nozzle of a large, possibly afterburning, jet engine lies exposed and unshrouded on the aft fuselage. At the same time, the pictures reveal new and interesting advances in the sophistication of Chinese aircraft designs. By making the Lijian a flying wing and tailless, China pronounces itself ready to tackle one of the hardest problems in aerodynamics and flight controls. Flying wings are a holy grail for aerodynamicists seeking to optimize lift, and for electromagnetic frequency experts seeking to minimise the structural corners that are easy reflectors of radar waves.

Chinese industry has been looking at tailless, flying wing designs for several years. SAC engineers, for example, published an academic paper in 2007, *Application of Flying Wing Configuration to UAV for Reconnaissance,* which concluded that such a tailless design is "an optimal selection" for aerodynamic purposes.

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GARNET RIDGWAY

THE GOOD OLD DAYS: TRUE OR FALSE?

Is it more difficult to be a test pilot now than it was in days gone by? Aerospace engineers Garnet Ridgway and Sophie Robinson, who met at the Flight Science and Technology group at the University of Liverpool, have a difference of opinion

SOPHIE ROBINSON

One of the primary design aims for modern military aircraft is to achieve 'capability density' – the ability to 'do more with less'. To this end, many such aircraft feature glass cockpits that, at first glance, appear to represent a simpler solution than the regimented rows of instruments of the traditional cockpit. However, what lies beneath the surface of the touchscreen user interface is a virtual equivalent that, if laid out conventionally, would be many times the size. Additionally, this

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

interface not only provides information, but demands user input on an unprecedented scale. In terms of pilot workload, the operation of such systems represents a challenge comparable with any historical examples.

With increased levels of complexity inevitably comes increased expense per flying hour. Also, implicit in the concept of increased capability density is the fact that fewer airframes will be produced. The combined effect of these two factors is a vastly reduced number of flying hours available for the testing of a new aircraft compared with an equivalent project in the past. This means that it's not only the capabilities of the aircraft that are condensed, but also the content of the flight test program. With this in mind, test pilots will know that any decisions they make that delay the program will have significant financial implications, against which is the ever-present need to avoid endangering flight safety. The resulting compromise is one that can have immense implications if misjudged in either direction – a hugely significant responsibility that rests squarely on the shoulders of the test pilot.

Away from the cockpit, the modern test pilot is typically part of a large test team, which can consist of hundreds of personnel from a variety of disciplines. As the 'end user', the pilot is constantly in demand for input to non-flying activities such as document reviews, customer meetings and safety consultations. These roles require skills that are totally distinct from those taught at test pilot school, but which are vital to the success of the project; and such diversity in the role is an entirely modern phenomenon.

Modern test pilots are presented with novel aircraft that would be inconceivable to their predecessors. The physical danger may be reduced, but the mental capacity demanded of test pilots has never been higher. ∎

The Empire Test Pilots' School (ETPS) celebrates its 70th anniversary this year. Based at MoD Boscombe Down in Wiltshire, UK, ETPS was established as a response to the increasing numbers of fatalities during flight tests. It was the first test pilot school, and as such this anniversary also represents 70 years of professional flight testing. Test pilots have a reputation for being at the pinnacle of their profession, but is the role as challenging today as it once was?

ETPS's motto is "Learn to test; test to learn" – and for the first

test pilots, this applied to their person as much as it did to their aircraft – they were subjected to unknown risks. In 1953, Chuck Yeager set a world speed record with the Bell X-1A. After achieving Mach 2.44, the aircraft spun out of control and plummeted 51,000ft in just 51 seconds, exposing Yeager to forces in excess of 8g. Yeager also broke the canopy with his helmet, but managed to successfully land the aircraft. Engineers had warned Yeager to stay below Mach 2.3 as the aircraft might 'go divergent' at higher speeds, but they were unprepared for such an extreme response – this was test flying at its most experimental, and such leaps into the unknown would not be attempted today.

Pilots were also subjected to known risks; exposure to extreme cold and low pressure at altitude

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

and large accelerations were all part of the job. One man exposed to all these risks was Joseph Kittinger, who held the record for the highest parachute jump from 1960 until 2012. During his quest to set this record, Kittinger was lassoed by his parachute, spinning him out of control at 120 revolutions per minute. He lost consciousness, his life being saved only by his parachute opening automatically at 10,000ft. During other jumps, Kittinger lost the use of his right hand due to a pressure seal in his glove failing and his skin was exposed to temperatures as low as -70°C. Today, experiments with known risk levels as high as these wouldn't get off the ground.

Being a test pilot was more challenging in the past simply because of the absurdly high risk levels encountered on a regular basis. In the words of Yeager, "You don't concentrate on risks. You concentrate on results. No risk is too great to prevent the necessary job from getting done." ∎

Fifth-generation pilot

Under the glare of intense media scrutiny, the F-35 has suffered delays, technical problems, political wrangling and escalating budgets. However, according to chief production test pilot Bill Gigliotti, it will be well worth the wait

BY CHRISTOPHER HOUNSFIELD

Apparently it's a mindset, being a test pilot versus being an operational pilot. The test pilot has specifications to meet, then he designs and flight tests, and provides the data to meet the contractual obligations to provide the capability to the warfighter. This is the word according to Bill Gigliotti, senior production test pilot of the F-35 based with Lockheed Martin's production site, Fort Worth, Texas. He is an equivalent to Al Norman at Edwards Air Force Base. The next pilot down the flight test line.

It is here in Fort Worth that more than 20,000 individual components are tested, constructed, and tested again to produce the F-35 Lightning II at the mile-long factory.

Gigliotti's job is to test the finished product. He is an old-timer, having worked on the F-35 project for 10 years. His position is unique, as despite being a US Navy fighter and test pilot beforehand, he began on the program not as a pilot, but as a designer and engineer, involved with control, handling qualities and mission designs within the test program. On top of that, he is one of the rare people to have flown all three variants.

Gigliotti returns to the mindset, but focuses on the F-35 test pilot: "We're going to give them [warfighters] capabilities and tools that require a new and better approach to how you tactically employ those capabilities. I like to use this kind of analogy: if you were to walk through the American West, the first time the Native Americans got a rifle in their hands, a gun, they used it as a club. You could use it as that, but that's not the way you would use it.

"When you showed them how to use that rifle as a rifle, their eyes opened and they were brought into a new world of weapons employment. We are going to do that with the F35, with the new customers operating fifth-generation fighters after having operated older fourth-generation fighters. It's that much of a revelation to them because they will be operating an aircraft that provides immensely increased situational awareness. It's up to them to come up with tactics, but up to us to provide the capability."

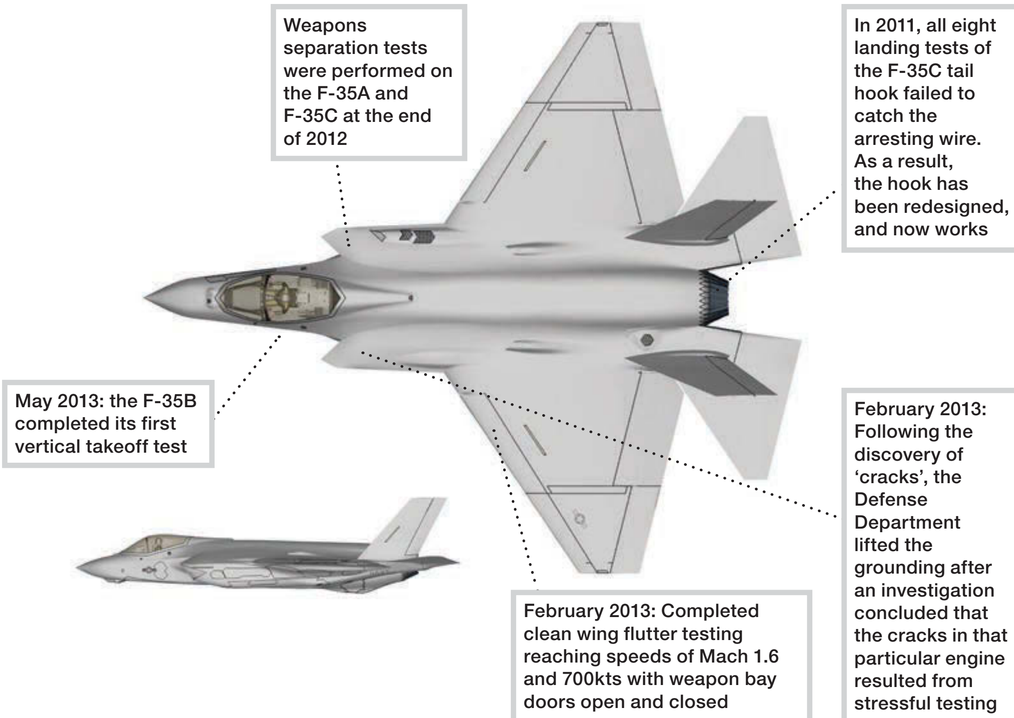
Gigliotti is pretty familiar with aircraft – having flown 25 different types – and he continues to be chief airshow pilot on all models of F-16 regularly performing at the Paris and Farnborough airshows. He points out the huge difference in capabilities, including other fourth-generation fighters: "The F-16 can do a very good job, a really nice job, but as we look over the horizon at the threats of tomorrow, that's the threat the F-35 is designed to meet and defeat candidly.

"They built an aircraft [F-16 and F-18] and then they scabbed [bolted] on these other sensors and weapons. They were not afterthoughts, but they started with a basic air frame and the package included a radar and some other stuff. However, the F-35 is those two airplanes combined on steroids and wrapped in a stealthy envelope, because we built them from day one with internal weapons with mission systems or radar. Radar EO DAS, our EOTS and our EW system are all embedded in the aircraft. These are not scabbed-on systems; they were fully integrated from day one."

THE PROBLEMS

The F-35 has been beset by well-publicised problems, from budget (US$400bn), to overruns, to international politics, to technical difficulties, to numerous design review boards.

"RADAR EO DAS, OUR EOTS AND OUR EW SYSTEM ARE ALL EMBEDDED IN THE AIRCRAFT. THESE ARE NOT SCABBED-ON SYSTEMS; THEY WERE FULLY INTEGRATED FROM DAY ONE"



At times, the whole program looked like it could be completely derailed, but in 2009 it got a kickstart with an extra US$6bn put into the test bank, and three years added to the program. Slow and steady progress is now on track, particularly for two significant deadlines: 2015, when the US Marine Corps is scheduled to have combat-ready aircraft; and 2017, when, according to the program director Air Force executive director Lt Gen Christopher C Bogdan, the development is scheduled to end. "Those two dates are extremely important," Bogdan says, "because if I don't get to those two dates or I don't reach the finish line there, then we will continue to produce airplanes that don't have the capability that the warfighter needs."

The politics do not affect Gigliotti, but the test flying and technical engineering and production operations very much do, and he does not back down in terms of how great the aircraft is, despite what gets discussed behind closed doors.

What are some of the long-term technical problems?

"It was a big task to overcome overall. You have three different airplanes, two different engines, now we're down to one," Gigliotti explains. "You're right, there were some problems early on that were unlike any other legacy program. It's just that this one, being as big as it is, is under public scrutiny, not just here or with one service in the USA, but across multiple countries and all their services. So it tends to get brought up and discussed quite openly at the highest levels. In fact, in the meetings I've been in with our senior leadership when they ask questions such as, 'Do you need any more help?', the response is, 'Actually we have the margins to meet the schedule right now'."

The world's media did pick up on some problems, which have come under public scrutiny. Arguably the biggest hitch has been the issue of complicated fan blade cracks. Within a moment, Gigliotti puts me right: "What I do know is that we don't call it 'a crack', it wasn't a crack. It was called engine 'creak'. That's what we call it and it's a thermal stress on the engine. It was not unexpected." He does concede, though, "We were off a factor in our predictions with what we were doing in flight tests versus what we would have expected to see. We were using the hot section of that one engine at almost twice the rate we thought we were going to use it prior to those inspections. So what we found out was not an issue really; it was just an issue with our inspections."

But the aircraft was still grounded? "No," he replies. "They grounded certain airplanes with those engines only until they could, I believe, identify what they had found. Then it was a 'head slapper' and they told everyone to get back to flying. They did a quick hot section inspection of all the engines, as you would expect, and all the engines were placed back in service. That's all behind us now – that was the last time we discussed engine 'creak'."

However, there have been other hassles that have cropped up: blind spots, wing buffers, visual systems, but again Gigliotti refuses to be drawn into technicalities: "Early on in some of

HIGHLIGHTS 2012/2013

- F-35 test and production aircraft flew 2,106 flights in 2012
- First F-35B deliveries to MCAS Yuma
- Airstart testing
- High angle-of-attack testing
- First International F-35 delivery to the UK
- First flight of the first F-35C production aircraft
- Production of the 100th F-35

BELOW: **A series of night flights are currently being undertaken to test the ability to fly the jet safely in instrument meteorological conditions where the pilot has no external visibility references**

our night vision testing, we realized we had a wrong coefficient and we were kind of all down in the mouth about some of this system and then we realized we had the wrong coefficient in the software. We fixed it and now it's as we expected it to be. So in flight tests you are going to be able to find that on occasion, we as humans, and sometimes systems, have process failures and it leads to a discovery. That's what flight testing is for – discovering things we thought we had covered, but maybe we had just missed. What we're learning is that we have missed a few things, but none of those things have been insurmountable.

COMPUTATONAL DYNAMICS

The F-35 is an aircraft built from the computer up, including, more recently, the Vehicle Management Computer and the Vehicle Management Computer Engineering Test Stand – requiring huge amounts of modeling software.

On board, the computer systems are unsurpassed by any other aircraft. These include Autonomic Logistics Global Sustainment, the Autonomic Logistics Information System and the computerized maintenance management system, which all help to ensure aircraft uptime with minimal maintenance manpower.

Gigliotti expands somewhat on other levels: "The level of automation and the level of computing technology brought to bear on this program is really bearing fruit. There are a lot of naysayers because some of the stuff hadn't been done this way before.

ABOVE: **The initial cadre of US Air Force F-35 instructor pilots at the 33rd Fighter Wing recently qualified in aerial refueling for the F-35**

"We were able to see [with software] in and around the transonics, which we've already put back into modeling and fixed, but we have seen almost point-for-point matching of our predictions with the actual flight test data. I'll give you an example of the computational stuff and the advancements of the aircraft. When we first built the aircraft, different parts from around the world were brought here and put together. When we put the first production aircraft together, we were concerned because those parts came from right across the world so how was it all going to work? So we gave ourselves about two weeks to get that aircraft together and shim it, and make all the parts fit. But they started the process and it was all done in 45 minutes.

"The challenge we have right now is that we have to get all the software through testing in the labs and into the jets to meet the IOC dates."

THE ULTIMATE FLYING HELMET

Vision Systems International, along with Helmet Integrated Systems, developed the unique helmet-mounted display system (HMDS) for the F-35. HMDS fully utilizes the advanced avionics architecture of the aircraft and provides the pilot with video imagery in day or night conditions. The F-35 is the first tactical fighter jet in 50 years to fly without a head-up display (HUD), although that is not without its own problems.

MISSILE SEPARATION

On June 5, 2013, an F-35A conventional take-off and landing aircraft completed the first inflight missile launch of an AIM-120 over the Point Mugu Sea Test Range.

It was the first launch where the F-35 and AIM-120 missile demonstrated a successful launch-to-eject communications sequence and fired the rocket motor after launch – paving the way for targeted launches in support of the Block 2B fleet release capability later this year.

As Gigliotti states, this is the prime focus for the year: "This whole year is really focused on weapons, so it's giving those combat forces the combat capability, the weapons sensors – the kill chain we call it – but also being able to employ the weapons that the aircraft is designed to carry, and deliver them accurately. That will be the next focus for flight test."

The fighter is designed to carry a payload of up to 18,000 lb using 10 weapon stations. The F-35A features four internal weapon stations located in two weapon bays to maximize stealth capability. The CTOL aircraft can also utilize an additional three external weapon stations per wing if required.

ABOVE: The HMDS displays head-steerable symbology – the pilot's line of sight dictates the content that appears on the visor

BELOW: In April 2013, an F-35B completed the first short take-off and vertical landing during a test mission at night to expand the flight envelope

"When I first came on the program and realized we were going to a purely helmet-mounted display, I was a little bit excited and very cynical," says Gigliotti. "And that's the engineer in me thinking, how are we going to integrate this and how's it going to display?"

As soon as, or even before, a pilot sees another aircraft in the distance, the system projects a marker on the visor to locate, identify, and track the aircraft. If the designated aircraft is determined to be hostile, the pilot can use the targeting info to cue weapons.

"There have been some minor issues with the night environment – we call it 'green glow' – that already have a 'fix' in place. We haven't got it on the aircraft yet – it's been tested in the lab but, hasn't made it to the production helmets," says Gigliotti.

"It's a comfortable helmet to wear over a long period of time, which to me is a winner. I prefer the display symbology over an HUD as I can look around the cockpit. The other thing is I can call up the data acquisition system imagery on my helmet and look through the structure of the aircraft. I can look down below the aircraft and target or slew sensors to things I see below, when previously I had to roll the aircraft up or point the nose at it. With an HUD, I have to point the nose of the aircraft at something to do that; with this I just turn my head. I can target other airplanes just by putting my helmet display symbology up there and find the target and just lock onto them. Without maneuvering, I start putting people into what we call a 'shoot list', which is identifying them as a potential target."

However, if the system falls short of its requirements, key tasks such as night-time aerial refueling and shipboard vertical landing will be severely hampered. There is a possibility to install a new night-time camera into the helmet and incrementally introduce equipment to address the near-field, night-vision issue and other problems. A so-called Gen 3 helmet is expected to fly in the F-35 in January 2014.

NEXT PHASE

Next on the agenda for the latest C variant are aircraft carrier tests, as the main version has yet to land on one. "The STOVL Jet is getting ready to go back to the amphibious assault aircraft carriers here for the US Navy this summer, so they'll do another ship test cycle. This is in preparation for an 'at sea' period in early 2014, so a lot of the field testing will occur this year and early next year. A lot of work is now going on toward creating and providing the warfighter with the capability the Navy so desperately needs," notes Gigliotti.

However, nothing can take away from Bill Gigliotti's utter enthusiasm for the F-35 Lightning II fighter. His interview was very long, and the majority of it was taken up with emphatic dedication to what he sees as the most remarkable aircraft and test program of its time.

He sums up, "It's got a range that exceeds any airplane I ever flew as a tactical fighter; it has sensor capability that far exceeds any airplane I ever flew; it's the easiest airplane I've ever flown; from a pilot's training standpoint it has to be exceptionally easy for young student pilots to transition to the F35; it's easy to fly, easy to assimilate data; it's just really that good. But the truth is, until people fly fifth-generation aircraft, stealthy aircraft, they don't really get it.

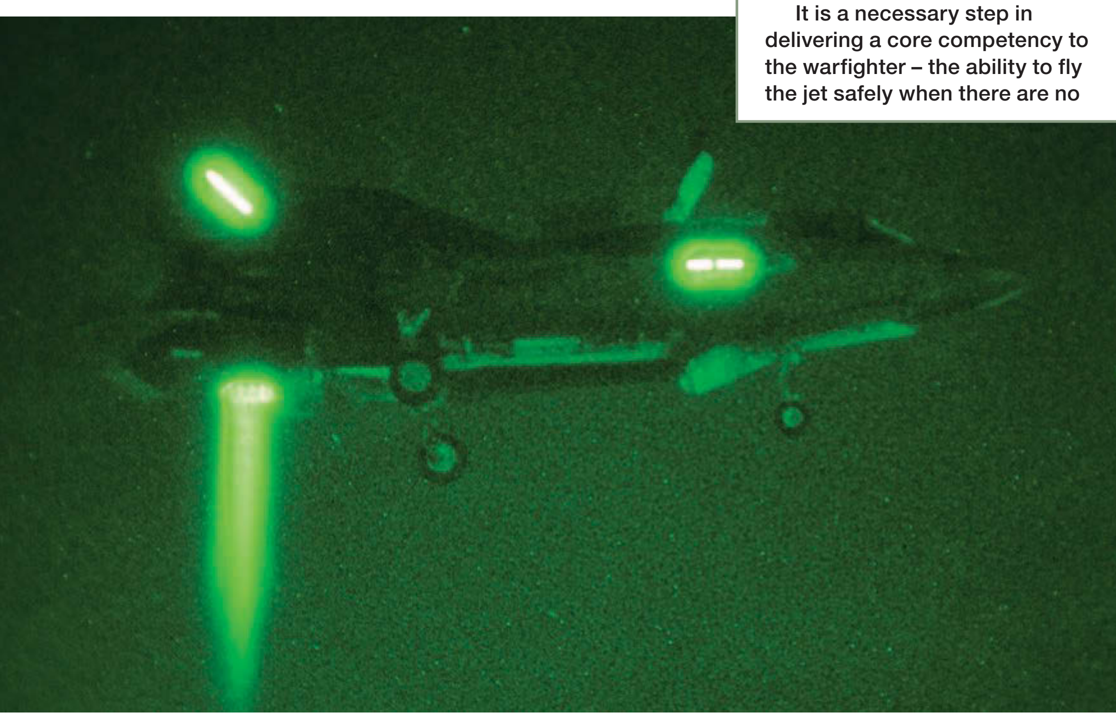
"If you have a squadron of F-35s, wherever you place them they become a strategic deterrent to other countries. The F-35 is going to show up and the first time you know you're up against it is when everything starts blowing up and that's scary."

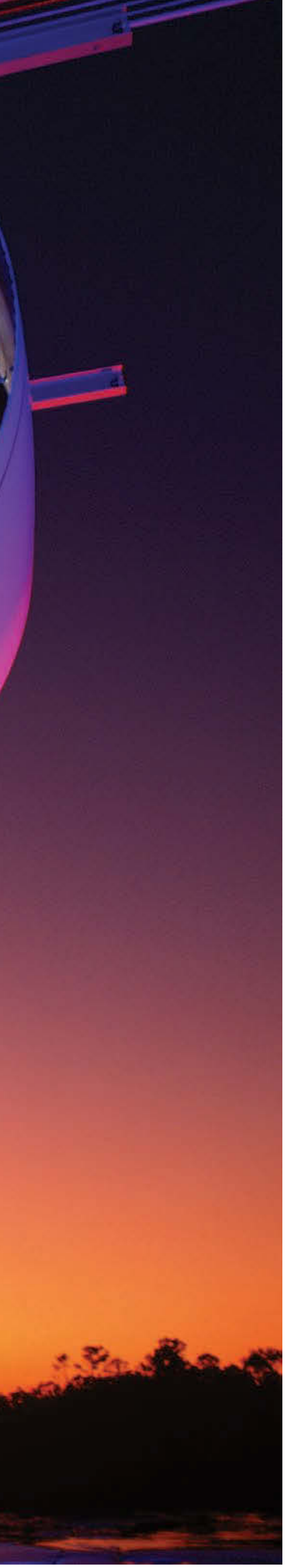
Well, hopefully, and with no more problems, budget cuts or politics, that may become an awesome and frightening reality. ■

WATCH THE WEATHER

The F-35 Integrated Test Force is undergoing a series of night flights, which are testing the aircraft's ability to fly in instrument meteorological conditions.

It is a necessary step in delivering a core competency to the warfighter – the ability to fly the jet safely when there are no external visibility references for the pilot. Gigliotti explains, "Right now, we have a challenge of trying to get the aircraft IMC [Instrument Meteorological Conditions] and night compatible; those are challenges left for us. In other words, flying fully certified through all types of weather."





LEFT: **Cowlings peeled open, a PW4000-112 engine comes under inspection on a Pratt & Whitney test rig**

Rise of the super fans

Testing the big jets is a lengthy and costly business. How do industry leaders General Electric, Pratt & Whitney and Rolls-Royce test their high-technology large-aircraft turbofans?

BY PAUL E EDEN

General Electric, Pratt & Whitney and Rolls-Royce dominate the global market for large commercial aircraft engines. Vying to produce the most effective engine choice for customers who demand more and more in terms of fuel efficiency, reduced emissions, lower noise and minimal maintenance, all three companies run complex test programs.

With a typical engine development program from clean sheet to certification spanning upward of six years and the test segment of that alone running to around four years, the investment is huge. Add to this the test burden for ongoing product improvement packages (PIPs), and budgets become vast. According to General Electric's Deborah Case, the company "spends about US$50 million annually on testing new technologies for the GE90 engine alone and GE's overall spend on research and development efforts is more than US$1 billion per year".

General Electric performs the majority of testing in-house, much of it at its facility in Peebles, Ohio, which boasts multiple test cells. Today, many engine components will have been modeled and tested long before a full engine is run and many hours before flight testing begins. This component testing, along with research and PIP work, keeps facilities very busy; Case reports that GE's laboratories have run advanced engine cores on an almost daily basis over the past 25 years.

Describing a representative test effort, James Dunn, Pratt & Whitney chief engineer, systems engineering and validation, explains: "A typical large commercial turbofan program at Pratt & Whitney spans a period of 36-48 months. The first 12-18 months are dedicated to preliminary/detailed design and hardware procurement, with component testing typically starting during this period. As the designs mature and hardware is procured, subsystem-level testing starts, building up to the first full engine test after around 18-24 months.

"Engine-level testing starts with a series of development tests designed to characterize engine performance and durability and to identify any redesigns required to achieve customer and regulatory requirements. Once this series of tests and any required redesign effort is complete, engine certification testing will be executed leading up to the certification of the design. Engine-level testing typically spans 18-24 months from the first engine testing to certification of the engine."

REAL PERFORMANCE DATA

Component and subsystem testing, as well as modeling, are hugely important. Data and experience gathered early on, long before a full engine test is possible, provide a detailed understanding of predicted engine behavior, such that engineers often look to gather real performance data from tests to validate their models.

Procedures are adapted to suit specific requirements and Dunn says that at P&W: "Testing at the component and subsystem level prior to the first

whole engine test varies considerably from program to program. On average, several thousand hours of tests are completed, however, examining component-level high-cycle fatigue characteristics of airfoils and control system component functionality, for example. Subsystem tests on gearbox systems, compression modules, combustors, lubrication systems, control systems and so on are also generally completed, ensuring that these subsystems will work properly when assembled into the whole engine."

Rolls-Royce flew its Trent XWB engine on an A380 testbed for the first time on February 18, 2012. By February 2013, the engine had achieved 3,100 hours of operations, due to more than 2,000 Rolls-Royce scientists and engineers who conducted engine research and development on around 300 test rigs with 18,000 individual components, since the development program began in 2006.

Expanding on the role of modeling and simulation, Dunn notes that Pratt & Whitney uses very advanced computational capabilities not only to investigate component and system performance, but also for full engine assessments. "Whole engine structural models, performance and operability models, and lubrication system models, to name just a few, are created to analyze the capability of the component designs to meet system-level requirements. Much of the subsequent testing is completed to validate and refine these system-level models with actual data."

ENGINE TESTS A TRIAL

Even with input from advanced computer models, engine testing is a long, expensive business. The GEnx-1B for the 787, for example, ran ground tests for almost a year before the first example flew on General Electric's 747-100 testbed on February 22, 2007. In total, the certification program extended to 800 cycles and 3,600 hours of engine running. General Electric reports that it expects to run between eight and 10 engines for Federal Aviation Administration certification.

Pratt & Whitney typically works between 200 and 400 hours of ground running before air testing begins, this preliminary whole engine investigation examining basic engine level performance and operability, and the lubrication and fuel system to confirm that engine operation is consistent with analytical predictions. Fan blade stress tests under clean and distorted inlet conditions are also run to confirm basic structural integrity. Finally, a limited amount of durability testing of the flight test engine itself is completed, demonstrating its structural integrity and correct assembly.

Applying these typical, fundamental test points to a real-world program, Kim Sullivan, executive vice president at Engine Alliance – a 50/50 joint venture between General Electric and Pratt & Whitney – says: "The first five years of the GP7200 test program were devoted to component and module rig testing to assure the 'mature' reliability of component technologies. Specific examples include a progressive test program to introduce swept technology to the highly

ABOVE: General Electric began full engine running on the GEnx back in March 2006. Here that first engine is on the test rig at Peebles, Ohio

RIGHT: Trent XWB under preparation for test at Rolls-Royce's Derby facility in 2010

successful Pratt & Whitney hollow titanium blade. We also ran a five-year core test program at GE to mature our HPC [high-pressure compressor], while extensive testing of the combustor and turbines further matured the technologies on which the GP7200 hardware is based.

"The GP7200 engine underwent an extremely rigorous development program, with eight development engines tested at multiple sites, complemented by two flight test programs on our flying testbed. FAR33 certification was achieved in December 2005, leading to a flight test program over 20 months. FAR25 certification was achieved in December 2007."

TESTS AROUND THE WORLD

Rolls-Royce has already completed Trent XWB icing and cold weather tests in Canada, with temperatures down to -29°C, hot weather tests at 40°C in the UAE, altitude and crosswind tests in the USA, endurance tests in Spain, flight tests in France, and testbed performance trials in the UK. Nevertheless, the company says that the final tests prior to certification – the fan module and full engine blade-off tests, which were successfully completed in Germany and the UK at the end of 2012 – were among the most significant.

ENGINE ALLIANCE GP7200

General Electric and Pratt & Whitney formed the 50/50 joint venture Engine Alliance in 1996. Its aim was the development of technologically advanced turbofans for the next generation of large commercial aircraft. The result was the GP7200, offered as a standard engine choice on the Airbus A380. Using elements of the General Electric GE90 and Pratt & Whitney PW4000 as its basis, the GP7200 has been certified at 70,000 and 76,500 lb (311.3 and 340.2kN) thrust, while a 72,000 lb (320.2kN) version is expected this year and an 81,500 lb (362.5kN) derivative has been suggested.

> **Program start:** 1996 (GE and P&W joint venture established)
> **First flight:** December 2004 (747-100)
> **Certification granted:** December 2005 (FAR 33), December 2007 (FAR 25 and EASA)
> **Service entry:** August 2008

PRATT & WHITNEY PW4000

In its initial PW4000-94 form, with 94in (238.8cm) diameter fan, the PW4000 entered service in 1987. Introduced to replace the classic JT9D in the P&W range, the PW4000 has since been developed into the PW4000-100 (100in/254cm fan) for the Airbus A330 and PW4000-112 (112in/284.5cm fan) for the Boeing 777.

> **Program start:** December 1982
> **First flight:** August 1985
> **Certification granted:** July 1986 (PW4000-94)
> **Service entry:** 1987 (PW4000-94)

GENERAL ELECTRIC GENX

GEnx was designed as a new-generation large turbofan for a new generation of airliner – the Boeing 787 and 747-8. General Electric claims that compared with its immediate predecessors, it reduces specific fuel consumption by 15% and its NOx gas output is 56% below current limits. Output of other gases is 94.5% below current regulatory limits and noise is reduced by around 30%. The GEnx-1B is optimized for the 'electric' 787, which uses engine-driven generators, rather than engine bleed air, to provide system power.

> **Program start:** April 2004
> **First flight:** February 2007 (GEnx-1B, 747-100)
> **Certification granted:** March 2008 (GEnx-1B)
> **Service entry:** October 2011 (GEnx-2B, Cargolux); March 2012 (GEnx-1B, JAL)

GENERAL ELECTRIC GE90

Certified at 84,700 lb (376.8kN) thrust in 1995, the GE90 has been developed to suit the various evolutions of Boeing's 777. In its most powerful version, as the GE90-115B for the 777-300ER, the engine is certified at 115,000 lb (511.6kN), although it produced 127,900 lb (568.9kN) thrust during certification testing. General Electric is working on a next-generation GE90, the GE9X, launched this year for the Boeing 777X. The company has been testing new technologies for this evolution at component level since 2010 and plans to run a full core test for the first time in 2015.

> **Program start:** January 1990
> **First full engine run:** March 1993
> **Certification granted:** 1995 (at 84,700 lb/376.8kN)
> **Service entry:** 12 November 1995 (BA)

ROLLS-ROYCE TRENT

Rolls-Royce serves the large turbofan market with a series of engines based on the RB211-derived Trent 700. Launched on the A330 in 1995, the engine is certified at up to 72,000 lb (320.3kN) thrust.

Using a similar fan to the Trent 700, allied with a scaled-down Trent 800 core, the Trent 500 was developed for the Airbus A340-500/600 and entered service in 2002 at a certificated output of 60,000 lb (266.9kN). The Trent 800 itself began revenue operations on the 777 in 1996 and is now certified across a range of ratings from 75,000 to 95,000 lb (333.6 to 422.6kN).

The Trent 900 is a development for the Airbus A380, while the Trent 1000 was developed as an alternative to GEnx on the 787. A new variant, Trent 1000-TEN (Thrust, Efficiency, New Technology), is under development for the Airbus A350 XWB.

> **Program start XWB:** 2006
> **First full engine run:** June 2010
> **First flight:** February 2012 (A380)
> **Certification granted:** February 2013 (EASA)

With Trent XWB certification achieved, Chris Young, Rolls-Royce Trent XWB program director, says: "We now move on to testing engine capability and robustness prior to the A350's entry into service. As a result we'll see our test hours accelerate quickly." Meanwhile, test and development work continues on an 84,000 lb (373.7kN) thrust variant of the engine, planned to deliver the extra power without affecting fuel consumption. A first test run is expected in 2014.

IN-SERVICE TESTING

With a new engine in service, it seems manufacturers might sit back for a period of self-congratulation, before monitoring the aging process. GE's Case confirms that at a basic level, "We have fleet leader engines that we gather data from to help us see how our engines are operating in the field and this data allows us to develop any necessary repairs ahead of the fleet", but ongoing testing is actually far more extensive.

Sam Descoteaux, Engine Alliance vice president, sales and marketing, noted: "To date, more than 22,000 cycles and 6,000 hours of engine testing has been done to evaluate the [GP7200] engine, validate product improvements and identify engine enhancement.

"Specific to performance improvement packages, Airbus continuously monitors the performance of delivered engines. Following sustained demonstrated performance improvements, revisions to the published performance handbook unique to the engine-aircraft combination may be made. Since certification, Airbus has revised the performance handbook for the GP7200-powered A380 three times – most recently in February 2012, as a result of improved GP7200 performance."

Rick Krueger, chief engineer, Pratt & Whitney Operational Commercial Engines, explains that endurance-type testing is usually carried out soon after product launch, providing insight into wear-out modes to inform solution development before operational engines require intervention. Ultimately the fleet catches up, of course, as Krueger says: "Eventually the fleet hours will overcome and outpace what can be realistically accumulated on test stands. In this phase a combination of prudent shop inspection programs, fleet leader engine teardowns and so on is leveraged to identify wear-out modes."

Interestingly, even engines as well established as the PW4000 are subject to infrequent manufacturer testing, as Krueger notes: "Pratt & Whitney occasionally runs PW4000 engine tests as required for product improvement packages, but much of that verification is done with analysis and models."

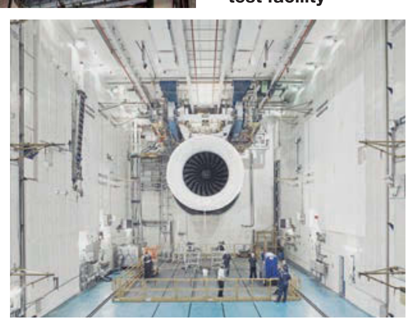
Testing on new programs occasionally throws up a nugget of technology with potential benefits for established engines and units of an even older vintage may come under test scrutiny. As Case says: "GE Aviation conducts tests every day on new technologies. If we identify something that can be incorporated into existing engines in operation to benefit customers and lower their cost of ownership, we work to flow them into the fleet as appropriate."

With older engines in mind, Krueger raises the subject of an entirely different, yet vital engine test function. "Although there are no current or future test efforts planned to support any changes/development efforts for JT9D engines, for example, Pratt & Whitney has facilities worldwide regularly testing JT9D engines after maintenance." ∎

Paul E. Eden is a freelance aviation journalist for Aerospace Testing International

POWER THRUST

The Pratt & Whitney PurePower PW1100G-JM engine completed its first flight on May 15, 2013, starting the engine's flight test program. The PW1100G-JM engine for the Airbus A320neo aircraft flew on Pratt & Whitney's Boeing 747SP flying testbed. The ground test program led to more than 365 hours of ground performance and operability testing, which cleared the way for first flight. Three additional PW1100G-JM engines are currently undergoing ground testing. To date, the PurePower engine program has completed more than 4,800 hours and 13,700 cycles of full engine testing.



LEFT: The Rolls-Royce Trent 1000 competes with General Electric's GEnx for Boeing 787 orders

BELOW: Trent XWB installed in an indoor Rolls-Royce test facility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Come together

The US Missile Defense Agency has proved its integrated systems concept in the biggest and most ambitious advanced threat test and raid assault ever: FTI-01

BY JON HAACK

Guided-missile destroyer USS Fitzgerald (DDG 62) launches a Standard Missile-3 (SM-3) as part of a joint ballistic missile defense exercise. Photo: US Navy

On October 24, 2012, the US Missile Defense Agency (MDA) led a team of engineers and US military warfighters in accomplishing the largest integrated live-fire missile test in history. US Navy sailors aboard the USS Fitzgerald, soldiers from the 94th and 32nd Army Air & Missile Defense Commands (AAMDC) and Airmen from the 613th Air and Space Operations Center (AOC), along with the MDA flight test team, successfully executed Flight Test Integrated-01 (FTI-01) at the army's Ronald Reagan Ballistic Missile Defense Test Site (RTS) on Kwajalein Atoll in the Marshall Islands.

FTI-01 took a major step in advancing the MDA mission, which is to develop, test and field an integrated, layered Ballistic Missile Defense System (BMDS) to defend the USA, its deployed forces, allies and friends against all ranges of enemy ballistic missiles in all phases of flight.

FTI-01 supported the mission by demonstrating an effective integration of BMDS to engage a group of simultaneous missile threats – also called a raid – of varying attack profiles.

The three fielded systems that participated in the test – Aegis BMD, Patriot and Terminal High Altitude Area Defense (THAAD) – had been thoroughly tested individually, but never together in a raid scenario. With developmental and operational test aspects, FTI-01 provided an opportunity to not only prove the communications technology enabling these weapon elements to operate in concert, but also to test and evolve the approved tactics, techniques and procedures (TTPs) used by the warfighter combating the BMDS.

THE SHIELD

The weapons and sensor systems used in FTI-01 represent an operationally accurate picture of MDA's progress in creating a robust, layered BMDS. Aegis BMD extends the Aegis Combat System to short-through-intermediate-range ballistic missile defense with the addition of the Army Navy/Shipboard Radar Surveillance AN/SPY-1 passive electronically scanned S-band system and the Standard Missile (SM) series of interceptors.

A Standard Missile-3 interceptor is launched from USS Lake Erie during a Missile Defense Agency test in the mid-Pacific

Operators from the 32nd AAMDC brought one of their THAAD batteries to RTS, including the electronically steered, high-resolution Army Navy/Transportable Radar Surveillance X-band in Terminal Mode (AN/TPY-2 (TM)) and truck-mounted launcher with THAAD interceptors. The Patriot weapons system, operated by soldiers from the US Army's 94th AAMDC, featured the MPQ-65 phased-array radar and launchers with Patriot Advanced Capability-3 (PAC-3) hit-to-kill interceptors.

An additional AN/TPY-2 radar, configured in forward-based mode (FBM) provided essential capability to detect and track threats in the early stages of flight.

INTEGRATION TECHNOLOGIES

As the mission name suggests, the driving goal of FTI-01 was testing newly developed integration technologies to bring the constituent defense systems of the BMDS into a shared information space. The resulting, expanded situational awareness drastically improves the efficacy of the BMDS in a number of ways: weapons are better tasked to their particular strengths; threats are detected and engaged earlier, and with greater accuracy; interceptor rounds are used more efficiently.

The information broker that makes this possible is MDA's Command and Control, Battle Management and Communications (C2BMC) program. Connected to the tactical data network linking all of the weapon elements, C2BMC broadcasted data from and among AN/TPY-2(FBM) and the other BMDS sensors to provide each with a complete, current threat picture.

STAYING IN TOUCH

Communications needs for the test required the expansion and maintenance of the data networks on Reagan Test Site. Range, telemetry and information technology teams battled supply shortages and delays, tight schedules and, as mentioned, corrosion to provide land, radio and satellite links from RTS to test participants. They ultimately connected Hawaii, Wake Island, ships and airplanes on the North Pacific, and locations in the continental USA, with a real-time voice and data network.

Employing hundreds of assets, each with myriad dependencies affecting its ability to participate in the test, FTI-01 saw some inevitable schedule setbacks due to unforeseen equipment failures. In one case, a range safety aircraft crew member spotted a cracked propeller blade during a post-flight inspection on the day before the test. The ensuing repair delayed the mission by two days, to allow for part delivery from Hawaii and required testing of the installed part. Fortunately, such 'show-stopper' problems were minimized by vigilant test resource and logistics teams who took immediate action on potential equipment issues and repairs.

MDA conducts developmental flight tests primarily to capture data that validates and augments work done in modeling and simulation. To that end, the situational realism of a test is paramount and, as with FTI-01, threat targets reflect characteristics and attack profiles faced by the warfighter today, or expected tomorrow.

The broad swathes of the North Pacific and sparsely populated Marshall Islands surrounding RTS allow for geographic launch configurations that represent those real-world threat placements while minimizing the risk to inhabited areas. MDA further extends that range flexibility with test support assets that allow for sea and air-based target launches. The test configuration for FTI-01 called for launch points and threat types emulating a possible ballistic and air defense scenario in the dynamic theater of the US Central Command (CENTCOM). MDA met those requirements with a combination of ground, sea and air launches of both theater ballistic missiles (TBMs) and air-breathing target (ABT) drones.

Once the first threat target of FTI-01 was launched into a clear October sky on the afternoon of the 24th, a test that took more than two years of meticulous development was executed in less than 20 minutes. In the broad ocean area north of Wake Island, a C-17 aircraft from the 613th AOC out of Joint Base Pearl Harbor-Hickam in Hawaii air-dropped a medium-range ballistic missile (MRBM) target.

Once clear of the airplane, the extended long-range air launch target (E-LRALT) launched from its delivery system on a southern trajectory toward RTS. Next, an MQM-107 ABT drone was launched south from Roi-Namur, flying an indirect path toward Meck Island and the Patriot system stationed there. Moments later, a modified Gulfstream support aircraft launched a second ABT, a BQM-74E, in a loitering loop toward the USS Fitzgerald that would eventually mimic a low-altitude, cruise missile attack.

Two more TBMs joined the raid as those initial threats headed toward their targets. An Aegis Readiness Assessment Vehicle-B (ARAV-B) SRBM rail-launched from Wake Island on a southern course toward RTS. Next, a unitary-bodied SRBM was launched toward RTS from the MDA's sea-based mobile launch platform (MLP) in the ocean area north of Kwajalein Atoll. In all, five missiles of vastly different attack profiles – ballistic and powered, exoatmospheric and near-surface – flew in a choreographed pattern to challenge the BMDS with simultaneous ballistic and air-defense engagements.

NEXT STAGE

On Roi-Namur, AN/TPY-2 (FBM) radar acquired the ballistic targets, E-LRALT, ARAV-B and SRBM, in the early boost stage of flight. It reported the returns to C2BMC, which cued the 'shooters', THAAD, Aegis and Patriot, to track and eventually engage the missiles. AN/TPY-2 (TM) radar began tracking the E-LRALT once it came within range, and the THAAD fire control and communications unit (TFCC) directed the launcher to fly an interceptor, engaging and destroying the target. Aegis BMD tracked the ARAV-B, supplementing its AN/SPY-1 radar tracks with data received from C2BMC.

Aegis BMD developed a fire control solution and launched a Standard Missile-3 (SM-3) Block IA hit-to-kill interceptor at the exoatmospheric target. Despite a nominal flight, however, the SM-3 failed to intercept, and a failure review is continuing.

BELOW: A Terminal High Altitude Area Defense (THAAD) interceptor is launched from Meck Island, to intercept a ballistic missile target during MDA's historic flight test on October 24, 2012

INTERCEPT FLIGHT TRIAL

Flight tests are ongoing. MDA and US Navy sailors aboard the USS Lake Erie successfully conducted a flight test in May 2013 of the Aegis Ballistic Missile Defense (BMD) system, resulting in the intercept of a separating ballistic missile target over the Pacific Ocean by the Aegis BMD 4.0 Weapon System and a Standard Missile-3 (SM-3) Block IB missile.

The test exercised the latest version of the second-generation Aegis BMD Weapon System, providing capability for engagement of longer-range and more sophisticated ballistic missiles. The event, designated Flight Test Standard Missile-19 (FTM-19), was the third consecutive successful intercept test of the Aegis BMD 4.0 Weapon System and the SM-3 Block IB guided missile.

Patriot used C2BMC tracking reports of the SRBM to steer its MPQ-65 radar onto the inbound target. Patriot engaged with PAC-3 hit-to-kill interceptors launched from nearby Omelek Island, destroying it in the terminal phase of flight.

With the ABTs approaching their targets, Patriot acquired the MQM-107 heading toward Meck Island and successfully intercepted the target at a low altitude with a PAC-3. The BQM-74E on its way to the USS Fitzgerald was picked up by the Aegis BMD AN/SPY-1 radar and engaged successfully with a SM-2 Block IIIA missile.

THE CHALLENGE

As MDA's largest flight test to date, FTI-01 brought with it a proportional number of challenges and setbacks that faced the mission team every day. Environment, communications and infrastructure were some of the many factors that seemed to conspire against the flight test execution and support teams. The proximity of the Pacific Ocean and exposure to intense, near-equatorial sun makes RTS one of the most punishing environments for the infrastructure and equipment used in missile testing. The buildings, vehicles and outdoor structures at RTS face a severely corrosive environment due to the high relative humidity and atmospheric salt content.

Maintenance and repair was a constant activity during the mission, as technicians and engineers labored to keep sophisticated test equipment in prime condition and away from the mission schedule's critical path. The region's rainy season of May-November presented inclement weather and visibility problems to air and sea shipping, as well as the test support equipment on RTS, often delaying activities as what appeared to be the bulk of the 100+ inches of annual precipitation fell in the weeks surrounding the test.

Despite staging the test in one of the most remote locations in the world, the footprint of FTI-01 still pressed against the commercial activity of the Pacific Rim, with the pressure felt on both sides. The hazards inherent to a live-fire test event required that the major air and sea transport corridors cutting across the test range be cleared of traffic for the hours surrounding the test window to keep travelers out of harm's way. Standard procedures for test range safety at RTS include filing with the US Federal Aviation Administration (FAA) and the US Coast Guard to issue required notices to airman (NOTAMs) and mariners (NOTMARs) to avoid the area on potential test days. FTI-01 stressed the usual protocols in that launch readiness assessment had to consider many more variables introduced by the mission's sheer size. Unable to ask the FAA and other regulatory agencies to shut down the Pacific corridors for days at a time, MDA was able to work out a schedule where alternating days would be available for testing across a number of weeks.

THE DATA

FTI-01 was an overall success that broke new ground in many areas of MDA's BMDS flight testing and yielded invaluable test data for both BMDS technology and operational doctrine. As stated earlier, it was MDA's first test to evaluate the interoperability of Aegis, Patriot and THAAD systems.

It was also the first live-fire test to use AN/TPY-2 (FBM) for common tracking of targets. Patriot came to FTI-01 for first attempts as both a multi-tiered (ballistic and air defense) flight test and an ABT intercept over water, and was greatly successful at both. Equally valuable to the test were the challenges and setbacks faced; MDA is applying the lessons learned from FTI-01 for future flight tests, aware that the obstacles will only increase with the sophistication of the tests and the underlying BMD system. The missed Aegis MRBM intercept is still under investigation at this time as part of the MDA's rigorous engineering review process. Much of the continental USA was asleep in the late weeknight hours during this test, unaware of the missile battle in progress half a world away. FTI-01 brought the MDA significantly closer to realizing the integrated and robust missile defense system needed to protect America, her allies, friends and deployed forces so that, in a world with proliferating missile threats and geopolitical uncertainty, we can all rest a little easier. ∎

"MUCH OF THE CONTINENTAL USA WAS ASLEEP IN THE LATE WEEKNIGHT HOURS DURING THIS TEST, UNAWARE OF THE MISSILE BATTLE IN PROGRESS HALF A WORLD AWAY"

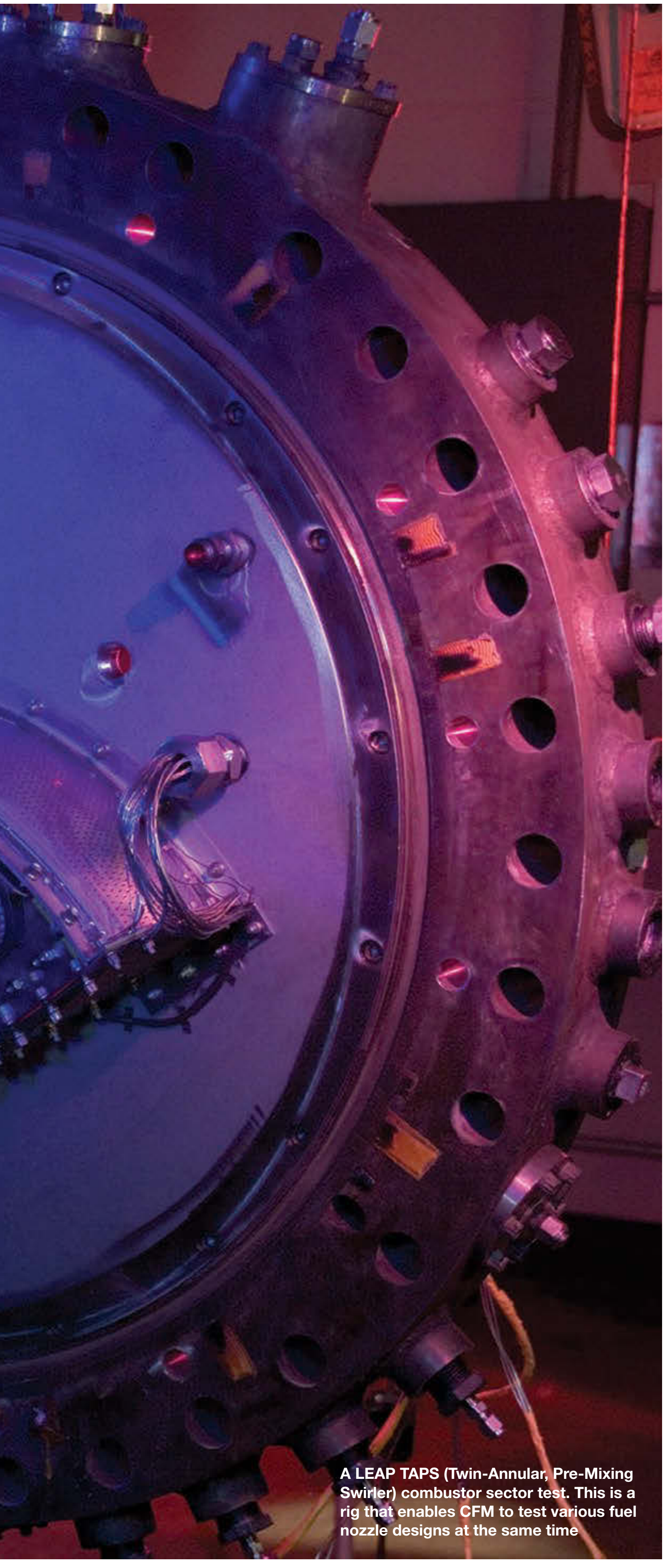
Jon Haack is a senior engineer with the Missile Defense Agency based in the USA

BELOW: **A Patriot Advanced Capability 3 (PAC-3) interceptor is launched from Omelek Island during MDA's historic integrated flight test on October 24, 2012**

Break Free

Just when we thought we had reached the pinnacle of engine design with standard fan blade jets, and rocket propulsion, fresh technologies emerge

BY SAUL WORDSWORTH



A LEAP TAPS (Twin-Annular, Pre-Mixing Swirler) combustor sector test. This is a rig that enables CFM to test various fuel nozzle designs at the same time

Propelling an airplane or rocket at greater speed, with increased safety and heightened efficiency, are primary goals for every aerospace engineer. Let us consider three examples of future propulsion, each markedly different in both purpose and design.

GOING NUCLEAR

The notion of the thermal-nuclear rocket will be familiar to many. During the Cold War, both the USA and the Soviet Union developed them, although both ceased experimentation before flight-testing began. Fifty years on, NASA's Nuclear Cryogenic Propulsion Stage (NCPS) team has embarked upon a three-year project to address critical technology and development challenges associated with nuclear thermal propulsion (NTP).

"The key is to establish confidence in the affordability and viability of this technology so that it can be seriously considered as the baseline for future NASA exploration missions into deep space," says Mike Houts, project manager for the NCPS at Marshall Space Flight Center in Huntsville, Alabama. "This brings us a step closer to safely sending humans to the Red Planet and beyond."

NTP systems offer the potential for significantly higher specific impulse capabilities, shorter and safer missions to Mars, smaller vehicles and fewer launches per mission. A first-generation system based on this technology could provide high thrust at a specific impulse of 900 seconds, roughly double that of state-of-the-art chemical engines. Nuclear rocket engines are also twice as efficient as their chemical equivalents and can carry weighty cargo, scientific equipment and fuel with greater ease.

"The NCPS and its liquid hydrogen propellant would not start up until the craft has reached a safe orbit and is ready to embark toward its distant destination," says Houts. "Prior to that, the nuclear system would be cold and not engaged."

A key technological challenge is advancing the maturity of the NTP fuel by confirming that those from the previous era can still be made, and will perform as demonstrated in the past. This is where the Nuclear Thermal Rocket Element Environmental Simulator (NTREES) comes into its own. The facility is designed to test fuel elements and materials in hot flowing hydrogen, reaching pressures of up to 1,000 lb/in^2 and temperatures of nearly 5,000°F (2,760°C) – conditions that enable space-based nuclear propulsion systems to provide crucial data. The simulator is a way of safely and thoroughly testing a wide range of nuclear fuel elements without endangering the environment.

"NTREES can perform realistic, non-nuclear testing of various materials for nuclear thermal rocket fuel elements," says Houts. "In an actual reactor, the fuel elements would contain uranium, but no radioactive materials are used during the NTREES tests. Among the fuel options are a graphite composite and a 'cermet' composite, a blend of ceramics and metals with a composition of 60% uranium dioxide and 40% tungsten metal."

Upon completion of the project, NASA will decide whether to proceed to more advanced nuclear fuels testing within representative reactor radiation environments to further mature the NTP fuels technology.

"This is vital testing, helping us reduce risks and costs associated with advanced propulsion technologies and ensuring excellent performance and results as we progress toward further system development and testing," says

Houts. "The information we gain using this facility will permit engineers to design rugged, efficient fuel elements and nuclear propulsion systems that in time could take humans further into the solar system."

FAST AND FURIOUS

In May 2013 an unmanned shark-nose missile nicknamed 'WaveRider' travelled at nearly 4,000mph above the Pacific Ocean, overall covering 264 miles in just six minutes. This was the X-51A, a demonstration program designed to study the viability of flying at hypersonic speeds on logistically supportable hydrocarbon fuels. The air-breathing engine contained within the X-51A promises to be the future of hypersonic weapons, hypersonic intelligence, surveillance and reconnaissance. Without the need for heavy onboard liquid oxygen, it could also shape future space travel.

"At the heart of this distinctive cruiser is the SJY61 supersonic combustion ramjet or scramjet engine," says Charlie Brink, X-51A program manager for the Air Force Research Laboratory Aerospace Systems Directorate. "It is built by Pratt & Whitney Rocketdyne, has virtually no moving parts, and is designed to burn JP-7 jet fuel. Hypersonic flight – or five times the speed of sound – presents unique technical challenges of heat and pressure. Since the 1960s, the US Air Force has been considering such technology, looking into ways to propel vehicles at speeds that cannot be achieved with mere turbine-powered engines. Until now, the technology has not matched the aspiration."

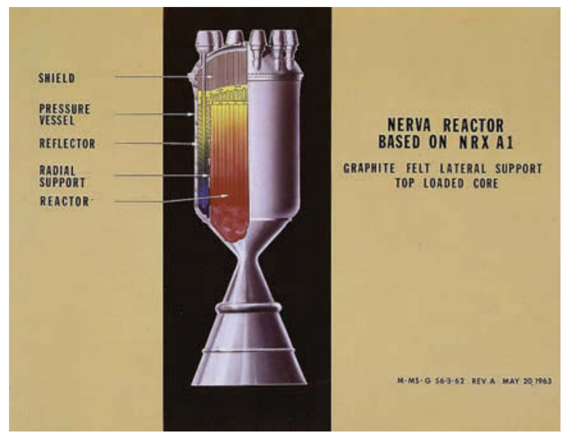
To produce such extraordinary results hydrocarbon fuel is injected into the scramjet's combustion chamber, where it mixes with atmospheric oxygen, producing a process Brink describes as "lighting a match in a hurricane". Some describe it as a surfboard that rides its own self-created sonic wave, hence the nickname. Hypersonic combustion generates intense heat so routing of the engine's own JP-7 fuel cools the engine and heats the fuel to optimum operating temperature for combustion. The fuel load and flight profile allow for a 240-second engine burn before the vehicle tails off.

The X-51A's first hypersonic flight took place May 2010 off the southern California Pacific coast. The test vehicle was released from the wing of a B-52 bomber and flew for nearly 200 seconds, with the craft accelerating to

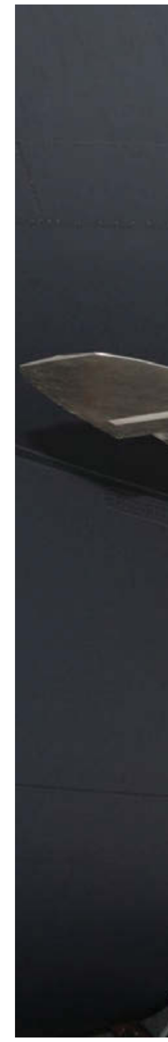
COLD WAR TRIALS

From the mid-1950s until the early 1970s, the USA and USSR both experimented with nuclear engines. The USA conducted many successful firings at the Nevada Test Site. Under program names Project Rover and NERVA (Nuclear Engine for Rocket Vehicle Application), a combined total of nearly 20 hours' run-time was accumulated. Both programs involved the Atomic Energy Commission, NASA and the Space National Propulsion Office. The Soviets meanwhile claimed to have analyzed their RD-0410 thermal rocket at the Semipalatinsk nuclear test site.

Tests on the USA's Pewee 2 rocket were cancelled in 1970 in favor of a lower-cost option known as Nuclear Furnace. The US nuclear rocket program officially ended in 1973.



LEFT: **The LEAP 3-D. A woven, resin transfer molding (RTM) carbon fiber composite fan begins ground testing at Snecma's facilities in Villaroche, France**



ABOVE: **The WaveRider, developed by Boeing, DARPA and the US Air Force, is designed to test the feasibility of Scramjet flight**

Mach 5 – nearly 3,400mph. After analysis of the flight data, the rear seal area near the engine exhaust nozzles was strengthened on the three remaining test craft. During the second test flight a year later, the X-51A was boosted by the rocket to just over Mach 5, was separated and the scramjet was then lit on ethylene. When the vehicle attempted to move to JP7 fuel operation, it was unable to re-orient itself and continued in a controlled flight orientation before plunging into the sea.

"After studying the data from the first two flights, engineers determined the inlet leading edge was flexing and producing fuel pressures that hadn't been observed during wind tunnel testing," says Brink. "That leading edge was changed from a ceramic to a metallic material."

The third X-51A was a qualified success, although it ultimately lost control. The final test flight in May this year met all the experiment objectives, with the cruiser reaching a peak speed of Mach 5.1 and going the intended distance. "Overall, the nine minutes of data collected from the X-51A program was an unprecedented achievement, proving the viability of air-breathing, high-speed scramjet propulsion using hydrocarbon fuel," says Brink. "For now, there is no immediate successor to the X-51A program. However, I believe what we have learned from the WaveRider will serve as the bedrock for future hypersonic research and the practical application of hypersonic technology for missiles, military aircraft and even commercial flight."

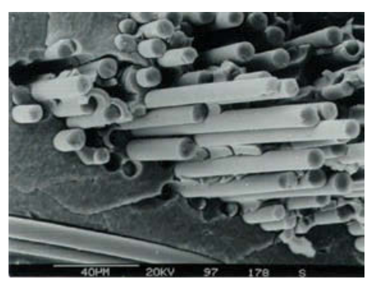
DARPA, the Defence Advanced Research Projects Agency, is looking to invest US$90m in hypersonic technology over the next two years.

ONE GIANT LEAP

So far we have considered two technologies that thrust propulsion engineering into a heady horizon, but what about the more immediate future? The LEAP Program is the answer.

CFM International is a joint venture between GE Aviation and Snecma. The company's LEAP is a high-bypass turbofan engine that incorporates technologies never previously seen in the single-aisle aircraft segment. The new engine combines advanced aerodynamic design techniques, lighter, more durable materials and cutting-edge environmental technologies. It promises 15% better engine fuel efficiency, and double-digit improvements in CO_2 emissions and noise levels. It has been chosen to power the Boeing 737 MAX

THE CERAMIC ENGINE

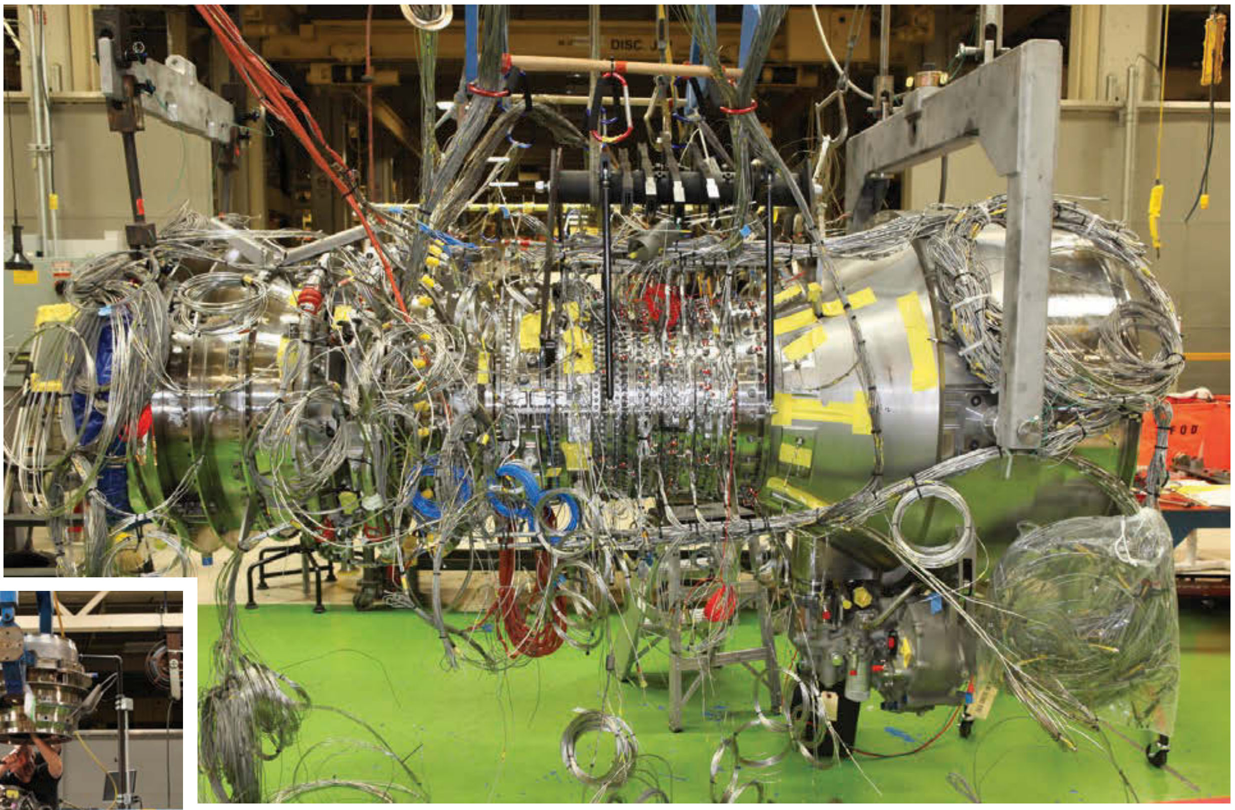


When the Space Shuttle Columbia suffered a cracked wing on its descent from orbit in 2003, General Electric (GE) and NASA helped develop ceramic composite patches that could survive extreme temperature variants. No one realized at the time just how great the potential was for this new material.

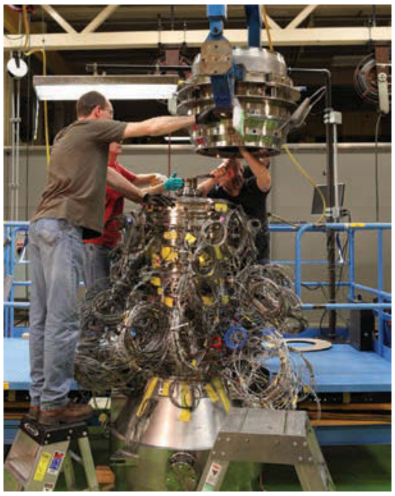
Ceramic has much going for it: it's harder and lighter than steel and can absorb punishing heat or intense cold. It's also liable to shatter as easily as a teacup dropped on a stone floor. However, scientists at General Electric, building on the work they did with NASA, have created a composite that outperforms the most sophisticated metal alloys. Known as ceramic matrix composites (CMCs) these materials are able to withstand fluctuations in temperature from -250°F in space to 3,000°F upon re-entry and are crucial components in CFM International's LEAP (Leading Edge Aviation Propulsion) engines. The use of CMCs reinforced with ceramic fibers help to prevent engine stalls, improve burn and save fuel, thereby improving overall engine efficiency.

The machines that manufacture the CMCs are developed by GE Global Research. The ceramic fibers are given a coating to make them durable before being formed into tapes, cut into panels and fused in a furnace.

RIGHT: **Fully instrumented LEAP eCore demonstrator hardware is prepared for testing. These core tests enable CFM to track more than 2,000 specific data points. It put the hardware through its paces in a special altitude test facility**



BELOW: **Vertical assembly of a LEAP eCore demonstration, mating the high-pressure turbine (top) to the compressor and combustor**



and China's new COMAC C919, and is one of two engine options on the Airbus A320neo. The three engine variants, namely LEAP-1B, LEAP-1C and LEAP-1A, are scheduled to enter commercial service in 2016/17.

"One of the most aggressive technologies going into the engine is a wide-chord composite fan," says Gareth Richards, LEAP Program manager. "For LEAP, the fan will have just 18 blades – half the number of the CFM56-5C. Building the fan required development of new resin transfer molding production processes, a development that has been underway at Snecma for more than 15 years. The fan has been undergoing ground tests since early 2009, including a 5,000 cycle reliability test, blade-out tests, bird strike testing, and acoustics analysis, in order to validate the design. The LEAP engine will be 1,000 lb lighter per ship set than if the fan and case were made of metal."

With the LEAP engine program, CFM has implemented the most extensive testing program in its history. The company has completed more than 550 hours of core testing, leading to a design freeze on the LEAP engine in early 2012. Technology development and component testing has been underway for more than a decade, while some engine materials have been in development for more than 25 years. The engine test plan includes 28 engine builds along with 30 additional flight test engines across the three engine models.

"BEFORE THE FIRST ENGINE IS DELIVERED, WE WILL HAVE ACCUMULATED THE EQUIVALENT OF MORE THAN 40,000 ENGINE FLIGHT CYCLES"

"Before the first engine is delivered, we will have accumulated the equivalent of more than 40,000 engine flight cycles," says Richards. "That represents more than 10 years of airline service."

CFM has four General Electric GEnx engines in which it is testing key LEAP technologies including CMCs, the combustor and the high-pressure turbine blade, with the parts scaled-up from the LEAP size. Testing began in 2012 and the test program is scheduled to encompass more than 7,000 simulated engine flight cycles. This program is designed to provide more full-engine test results to augment the data and learnings from the LEAP component tests.

"The testing program has been incredibly smooth," says Richards. "These technologies have been in development for more than a decade, so we have a lot of testing hours already logged. One of the unique things about CFM as a joint venture is that each parent company owns the technology it brings to the CFM product lines. As a result, there is a lot of successful cross-pollination of technologies from other engine programs. For example, the LEAP engine core is General Electric's responsibility. For the past 25 years, General Electric has put a new core on test every 12 to 18 months."

For LEAP-1A and -1C, ground testing begins in September of this year, leading to the first flight on CFM's own 747 flying testbed mid-2014. Flight testing on the A320neo and COMAC C919 starts in 2015, with engine certification that year. The engines are scheduled to enter commercial service in 2016, with LEAP-1B following in 2017. ∎

Saul Wordsworth is a freelance aerospace journalist for Aerospace Testing International

The frame grabbers

Using dynamic military transport aircraft the Embraer KC-390, so-called 'frame grabbers' have helped engineers unravel a complex picture of aerodynamic interactions for its refueling procedures

BY INDER KOHLI AND REINERT MÜLLER

Tests done on models of a military cargo aircraft in the Duits-Nederlandse Windtunnels (DNW) in Marknesse, the Netherlands, have given a new meaning to the adage 'a picture is worth a thousand words'. Huge volumes of position and flow visualization data, produced by high-speed machine-vision cameras set up in a wind tunnel, have explained the behavior of hoses that trail behind the aircraft while it is used as an airborne tanker in air-to-air refueling operations. Frame grabbers played a vital role in these tests by helping engineers capture, analyze and understand the complex picture of movements and aerodynamic interactions in the wind tunnel itself.

When the Brazilian Air Force contracted Embraer Defense and Security to design, develop and build the twin turbofan KC-390 military transporter, it set out specific requirements for the aircraft.

Commenting on the project, Paulo Gastão Silva, vice-president, KC-390 Program, Embraer, says, "The development of the KC-390 military transporter is one of the biggest engineering challenges our company has faced. In particular, the aircraft has to be versatile, as different missions require different configurations."

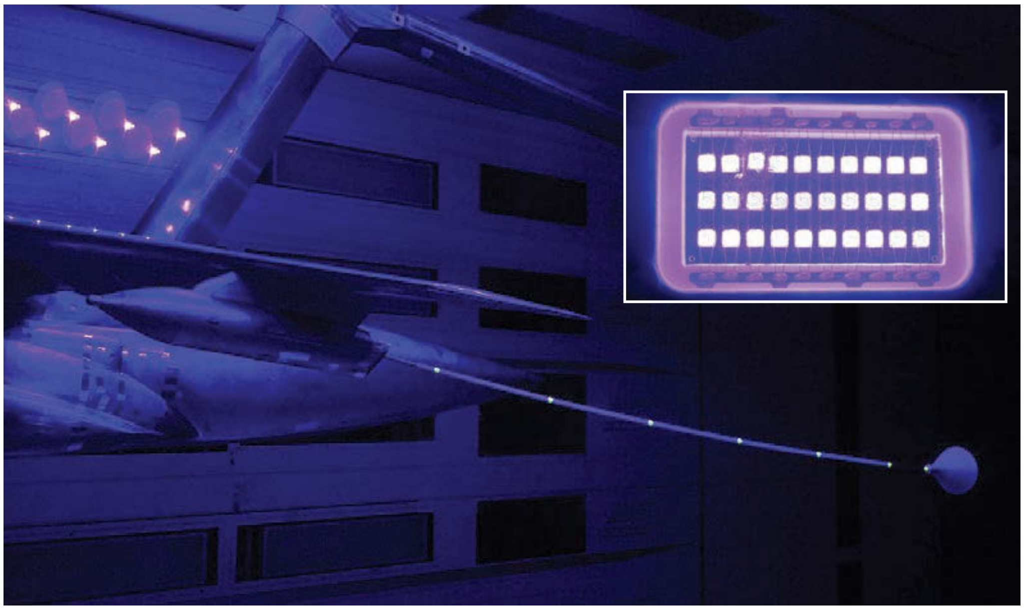
According to Gastão Silva, wind tunnel testing is one of the most important parts of the development process and a range of special tests have already been carried out at DNW to address aspects of the design.

He continues, "For the challenges we face, we employ DNW because it offers the best testing technologies for our wind tunnel campaign. DNW's large low-speed facility (LLF) enables development models to be tested and updated, giving us confidence in the design before the real aircraft is built and takes to the air."

WIND TUNNEL TESTING

Wind tunnel testing has been, and will continue to be, an essential part of the development process for the KC-390 before it makes its maiden flight, which is scheduled for 2014.

Engineers at Embraer are aiming to create a multipurpose aircraft that is able to operate in a range of environments



and climatic conditions. The designers also need to ensure that it is not only capable of being refueled in flight, but can also be quickly configured as a tanker itself using a trailing hose and drogue. The latter, which resembles a windsock or shuttlecock, stabilizes the refueling hose in flight.

An air-to-air refueling operation is fraught with difficulties and risks. A detailed analysis of the movement of the KC-390's refueling hoses, caused by vortices or turbulence, is now helping engineers understand their complex behavior and ensure that the approaching aircraft safely establishes a connection with the moving drogue. In addition, though it is not possible to produce a theoretical model to accurately describe the movement of the hoses, wind tunnel tests showing the actual motion are used to investigate different angles of attack of the aircraft's wings. This is necessary to study the effects of the cruising speeds required to enable slow- or fast-flying aircraft to be refueled by the tanker.

"THE CUSTOMER'S REQUEST WAS UNIQUE, SO WE HAD TO FIND A BETTER TECHNIQUE TO MEASURE THE BEHAVIOR OF THE HOSES"

In the case of significant or erratic movements, empirical wind tunnel tests can be used to reveal design flaws. For instance they are able to show that the housing on the aircraft's wing, from which the hose extends, may need to be modified or its position changed.

ABOVE: Light generated by UV LEDs (inset) illuminate the markers on the refueling hoses and on the model of the aircraft

BELOW: The updated KC-390 wind tunnel model used for inflight refueling testing

TWOFOLD TEST REGIME

Relying on an imaging system developed and integrated by Forschungsinstitut für Bildverarbeitung, Umwelttechnik & Strömungsmechanik (FIBUS) (Institute for Image Analysis, Environmental Control & Flow Mechanics), which uses high-speed machine-vision cameras in conjunction with Teledyne DALSA's Xcelera-CL+ PX8 full frame grabbers, the work carried out at DNW's LLF comprised two components.

The first involved using stereo pattern recognition (SPR) to measure the behavior and track the motion of air-to-air refueling hoses while extended from the model aircraft. The second was used to determine the exact position of the model of the aircraft in the wind tunnel's test-section, with respect to the particle image velocimetry (PIV) laser sheet. This is essential so that the complex flow field behind the wing can be analyzed (using PIV) to determine how tip vortices and turbulence influence the motion of the fuel hoses.

These tests presented various challenges, as Frenk Wubben, senior project manager, DNW, explains: "Previously used techniques applied to solving such challenging problems proved inadequate. The customer's request was unique, so we had to find a better technique to measure the behavior of the hoses trailing behind the wind tunnel model.

"Furthermore, in the past we have calculated the position of models using

IN THE WIND TUNNEL

DNW German-Dutch Wind Tunnels recently completed the aerodynamic testing of an advanced wind tunnel model of the Embraer KC-39. The wind tunnel model was designed and manufactured by the National Aerospace Laboratory of the Netherlands (NLR). The Embraer KC-390 wind tunnel model is an update of a previously tested older model. The latest wind tunnel tests included simulated inflight refueling of the aircraft, as well as payload parachute testing. In addition, a number of specially developed complex measurement techniques were applied to examine specific phenomena such as the velocity flow field. This wind tunnel test is one in a series of tests being conducted for Embraer. The project is based on close collaboration between DNW and NLR, with each party contributing specific expertise to offer the client a 'one-stop-shop' approach. DNW is equipped with a system that is capable of monitoring turbulence and vortex effects using an optical flow measurement technique called particle image velocimetry (PIV). DNW developed a high-power LED UV illumination source capable of illuminating approximately a 10 x 10m area of the aircraft under test.

MEASUREMENT TECHNIQUES

The hose and drogue system, designed and manufactured by the Nationaal Lucht- en Ruimtevaartlaboratorium (NLR, the National Aerospace Laboratory of the Netherlands) according to strict specifications set out by Embraer, was remotely controlled during the tests to simulate air-to-air refueling during flight.

Markers coated with UV paint were applied to both fuel hoses to enable their positions to be measured while they were extended at a constant speed from the wind tunnel model. Because of their dynamic movement it was not always possible to track the markers, so as a fall-back position, measurements could also be taken with the hoses fully extended. Similar markers were applied to the upper side of the model's fuselage at well-defined positions along its axis to enable the MRP to be calculated. SPR was then used to optically determine the spatial position of the markers, using cameras set up in stereo mode.

ABOVE: **The KC-390 will be the heaviest aircraft Embraer has manufactured**

support kinematics. The accuracy of this approach is limited because of the deflection of the support system, which can be only partly corrected. For this test, the position of the model needed to be determined with greater precision to accurately position it with respect to the PIV laser sheet. In other words, the position of the laser sheet with respect to the model had to be known accurately."

MACHINE VISION

Measurement data was obtained from images captured by two Bonito CMC-4000, four-megapixel cameras from Allied Vision Technologies, mounted on the ceiling of the test section of the wind tunnel. By illuminating the markers under UV light generated by high-power UV LEDs (395–405nm), high-contrast black-and-white images with no reflections were obtained.

Each camera was connected to two Xcelera-CL+ PX8 boards. These frame grabbers are based on the PCI Express x8 interface. Commenting on the machine vision setup, Dr Reinert Müller, FIBUS, says, "The complete system is complex because it consists of a fast SandyBridge-E computer system including fast graphics, four Xcelera-CL+ PX8 boards and a digital I/O card from National Instruments.

"In order to reach the desired high frame rate of 400fps, the cameras use a special left-half/right-half imaging mode. Each camera is connected to two frame grabbers, which are responsible for transferring their two 'half images' to a contiguous image buffer without any CPU overhead, using the unique child-buffer mechanism of the Sapera API. This configuration enables tracking to be done in real time."

Müller continues, "The 1500MB/s bandwidth of the cameras required the use of high-quality Camera Link cables to enable data to be conveyed over the 8m distance to the computer. Illumination using the UV light was difficult because of a shortage of the high-power LEDs that were specially designed for this measurement. As a result the acquisition and processing speed was limited to a maximum of 200fps. In future the use of a greater light output should enable us to reach the maximum speed of the camera of 400fps, making tracking the moving fuel hose much easier."

In order to take the fuel-hose and PIV measurements, SPR is used in dynamic and static modes respectively. Wubben adds, "In dynamic mode an acquisition time of 1.5 seconds was used to measure the position of the markers on the hose, with a sample frequency between 100Hz and 200Hz. In static mode, an acquisition time of 1.5 seconds was again used to measure the position of the markers on the model, at a sample frequency of 10Hz. "With a maximum sample frequency of 400Hz for the cameras and a resolution of four megapixels, the accuracy of the system is in the order of 1mm during dynamic and static measurements."

PIV MEASUREMENTS

In parallel with PIV measurements, the positions of the markers on the model were measured using SPR, as Müller explains: "The twofold tests are necessary to understand what is going on. If you do the deflection measurement only with the SPR system you will learn about the motion of the fuel hose and wing, but you will never understand what causes the measured motion. The use of PIV was necessary to learn about the flow-field behind the wing. This complex flow-field, with tip vortices and turbulence, influences the motion of the fuel hose."

PIV measurements are performed at positions. The desired PIV plane center coordinate is provided by the customer. Using the measured coordinates from the markers, the position of the model reference point (MRP) in the tunnel axis system is calculated using dedicated DNW software.

Wubben says the desired coordinates of the PIV plane are calculated using three data sets – the actual position of the MRP in the tunnel axis system, the relevant PIV plane center coordinate in the model axis system, and the model's angle of attack and side slip angle.

"The PIV plane is measured within the laser sheet. The position of this sheet in the tunnel axis system is traversed in a stream-wise x-direction. The (y, z) position with respect to the MRP is reached by traversing the model in the y and z directions," explains Wubben. "Adjustments to the position of the laser sheet and model are necessary until the actual PIV plane position matches the desired PIV plane position. The procedure is checked with a known coordinate on the model."

PROBLEM SOLVED

The machine-vision system was delivered in May 2012 and was used for SPR measurements over the following months. "It worked flawlessly," says Müller. "It is the only system capable of solving the problem we faced, which was to track the extended refueling hoses at the required high resolution and tracking speed of 200fps."

FIBUS says it is now starting to set up a complete real-time PIV system using DALSA grabbers and the Bonito cameras. According to Müller the first tests are scheduled for this summer. ∎

Inder Kohli is product manager at Teledyne DALSA. Dr Reinert Müller is director at FIBUS, the Research Institute for Image Analysis, Environmental Control & Flow Mechanics based in Germany

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NIAR equips its new Aircraft Structural Testing and Evaluation Center with MTS controls and data acquisition

National Institute for Aviation Research (NIAR) Aircraft Structural Testing and Evaluation Center, Wichita State University

The recently opened NIAR facility features 100,000 square feet (9,290 square meters) of structural test space, capable of supporting full-scale evaluations of aircraft as large as the Boeing 787. MTS FlexTest controllers, MTS FlexDAC data acquisition systems and AeroPro software deployed throughout the facility help NIAR maintain world-class levels of test precision and productivity as it engages increasingly complex test scenarios.

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MTS AEROSPACE SOLUTIONS

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Maintain position

Many readers of *Aerospace Testing International* are directly involved in getting new aircraft through their development and into service. Once this mission is completed, however, the job of making sure they remain fit for purpose is an entirely different matter

BY JOHN CHALLEN

Given the growing number of aircraft appearing in the world's skies, coupled with the pressure on operators to improve efficiency, these are boom times for companies involved in aerospace maintenance, repair and overhaul (MRO). Whether they are brand-new models or those making their way toward retirement, airplanes present MRO providers with some major challenges.

One recent and high-profile example of the perils of dealing with the systems and technologies found on new aircraft is the fleet of 50 grounded Boeing 787s that experienced complications with their battery systems earlier this year. Following FAA approval of improvements to the system, Boeing was able to commence recall of the airplanes. But this was only after some quite extreme measures had been taken.

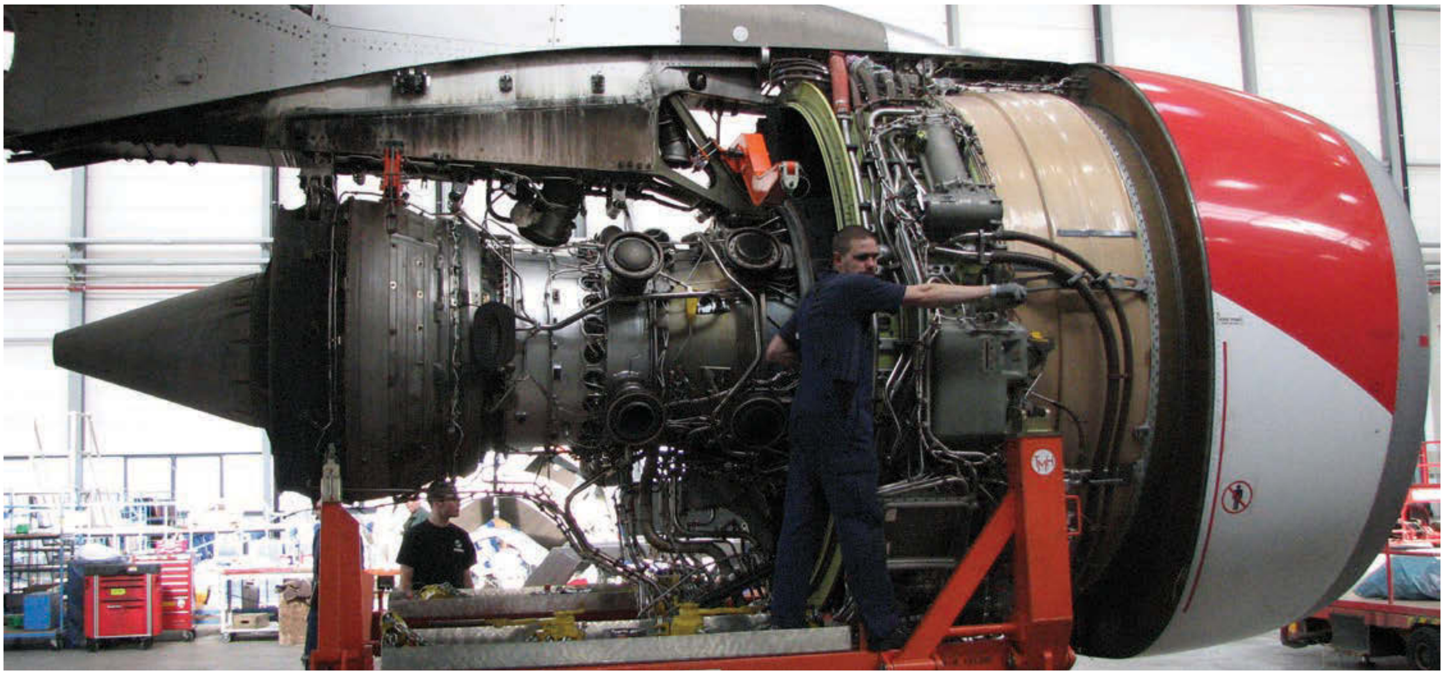
Extensive engineering analysis and testing was carried out to develop a thorough understanding of the factors that could have caused the 787's batteries to fail and overheat. A team of engineers spent more than 100,000 hours developing test plans, building test rigs, conducting tests and analyzing the results to ensure that the proposed solutions met all the FAA's requirements. A team of more than 12 battery experts was also dispatched.

The impact for MRO operators is wide-reaching as it means new procedures and parts to maintain. The battery system's overall design has changed, with a new steel enclosure being added to keep any level of battery overheating from affecting the aircraft.

The above scenario may be enough to deter some aerospace organizations from providing MRO services, but not Dresden's EADS-EFW (Elbe Flugzeugwerke), which is looking to further establish itself in the MRO world. The company is well-known for its freighter conversion work – indeed, it has been responsible for the conversion of 140 A300 and A310 aircraft – but has realized the potential that MRO operations offer and has invested accordingly.

"Our hangars date back to the mid-1950s, so we had to build new ones, as well as install all the tooling required for a new aircraft platform," explains Phillip Reiche, head of MRO services at EADS EFW. For the three airplane families that the company services, Reiche believes that 80-90% of the items in the tool catalogs can be found at EFW. "If you go into airplane structural work, you need a lot of investment in general tooling," he says. "Having come from this side of the industry, we already had many of the tools from our freighter conversion activities, but in the last few years we still concentrated on the back-shop capabilities needed to carry out MRO on the cabin and elsewhere on the aircraft."

EADS EFW's background is in freighter conversions, but the company sees big potential in the growing MRO market



ABOVE: Aircraft engines can be subjected to anything from routine maintenance to major repairs and modification at EFW

EASA APPROVAL

Looking at the range of services provided by EFW across the A300/A310, A320, A330, A340 and A380, it is understandable that the investment was needed. The company has to carry out a wide range of tests in accordance with EASA Part 145 approval, which is required to reach maintenance organization status. These include transition checks, structural inspections, corrosion prevention, non-destructive testing, fuel tank resealing, and modifications to the electrical and avionics systems.

Getting the right balance between maintaining end-of-life aircraft and looking after the next generation is the goal for EFW, and it seems to be paying off. Emirates recently transported one of its A380s to Dresden for EFW to install a permanent full-life fix of cracks in the aircraft's wing-rib brackets – work that is expected to take two months. Thanks to the reconstruction of an existing hangar, the complete fuselage could be accommodated. Having undertaken temporary wing-rib fixes in the past, this is the first time that a permanent solution will be completed by EFW, handled by a team of 100 technicians.

Reiche explains that the availability of human resources can be as important as the physical tools or spare parts needed for the base MRO work. "Young people are often not willing to train and invest time in learning about old aircraft types," he maintains. "They don't really want to learn because the aircraft are not so exciting and the technology and systems involved are not as interesting as those on board, say, an A380. In the future they will see fleet numbers and the market value of one aircraft type steadily diminishing. They see more potential in learning from newer aircraft, because they are the future."

So getting hold of the right people is tough enough, but having the right parts for aging aircraft such as the A300/A310 can be a major headache.

ASIAN MRO HUB

Located in the heart of Asia-Pacific, Singapore is the largest MRO hub in the region. The city-state accounts for over a quarter share of the region's MRO market with over 100 aerospace companies that collectively offer a comprehensive suite of aftermarket services.

Rolls-Royce's Regional Training Centre in Seletar Aerospace Park, Singapore

Companies are leveraging Singapore as the gateway to Asia-Pacific's emerging economies. Over the past 18 months, multinational corporations, including Bell & Cessna, Hawker Pacific and Standard Aero, opened new MRO facilities at Singapore's Seletar Aerospace Park (SAP). Others, such as Bombardier, Jet Aviation, Meggitt, Pratt & Whitney and ST Aerospace, broke ground at SAP.

Building on its established MRO base, Singapore is also fast becoming synonymous with high-value aerospace manufacturing. In 2012, Rolls-Royce opened its titanium wide chord fan blade manufacturing and Trent engine assembly and test facility in Singapore, the first such facility outside the UK. More recently, Pratt & Whitney commenced construction of its new manufacturing facility for its hybrid fan blades and high pressure turbine disks, which will be installed on Pratt & Whitney's new PurePower geared turbofan engines.

In 2012, Singapore's aerospace industry output reached a record S$8.7 billion – close to a 9% year-on-year growth over 2011.

"When the aircraft is on the ground, or on a maintenance layover, it is particularly difficult to procure structural components such as flaps, slats, doors, adapters, sleeves and brackets," explains Reiche. "Corrosion findings can often lead to complex procurement campaigns, where the supplier network is called into action. It's essential to manage and support the full supply chain, from the raw material through the 3rd and 2nd Tier suppliers through to delivery to our facility. Parallel to the procurement process in the early phase, if no repair is feasible we verify and prepare for in-house production."

"We sometimes have quite surprising structural findings that come up in the inspection phase of end-of-life airplanes," he continues. "To cover this, as well as our in-house test capabilities, we also have a worldwide network of information that is linked to our structural findings, through the increased amount of NDT work necessary with older aircraft. We are investing in a lot of equipment, such as x-ray inspection machines. Though the tools are expensive, we have to invest in them to meet the requirements of the test standards and our customers."

ADVANCED RECONTOURING PROCESS

The Advanced Recontouring Process (ARP) aims at extending the service life of engine compressor blades by recontouring their aerodynamic profile.

The compressor blades in modern jet engines are exposed to continuous wear. Dust particles entering with the airflow cause heavy erosion at the leading edges. The deformation of the compressor blades results in enormous performance losses. In the past, these expensive components were ground by hand and could be used only for another two repair cycles before they had to be scrapped.

Lufthansa Technik has developed a procedure that is unique worldwide, in that the worn compressor blades are first electronically analyzed and then recontoured in a precision method using robot technology. This increases the service life of the components to four repair cycles. Moreover, the improved profile also reduces fuel consumption.

The restored profile of the engine compressor blades is not identical to the profile of the new part. Rather, it is calculated as a factor of the reduced chord length of the worn blades so that the best possible aerodynamic profile is obtained.

In contrast to traditional manual grinding of the engine blades, the quality obtained by robot grinding is reproducible again and again. Furthermore, only the necessary minimum material is removed.

Torsten Thomsen, Lufthansa Technik AG, Hamburg, Germany

"WE SOMETIMES HAVE QUITE SURPRISING STRUCTURAL FINDINGS THAT COME UP IN THE INSPECTION PHASE OF END-OF-LIFE AIRPLANES"

US OPERATIONS

Some reports suggest that servicing an aircraft at a local MRO helps an airline save up to 40% in a airplane's maintenance costs, despite the tax on imported spares. This is a factor that has been taken into consideration by Commercial Jet, which has recently expanded its MRO operations.

When the company opens its 400,000ft^2 facility at Dothan Regional Airport in Alabama it will more than triple its capacity to provide freighter conversions and MRO services. Being built in stages and due to be competed by October 2013, the US$12m facility will offer 54 acres of ramp space to cope with the overflow from the company's existing site in Miami.

"We didn't have enough room for all the customers we had scheduled in Miami," says John Schildroth, vice president and general manager of Commercial Jet's Dothan operations, adding that the 737 conversion area of the business has grown substantially, with Dothan handling three aircraft for the rest of the year that couldn't be accommodated in Miami.

There is a split between 'classic' aircraft and new-generation work, the requirements and challenges of which are very different. The facility at Dothan will be looking to focus on new-generation work, mirroring that done in Miami. "We want to work on a wide range of aircraft – 757s, 737s, MD80s and DC-10s, as well as A300s, A600s and A330s from Airbus."

The company typically covers heavy maintenance checks, but also does paint repairs. "Normally sheet metal repair is required when someone has run a baggage truck into the side of the

Structural repairs, such as this skin panel replacement, are common MRO procedures

THE FINANCIAL SIDE TO MRO

Recession-resilient companies in the aerospace and defense (A&D) industry that have developed strong maintenance, repair and overhaul (MRO) offerings can provide a valuable model for any manufacturer worried about budget cuts.

During the lean defense spending era of the late 1970s, the A&D industry learned that revenue needs to come from more than government spending. As a result, the industry turned MRO into a powerful tool for surviving revenue fluctuations.

Integrated CRM functionality helps support this account management tactic and identify related sales opportunities that arise.

When the service technician becomes a trusted advisor, recommendations for purchases, equipment upgrades and parts replacements are more readily adopted – often bypassing lengthy quoting and approval processes. This translates as more business, done faster.

Companies can also increase the level of their value-added service by increasing the speed of delivery, surpassing what any competitor can deliver. This all but ensures ongoing MRO contracts.

Edward Talerico is the industry director of aerospace & defense at Infor, based outside Atlanta, USA

airplane and there is no service or mechanics where the aircraft is located," explains Schildroth. "While there has been some investment, a lot of the tooling we have here has come from Miami." He states that getting the equipment from one site to the other can be done in a day, which doesn't greatly affect service schedules.

As well as new technologies, Schildroth claims that another major outlay for the company – as with EFW – is in its human resources. "The work we've already carried out on similar aircraft has required, on several occasions, the need to invest in training technicians as well as new tooling," he states. "With these airplanes, we spend around 40 hours training a technician, to get them up to speed with the tasks they need to carry out on the aircraft. Schildroth says that most of the key hardware investments for new aircraft are for avionics and electrical test equipment. As there are so many computers on new aircraft, and the systems are continuously being updated and upgraded, it is essential that thorough training is completed to enable the test work to be carried out properly.

EFFICIENCY GAINS

Schildroth says that the company does everything it can to ensure improved efficiency, especially when it comes to MRO work on older aircraft. "Problems can depend on a number of factors, including the package, the customer, the airplane model and age, and also the parts and materials you have to buy. For some older aircraft you need parts that aren't readily available, so for a repair or overhaul on a part you might have to wait up to two weeks for a replacement item, which adds to the downtime on the airplane.

Commercial Jet has measures in place to improve the processes involved in end-of-life MRO work. "We're looking at a new computer-based operating system that will make our maintenance operations more efficient," Schildroth reveals. "Advanced software will aid our business and we are constantly buying tooling, looking for ways to improve in that area. Whatever we need, the owners of the company will make the investment. Anything from general tooling, such as jacks, to specific tooling that we need for particular jobs on individual airplanes."

For EFW, future challenges include dealing with the trends in airplane lightweighting. "We have to deal with new materials such as carbon fiber, and we find that the A330 is very different from the A300, for example," says Reiche. "There is a large number of suppliers for the cabin, and for IP systems there are numerous generations and suppliers, so you end up with a number of different elements for each model, which can be hard to monitor." ∎

John Challen is a freelance aviation and automotive journalist for Aerospace Testing International

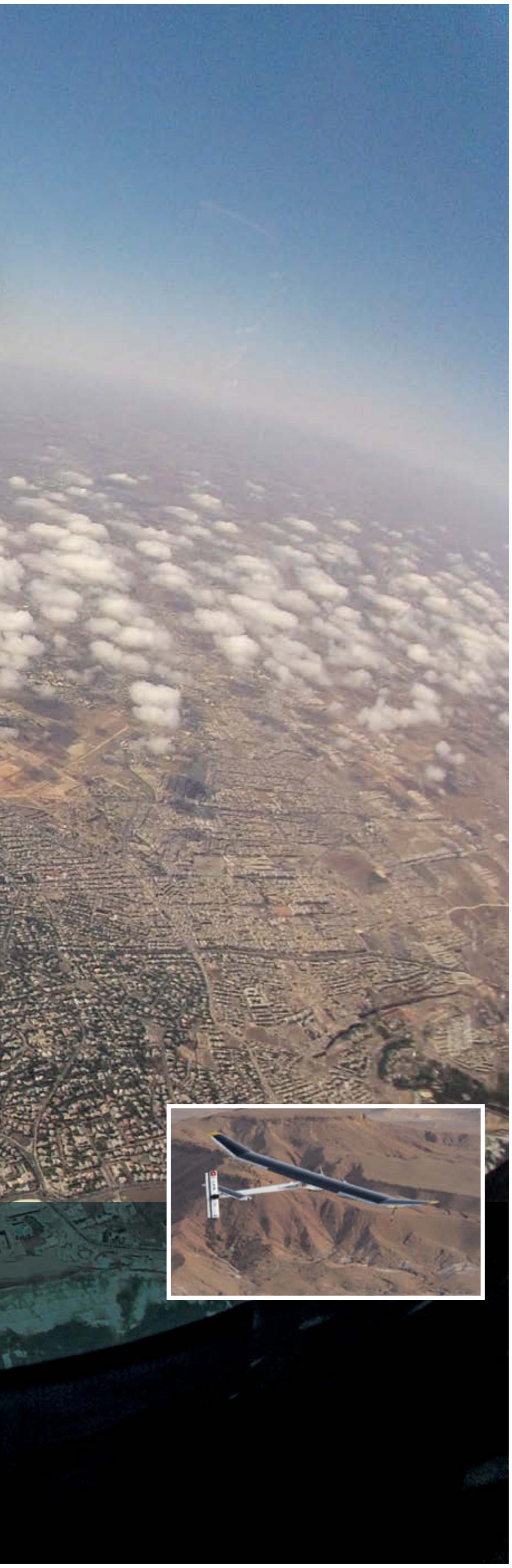
BELOW: **EFW has upgraded its hangars to take more aircraft, and increase its MRO capabilities**

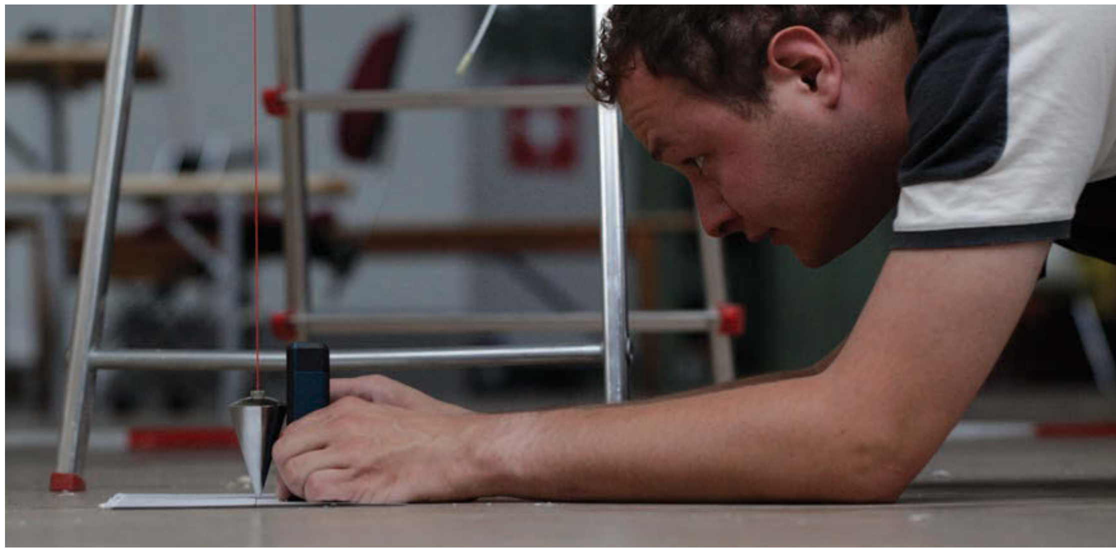
BELOW INSET: **Cockpit and cabin repairs are an essential part of the process**

Solar flair

As Solar Impulse, the most innovative aircraft for decades, finishes the final leg of its record-breaking solar-powered test journey from San Francisco to New York, *Aerospace Testing International* looks at the next stage of development, and enjoys an inflight interview with the pilot

BY VIKTORIA DIJAKOVIC AND CHRISTOPHER HOUNSFIELD





ABOVE: **Engineer Yves Heller, who is checking the status of the wing spar during the pre-flight tests (Photo: Stéphane Gros)**

Solar Impulse is the world's first solar airplane able to fly day and night. The project's final goal is to fly around the world, but it will be Solar Impulse's second-generation airplane (not the transAmerican aircraft), currently under construction in Dübendorf, Switzerland, that will take on the challenge. The new airplane is an optimized and more complex version of HB-SIA. It will be larger (by 11%), able to carry more weight, more resistant to humid climates and, most importantly, the pilot will have added comfort during the longer legs, which can last several days. As André Borschberg, Solar Impulse's CEO, states, "From the very start of the project, we understood that our primary goal was to save energy."

The key to building a solar airplane is the weight-to-energy ratio. Since $1m^2$ of solar cells can produce enough energy to lift 8kg, at least $200m^2$ of solar panels area is needed to transport pilot and airplane. Consequently, HB-SIA's wingspan is 64m, while HB-SIB will be even larger.

For each component, designers and structural analysts work in tandem. Using specialized 3D software, designers create a part and submit it to the structural analysts, who verify it is resistance to loads during flight and its integration into the larger structure. Although HB-SIA and HB-SIB will have a certain resemblance, the complexity of HB-SIB's design phase was greater. Everything was optimized, improved and pushed to the limit. With a larger wingspan and higher speed, HB-SIB will carry heavier loads.

Solar Impulse's airplanes are prototypes. Every component is tested and approved by the Swiss Federal Office of Civil Aviation – a necessary procedure to receive the permit to fly. Tests verify components' structural integrity and are done by setting up a test jig and gradually adding loads – bricks of lead. Tests can include bending, torsion, tension and compression exercises. Because the airplane has to be as light as physically possible, stability issues could arise. For this reason, everything is designed to avoid buckling and to maintain stress below the tolerable level. Engineers also check the stiffness of certain parts to ensure deformation due to applied loads doesn't jeopardize mechanical functionality.

THE TRIALS

To cite a couple of examples: the wing went through bending and torsion tests with up to 5 tons of loads. There were four load cases simulating situations of turbulence, as well as maneuvering scenarios (inputs that could be given by the pilot). The fuselage was tested even further, amounting to 10 load cases, including six sub-cases. The tests covered different landing scenarios, including tail-down landing, maximum acceleration and various cockpit tests – the cockpit being an integral part of the fuselage.

The Iron Bird – testing of all electronic systems in a mock cockpit – is taking place through 2013. It tests the cockpit in flight mode with the hundreds of wires pulled through the mock wooden structure. Most of the devices were designed and built by Solar Impulse electrical engineers, including: the Power Management Computer (monitoring power generation and motor functions);

the Independent Display (collecting all essential information such as battery temperature, power supply and motor efficiency); and the Mission Computer (providing the pilot with all essential flight information). The uniqueness of the aircraft necessitates careful data monitoring, including the status of the aircraft and the pilot while in flight. The data is sent via satellite to the mission control center in Switzerland, which supports the pilot from take-off to landing.

The most important systems, such as the independent display and the mission computer, are redundant in this context for safety reasons. The final step will be the flight tests, scheduled for early 2014, but simulations for the around-the-world flight have already begun. Thanks to complex calculations, weather statistics and the flight simulator, HB-SIB has already virtually flown around the globe. Flying eastward to the Persian Gulf over China, Hawaii, the USA and Europe, HB-SIB has virtually proven its resistance and ability to undertake the challenge. As HB-SIA retires after this year's adventure across the USA, HB-SIB will take the baton and continue the solar journey across the globe. ▮

Viktoria Dijakovic, David Oldani, Alexandra Gindroz, Gaël Lemoine and Christoph Schlettig contributed and are all part of the Solar Impulse team in Switzerland

LIVE 'ON AIR'

Editor Chris Hounsfield caught up with Solar Impulse pilot and co-founder André Borschberg, who was 17,000ft above Texas during the second leg of the transAmerican journey – the longest solar impulse flight to date

"THIS IS MISSION CONTROL IN SWITZERLAND YOU ARE NOW CONNECTED TO ANDRÉ IN THE COCKPIT":

Q: YOU ARE CURRENTLY IN FLIGHT. I'D LIKE TO KNOW HOW YOU FEEL AS THE PILOT. IS THIS A STRESSFUL EXPERIENCE OR IS IT QUIET AND SERENE? AND HOW IS IT FROM YOUR POINT OF VIEW AS THE DESIGNER AND THE ENGINEER OF THE AIRCRAFT?

A: Since morning it has been very beautiful. It was a little bit turbulent after take-off and now I am flying out of the state of Arizona at 17,000ft, but it's so beautiful at night-time to enjoy and look out at. I have to be careful this evening more than anything because it's going to be a bit more difficult.

Q: CAN I ASK YOU HOW THE AIRCRAFT HAS HANDLED SINCE YOU TOOK OFF?

A: When it's very calm, it's extremely nice to fly with two fingers. We have no autopilot so we still have to keep the console on all the time, and when it's turbulent, it's a heavy workload. So it needs the full attention of the pilot. You could say that the aeroplane has two personalities and currently I am enjoying the nice personality.

Q: HAVE THE WEATHER, THE CLIMATE AND THE TERRAIN AFFECTED THE FLYING PATTERN AT ALL?

A: We have to make sure that we fly above the thermals, above the turbulences; that's the reason why we climbed quite early, and have been using the oxygen mask for quite a while.

Q: DID YOU HAVE TO MAKE ANY MODIFICATIONS OR ALTERATIONS TO THE AIRCRAFT PRIOR TO THE SECOND LEG OF YOUR AMAZING WORLD RECORD JOURNEY?

A: No. The aircraft is quite reliable despite [the fact that it is a] prototype. It's the first airplane we have built and it really works extremely well. You know when you switch on the slow generator how much energy you can get; you know how much power you can get to propel the aircraft. That reliability is impressive.

Q: CAN I ASK YOU HOW THE BATTERY POWER AND THE AVIONIC TECHNOLOGY IS WORKING IN COOPERATION WITH THE AERODYNAMIC DESIGN. HOW IS THE WEIGHT-TO-POWER RATIO?

A: The aircraft is designed to fly day and night on solar energy only, so fundamentally it has been designed to use as little energy as possible. Interestingly, all the technologies that we have on board the aeroplane can be used by anybody on the ground as well: the battery cars, the solar cells. Solar power can be used in homes, and the insulation materials we had to develop for the batteries can be used in refrigerators. So all this has direct practical use, but the goal of reducing energy consumption made us design an aeroplane the size of a 747 and with a weight not exceeding that of a car.

Q: WHEN YOU LAND IN DALLAS, WHAT WILL YOU DO? MAINTENANCE, REPAIR AND OVERHAUL TO IMPROVE THE FINAL LEGS OF YOUR TRANSAMERICAN JOURNEY?

A: We will certainly do maintenance. We do thorough preflight checks, post-flight checks and, like any other aircraft after a certain number of hours, we thoroughly check the water, the various systems, the structure and the way it's assembled. We're very careful to follow the rules that have been dictated by the different authorities such as the FAA. So that will be part of the work of the ground crew when we land in Dallas. There shouldn't need to be any modification because the airplane is flying very well as it is. We are also building a second airplane.

Q: CAN I ASK HOW YOU'RE FEELING? IT MUST BE VERY TIRING.

A: We are used to flying 20-hour legs. I have done many now – my longest flight so far is 26 hours – but I try to relax in between. I do yoga and meditation every day and use breathing techniques; this helps keep up energy and attention levels, to keep the alertness necessary to fly the airplane.

Q: IS THERE ANYTHING YOU WISH TO SAY FROM A PERSONAL VIEWPOINT ABOUT THE NEXT PHASE OF TESTING AND DEVELOPMENT?

A: There is a team in Switzerland that is building the second aircraft, which should be ready to be tested in early 2014. The goal of the second aircraft is to fly around the world in 2015. In summary, this is the last test and a very important test, not just for the pilot, but for the entire team on the ground, the crew and in the control center.

I WISH YOU THE VERY BEST OF LUCK IN YOUR GROUND-BREAKING WORLD-RECORD ATTEMPT!

TO VIEW THE FULL BROADCASTED INTERVIEW GO TO
WWW.AEROSPACETESTINGINTERNATIONAL.COM

Root cause

The US National Institute of Aviation Research gives an exclusive insight into the latest technologies and experiments on the aging of composite structures and bonds with a focus on the F/A-18 first-generation composite aircraft

BY DR WARUNA SENEVIRATNE

LEFT: **Whiffletree loading mechanism of F/A-18 inner wing**

The first generation of composite primary structural components are now entering the twilight of their certified service lives. Life-extension efforts are underway for many affected aircraft, and efforts are primarily geared to the continued safe operation of the metallic components, for which a fatigue life can be quantified. However, many of the composite components do not have a known measurable fatigue life, so any extension of their lives cannot be accomplished via the same methodology.

Scientists at the National Institute for Aviation Research (NIAR) at Wichita State University are investigating aging of the McDonnell Douglas (now Boeing) F/A-18 Hornet's wing structure, which consists of AS4/3501-6 carbon/epoxy composite wing skins and composite-to-titanium step-lap joints bonded with FM-300 film adhesive at the wing root and pylon fittings. The research program is funded by the US Office of Naval Research and monitored by the Airframe Technology Branch of Naval Air System Command (NAVAIR) – Air Vehicle Department.

The research team has formed collaborations with international F/A-18 users, such as the Royal Canadian Forces and Defense Science Technology Organization (DSTO) of the Royal Australian Air Force, to expand the use of data gathered during this effort. This program provides a quantifiable, risk-based assessment methodology for determining the capability for life extension in composite structures, combining original certification and operational use methods.

The research program is designed to address one of the biggest concerns with an aging aircraft fleet – the unknowns that emerge with little or no warning, raising the concern that an unexpected phenomenon may suddenly jeopardize an entire fleet's flight safety, mission readiness and/or support costs.

F/A-18 WING ROOT

The F/A-18 wing root 'step-lap joint' is one of the best examples of a bonded primary structure certified and deployed on an aircraft in the USA. Since a wing root bonded joint transitions from the composite wing skin to a titanium fitting for attachment to the fuselage, it is a complex joint.

The research program first focused on evaluating the residual strength of the composite-to-metal wing-root joint area after a lifetime of aircraft service and assessing the service life remaining based on the history of use. More than 60 25in-long tapered dog bone test specimens were extracted from eight decommissioned F/A-18 wing skins. A reliability analysis was conducted on residual strength and fatigue life data to compare against the original certification data.

Spectrum loading, representing fleet use, is used for cyclic testing to determine the remaining life of the step-lap joints. The residual strength tests conducted on elements extracted from decommissioned wing skins after one service life indicated that the service history, including environmental exposure, had no significant effect on the residual strength of the bonded joint.

Furthermore, the additional spectrum fatigue tests in a laboratory environment indicated that the remaining life of the joints was substantial and the residual strength was unaffected by the additional fatigue lifetimes. Prior to fatigue testing, some of the elements were exposed to an extreme salt-fog environment to simulate the exposure to aircraft carrier-based operations. Based on the testing conducted during this phase, the elements had more than five additional fatigue lifetimes remaining under a tension-dominant fatigue spectrum, and several specimens survived 10 lifetimes without significant residual strength degradation.

During tension-dominant spectrum fatigue loading, which is more critical on metallic components, a corner crack in titanium was observed in one of the step-transition areas. This crack propagated first through the thickness of the titanium and then across the width. Although the titanium was completely severed and the crack continued into the composite and propagated as a large delamination, the remainder of the joint continued to carry loads for a large number of fatigue cycles before overloading the adjacent structure and resulting in final failure.

When subjected to a compression-dominant fatigue spectrum, which is more critical on composite parts, specimens survived 30 lifetimes of additional fatigue cycles with no significant residual strength degradation to the parts.

NON-DESTRUCTIVE INSPECTION

During fatigue tests, the specimens were non-destructively inspected using ultrasonic scans and pulse thermography equipment. In addition, traveling microscopes were used to monitor microcrack formation in the joint area and a photogrammetry image-correlation technique was used to monitor full-field displacements and strains.

Specimen compliance was monitored periodically to detect potential stiffness loses due to damage growth. Non-destructive inspections around the joint area were instrumental in understanding the microcrack formation of composite details near the joint area, enabling inspectors to interpret similar findings in the field. Fatigue data indicated that despite the formation of microcracks, the joints were able to carry fatigue loads and showed no change in stiffness. A detailed failure analysis and an investigation into findings from non-destructive inspections were carried out to understand the progressive failure mechanism.

F/A-18 INNER WING

Upon completion of the fatigue life assessment of the step-lap joint, the research was expanded to evaluate the remaining life of the F/A-18 inner-wing, which consists of composite skins.

Test articles consisted of center fuselage, inner-wings and trailing-edge flaps. The center barrel section of the

TEARDOWN INSPECTION

Upon completion of the full-scale fatigue testing, teardown inspections of critical areas will be conducted to assess the condition of the structure and compare the findings of previous teardown inspections conducted by the US Navy to identify the extent of known or suspected damage threats as well as any unexpected damage threats resulting from the service life extension. Furthermore, the post-test teardown findings will provide vital data to validate the NDI findings during durability testing and identify equipment capabilities and limitations.

fuselage is used as part of the inner-wing test fixture to ensure proper load transfer at the wing-root lugs. Simulated inboard leading-edge flap and the outboard wing are attached to each inner-wing box for fatigue-load application. This structure provides an opportunity to look at service life management and offers a useful insight into the sustainment of the active fleet.

Current methods of certification for aircraft composite structures rely on the development of safe use through fatigue testing. Since composite structures are designed to withstand environmentally compensated static loads with considerable analytic reductions in strength, it is rare that the full-scale fatigue testing of aircraft components demonstrates the capabilities of the composite structural members. In addition, the expense of fatigue testing rarely permits continued testing past the original design goals of the program.

These factors combine to prevent composite structures from failing during the fatigue test. As a result, there is little capability over the course of the aircraft's life to relate in-service events to known fatigue limitations of the original certification test, and no mechanism by which to employ engineering principles for the extension of life.

The ability to use end-of-life aircraft structural components has been shown to be beneficial in many instances for the support of the existing fleet and provides a proactive approach to fleet maintenance.

NEXT PHASE WING TESTS

During the first phase, the wing structure will be cycled for an additional lifetime of test loads while monitoring for potential fatigue-induced damage through various types of health-monitoring techniques. This full-scale test program also provides an opportunity to evaluate current field-inspection techniques and structural health-monitoring systems for detecting known or suspected damage threats found during teardown inspections for the extended life period, as well as assessing novel inspection techniques to detect damage threats in a controlled environment.

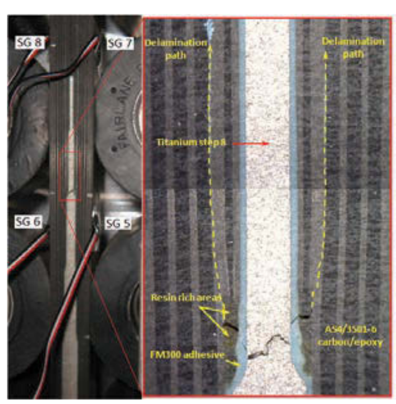
The second phase will focus on damage tolerance of the structure to avoid catastrophic failure due to fatigue, corrosion or accidental damage throughout the operation of the aircraft. Low-energy, barely visible impact damage (BVID) to large battle damage will be simulated and monitored during continued fatigue cycling to assess damage containment and/or the rate of growth so that the assumptions used during original certification related to damage tolerance philosophy and failure mechanisms are further validated. Subsequently these damages will be repaired and the durability of the repairs will be evaluated through further fatigue testing. An accidental crack detected on the aluminum leading edge of the right trailing-edge flap was repaired following a procedure documented by US Air Force Research Laboratory.

This composite 'wet lay-up repair' was subjected to pulse thermography and photogrammetry (image correlation) full-field strain evaluation prior to spectrum fatigue loading, and it was found that the localized displacements and the far-field strain at the periphery of the composite repair patch remained consistent with measurements prior to the repair. In addition, periodic inspections during one lifetime of fatigue testing of the trailing-edge flap indicated that the composite wet lay-up repair successfully prevented further damage growth without adversely affecting the local stiffness of the structure.

F/A-18 CONCLUSIONS

The results of this test program will help to determine the airworthiness of the F/A-18 airframe and to assess any need for preventive maintenance for mitigating risks beyond its original design life. Lessons learned from this research will provide insight into the aging aspects of other non-metallic aircraft structures and influence the use of advanced materials on new aircraft being proposed for military service as well as maintenance of the existing fleet.

The full-scale structural test provides the opportunity to look at service-life management and gives useful insight into the sustainment of the active fleet. This research program will provide useful information on service life assessment, which assesses assumptions used in establishing the remaining service life, as well as on service life extension, which develops structural modifications to increase service life. ∎



ABOVE: Flight testing started in 1996 with the F/A-18E/F's first carrier landing in 1997

RIGHT: Progressive damage growth of F/A-18 inner wing-root step lap joint under tension-dominant fatigue spectrum

Dr Waruna Seneviratne currently serves as a technical director at the National Institute for Aviation Research (NIAR) at Wichita State University and is the lead scientist in the aircraft airworthiness and sustainment research program

Canadian unique

The Canadian Armed Forces and Boeing have formed a test team that will validate new capabilities in the latest Chinook, the CH-147F

BY FRANK COLUCCI

Boeing's Vertical Lift division last year celebrated 50 years since the first CH-47 Chinook was delivered to the US Army. Now the Canadian Department of National Defense (DND) and Boeing have a combined test force conducting developmental test and evaluation (DT&E) on a largely new Chinook, the CH-147F.

With an integrated cockpit, Digital Automatic Flight Control System (DAFCS), and structurally tuned airframe, Canada's 'fat tank' CH-147F builds on the CH-47F cargo and MH-47G special operations helicopters in service with the US Army. "Our DT&E is heavily weighted toward those systems that are Canadian-unique," explains Medium-to-Heavy Lift Helicopter (MHLH) project systems engineering manager Lieutenant Colonel Andrew Fleming. "The certification and verification approach that has been used for the aircraft has been to grant the maximum credit possible to previously completed work. The aircraft in itself is as much as possible a basic Chinook."

Despite the Chinook heritage and after-action reports from the US Army, the CH-147, with unique Canadian electrical system, integrated Aircraft Survivability Equipment (ASE), and refinements in the Rockwell Collins Common Avionics Architecture System (CAAS), requires testing throughout the flight envelope. "It is envelope validation rather than expansion," explains Lt Col Fleming. "What we're doing is validating the envelope where systems have not been validated on the aircraft."

JOINED-UP THINKING

The MHLH Combined Test Force pools resources from two diverse organizations. The Aerospace Engineering Test Establishment, based at Cold Lake, Alberta, is the exclusive fixed- and rotary-wing flight test agency for the Canadian Armed Forces, and includes crew systems, avionics and other specialties. "It in effect knits together all the test activities in the Canadian Forces," notes Lt Col Fleming. "What you see is the test teams needed to conduct CH-147F developmental and engineering test and evaluation, formed from personnel within the rotary-wing test flight. We do tend to pull folks from different test flights and use them on a program. It's not unusual for fixed-wing personnel to work on rotary-wing projects should they have the required expertise."

Boeing Test & Evaluation (BT&E) in Seattle, Washington, is the centrally managed test and evaluation organization of the Boeing Company. It has laboratory and flight operations across the USA supporting rotary-wing and fixed-wing programs both military and commercial, including the new Chinook and 747-8. In 2012 Boeing began consolidating Chinook, Apache and other developmental flight testing at its Rotorcraft Center of Excellence in Mesa, Arizona. CH-47 production flight testing remains based at the factory in Philadelphia, Pennsylvania.

The Canadian MHLH program was the first to tie managers and testers in Philadelphia to pilots, flight test engineers, and instrumentation and telemetry technicians in Mesa. "The flight test 2,000 miles away was as flawless as what was going on in the factory," observes Boeing head test pilot Jeff Bender in Philadelphia. Also significant, the CH-147F test program is holding to a contract schedule devised in 2009. "That speaks volumes to the quality of the software and the efficiency and quality of the program led by BT&E and the Combined Test Force team," says Bender.

As of May 2013, two instrumented CH-147Fs, one for envelope verification and the other for environmental and systems testing, had logged about 200 flight hours at Boeing Philadelphia, Boeing Mesa and the Patuxent River Naval Air Warfare Center in Maryland. "Thus far those are the only two used for DT&E," says Lt Col Fleming. "It's conceivable another aircraft may be used in the future." The first two aircraft underwent limited acceptance testing in Philadelphia before ferrying to Arizona. Electromagnetic compatibility testing was conducted to DND requirements at Philadelphia and Patuxent River. CH-147F environmental testing began in the USA and will continue at the Canadian Forces Flight Test Center at Cold Lake. The MHLH program is evaluating a requirement for new Chinook icing tests.

The third CH-147F is the first delivered to Canada, arriving at Canadian Forces Base Petawawa, Ontario, at the end of June. Plans call for 450 Tactical Helicopter Squadron to achieve Initial Operational Capability (IOC) with the MHLH in July 2014, and deliveries to Canada will continue at about one aircraft per month to fill out the 15-strong MHLH fleet.

DIFFERENT CHINOOKS

Canada first operated CH-147s from 1974 to 1991 but sold its seven Super C model Chinooks to the Netherlands in 1993. Boeing converted those aircraft to CH-47Ds with a four-screen Honeywell Avionics/Advanced Cockpit Management System, coupled flight director/autopilot, Honeywell 55-L-714A engines, composite rotor blades and other enhancements. Thirteen years later Canada announced plans to buy new MHLH aircraft based on the current production CH-47F, specifically to take Canadian troops off ambush-ready Afghan roads and resupply them at high-density altitudes. As an interim step, Canada bought six CH-47Ds from the US Army for the Canadian Helicopter Force Afghanistan, part of the Joint Task Force Afghanistan Air Wing.

Canadian helicopter crews and maintainers were initially qualified in the analog CH-147D by the US Army at Fort Indiantown Gap, Pennsylvania; Fort Rucker, Alabama; and at Boeing Philadelphia. Operational training simulating the dusty Afghan environment was carried out by the US Army National Guard in snowy New York state. The interim Chinooks were never certified to operate in Canada and went straight to war in Kandahar and Helmand provinces. From December 2008 to July 2011 they flew nearly 7,100 hours and hauled more than 90,000 passengers and 3,000 tons of cargo. Two were lost – one shot down by enemy forces and the other in a night landing mishap. The survivors now serve as non-flying trainers.

LATEST MODEL

The more capable CH-147F gives Canada the extended range fuel system initially developed for Boeing's commercial Model 234 Chinook, the Rockwell Collins digital cockpit common to the current MH-47G and CH-47F, and a new, machined airframe stiffened to reduce vibration. (See *Test Pilot at War, Aerospace Testing International*, September 2009.)

The big, crash-resistant composite sponsons on the CH-147F double the fuel capacity of the CH-147D from 1,078 to 2,060 US gallons. They are nevertheless the first Chinook 'fat tanks' hung on a new, stiffened airframe – air-refuelable Special Operations MH-47Gs delivered so far have been rebuilt from CH-47Ds, themselves remanufactured from earlier Chinooks. 'Renewed' Chinooks have local stiffening and repairs throughout their structures. BT&E instrumented the CH-147F airframe, the new Honeywell Auxiliary Power Unit adapted from the Black Hawk, and select systems on the two MHLH test aircraft in Philadelphia.

The first CH-147F – T1 – made its successful first flight on June 24, 2012, followed by the second test helicopter three months later. The Combined Test Force uses mixed customer-contractor crews. The two resident Canadian test pilots are alumni of the Aerospace Engineering Test Establishment training program. Canadian technicians, loadmasters and flight engineers started Chinook training at Boeing Philadelphia in February 2013, and plans call for about 45 trained maintainers and aircrew ready for the first Chinook in Canada. CAE is also under contract to provide flight simulators and other training facilities.

"IN EFFECT, IT'S JUST-IN-TIME TESTING. WE'RE SHOOTING FOR IOC A YEAR OR SO FROM NOW"

EVOLVING CHINOOKS

Changes tested on the Canadian CH-147F will be available to the US Army and other Chinook users.

The CH-47F continues in production to revitalize the US Army cargo helicopter fleet and win foreign military sales. By the end of 2012, the US Army had received 220 CH-47Fs and 61 MH-47Gs – a mix of all-new aircraft and remanufactured helicopters with renewed CH-47D dynamics – against planned totals of 464 cargo CH-47Fs and 69 special operations MH-47Gs. F-model Chinooks have been delivered to the United Arab Emirates, and the US Army has signed CH-47F Letters of Agreement with Australia and Turkey. The first of 14 new Chinook HC.4s for the UK with the Thales Julius integrated cockpit is near delivery.

Chinook improvements are already being incorporated in US Army aircraft. The Cargo On and Off Load Systems (COOLS) has been deployed on aircraft in Afghanistan. CH-47Fs built under the second multi-year contract will incorporate COOLS and other engineering change proposals, including health and usage monitoring systems and maintainability changes. The US Army 160th Special Operations Aviation Regiment is due to receive eight new-build MH-47G aircraft, leveraging improvements developed for the US Army CH-47F and Canadian CH-147F.

The US Army Training and Doctrine Command is meanwhile formulating requirements for a CH-47F Block II improvement plan to be implemented after the final CH-47F delivery. The notional Future Chinook 2020 effort may introduce an Advanced Chinook Rotor Blade (ACRB) that is predicted to provide 1,900 lb more lift and boost performance at high-density altitudes. The ACRB should begin flight testing in fiscal year 2015 for production FY2016. New engines may provide 15% more power with better specific fuel consumption than the current T55-GA-714A. The Canadian-inspired electrical system is already of interest to the US Army, and other systems improvements are expected to further enhance safety in degraded visual environments.

ABOVE: **The first Canadian CH-147F flew at the Boeing Philadelphia plant on June 24, 2012. The aircraft was ferried to Boeing Mesa after preliminary acceptance testing (Photo: Boeing)**

TOP RIGHT: **The Canadian Forces D-model Chinooks flew from Kandahar in Afghanistan (Photo: Canada DND)**

RIGHT: **The Common Avionics Architecture System (CAAS) in US Army CH-47Fs and MH-47Gs underwent hardware and software changes for the Canadian CH-147F**

The CH-47D and CH-47F are qualified to 50,000 lb gross weight. With an unrefueled range of 600 nautical miles and a gross weight cleared to 54,000 lb, the MHLH dramatically enhances the ability of Canadian forces to deploy domestically and abroad. Flight testing for the Canadian CH-147F so far has been modeled on that of earlier Chinooks. "The handling qualities we used were the ADS-33 testing standards," notes test pilot Bender. "They picked items off the standardized shopping list."

CANADIAN UNIQUE

For all the commonality with previous Chinooks, the MHLH program introduces powerful changes in mission systems, including the Common Avionics Architecture System (CAAS) flying in US Army CH-47Fs and MH-47Gs. Systems Integration Laboratories at Rockwell Collins and Boeing test CH-147F hardware and software changes. Like the CAAS in US Army cockpits, the five 6 x 8in multifunction displays show CH-147F pilots and co-pilots primary flight symbology, graphical mission and systems information, and mission management functions. Air defense threats appear on color digital maps, and weather radar and electro-optical images can be mixed with flight symbology on split-screen displays. The CH-147F has provisions for a weather radar not currently in MHLH plans, but the aircraft will be equipped with the L-3 Wescam MX-15 electro-optical gimbal.

Canada specified changes in some CAAS display pages. CH-147F test pilot Major Bryan Carrothers explains, "We tweaked the pilot-vehicle interface slightly to improve it, simplify some aspects, and make some of the information important to Canada more accessible in flight." The BAE Systems Digital Automatic Flight Control System (DAFCS) on the current Chinook has multiple modes, including automatic hover functions for safer landings in brownout conditions. The CH-147F 'displays' show pilots a new summary of DAFCS modes. "Pilot awareness of what the aircraft is doing is very important," says Maj Carrothers. "If it augments its mode of flight, it's very important that the pilot knows what mode." DAFCS provides automatic hover stabilization functions for safer landings in degraded visual environments, and the CH-147F CAAS will show new hover displays based on work done by NASA and Boeing.

AVIONICS UPDATE

Canada equipped the newest Chinook with four multiband radios. Bender notes: "They modified a mission page to enable different access to communication and to give navigation information – lists of radios available and frequencies." A new communications summary page can also be called up on the center MFD. CAAS pages also control and display the advanced CH-147F integrated aircraft survivability suite. The Canadian Chinook has a Terma ALQ-213(V) electronic warfare management system integrating Northrop Grumman APR-39 radar and UTC AVR-2B laser warning receivers, Northrop Grumman AAR-54 missile warning receivers, the Northrop Grumman AAQ-24(V) laser-based Directional Infrared Countermeasure (DIRCM) and BAE ALE-47 countermeasures dispensers. Terma previously developed the Chinook ASE (CHASE) sponson pods deployed on Dutch CH-47Ds.

New CH-147F mission and survivability equipment required increased electrical power from three 60kVA generators. "Whenever you put a new electrical system on the aircraft, it's a big deal," observes Bender. The electrical system upgrade in turn led Boeing to re-examine the data concentrator units (DCUs) that link the CAAS cockpit to systems throughout the aircraft. The two DCUs in the CH-47F system gave way to four new Curtiss-Wright DCUs providing more redundancy and input/output capacity.

The CH-147F test program is based on integrated testing and segregated evaluation. The Land Aviation Test and Evaluation Flight of 403 (Helicopter) Operational Training Squadron under 1 Canadian Air Division is responsible for Operational Test and Evaluation (OT&E) for all Canadian tactical aircraft. Aircrew assigned to the test flight are designated operational aircrew with specific OT&E training. Both the Aerospace Engineering Test Establishment and the Land Aviation Test and Evaluation Flight work with Canadian forces, and the DND has access to a variety of instrumented ranges.

All the CH-147F OT&E will be to support IOC. "We don't have a fixed timeline per se," says Lt Col Fleming. "In effect, it's just-in-time testing. We're shooting for IOC a year or so from now. Potentially we've got another three years of OT&E after the IOC date," he continues. "It's deliberately phased and sequenced." ▮

Frank Colucci is a freelance helicopter expert and writer for Aerospace Testing International

ARINC818 AT A GLANCE

The ARINC818 specification defines a digital video link that is used for uncompressed video data transmission

The ARINC818 specification enables avionics display manufacturers to choose the video format that best suits their application. Video formats can differ in their frame rates, resolution, pixel density, and interlacing techniques that drive the required data rates.

Different classes of video transmission are defined, varying from simple asynchronous to pixel synchronous video transmission, which require corresponding display capabilities. With ARINC818, the large contiguous video frame data is mapped onto a fiber channel (FC) connection. Each picture equates to one ADVB (Avionics Digital Video Bus) container, which is transmitted within one FC sequence. For example, an XGA resolution video has a picture size of 1024x768 pixels, which means one line has 1,024 pixels, and the picture has 768 lines. Each pixel needs 3 bytes for color information, so one line has an overall size of 3,072 bytes. This exceeds the maximum payload size of a single FC frame, hence it is split into two frames each with 1,536 bytes, carrying half a line each.

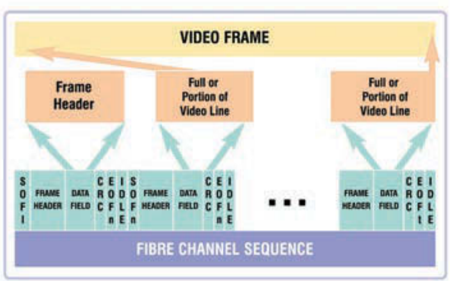
The complete picture data will be sent within 1,536 FC frames, called the Object2, with an additional ADVB header frame, called the Object0. These frames are all packed with one FC sequence. Each full picture is therefore a single FC sequence, as shown in the diagram below right.

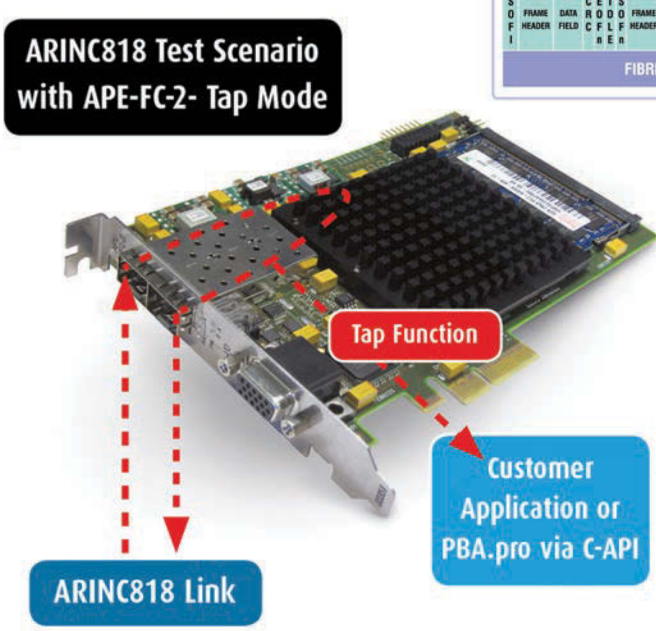
RECEIVING INFORMATION

Receiving picture information is quite similar. All necessary information for reassembly of the picture data is contained within the leading Object0 frame, and within the FC header of each Object2 frame. The receiver has to check each incoming frame for its position within the picture (based on a sequence number) and, of course, for errors during the transmission.

Placing all the FC payload data of the Object2 frames of one sequence in the right order will reassemble the picture. Beside the known APE-FC-2 Fiber Channel Layer 2 capabilities, which provide a comprehensive set of test and analysis possibilities, the APE-FC-2 now offers full-function ARINC818 analyzer capabilities. These currently allow the user to handle ARINC818 traffic over FC with a maximum of 1GFC. That would basically allow the periodic transmission of 1024x768 pixel resolution with 24bit color depth and a 40Hz refresh rate.

With the successor hardware APS-FC-2, available later in 2013, data rates of up to 4GFC will be possible, with software compatibility with the APE-FC-2. The Application Programming Interface (API) offers transmitter side functions to load single-picture data or picture sequences and send them over FC to drive ARINC818-capable devices/display in real time. For example, a single picture can be sent periodically with a software-configurable refresh rate, or simply acyclic (for example, on application request). The same is also applicable for picture sequences, which can be sent in a single shot or repetitive mode. In all modes it is possible to change or reload picture data during operation 'on the fly' while the board maintains picture data integrity and the configured refresh rates on the ARINC818 link accordingly. Import of picture data, for example in Windows BMP/DIB format, for transmission is also supported by the API, which also does the translation into the corresponding ARINC818 Object0/Object2 format, required for transmission over FC.





ARINC DATA

Application notification provisions, such as call backs, are also offered to provide maximum flexibility for customer applications. Different modes on the receiver side of the APE-FC-2 API offer great flexibility for analyzing incoming ARINC data on Upper Layer Protocol (ULP) level as well as on Layer 2 level. Different API helper functions support and simplify the programming effort, for example by the translation of chronologically captured FC-2 frames with full timestamp and meta information that represent the ARINC818 Object0s and Object2s into one or more visible pictures, such as in Windows BMP/DIB format.

Furthermore, a receive mode for getting the latest received picture is offered. A unique feature of the APE-FC-2 interface is the 'Tap' mode, which allows one to 'insert' the interface into an existing connection, for example between a generator and a display, in order to tap out ARINC818 data for monitoring, analysis and display purposes.

The PBA.pro will also support the ARINC818 modes of the APE-FC-2 via the ARINC818 ULP option for the PBA. pro-FC-2 resource component, taking advantage of all PBA.pro functions such as scripting and customized GUIs. The known scalability of the PBA.pro offers provisions for 'pure' ARINC818-based test, simulation and analysis solutions (including all FC Layer 2 capabilities) up to heterogeneous avionics databus test systems with a seamless integrated ARINC818 functionality. ∎

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LEAN THINKING TRANSFORMATION

Innovative aerospace electronics company Fokker Elmo has developed a global leadership in wire harness technology

In 1908 Anthony Fokker's imagination soared with the news of Wilbur Wright's exhibition flights in France. Two years later the aspiring Dutch aviator's father sent him to train as a mechanic for the growing automotive industry. But his passion was flying. That same year the 20-year-old Fokker built his first aircraft, 'de Spin' – the Spider.

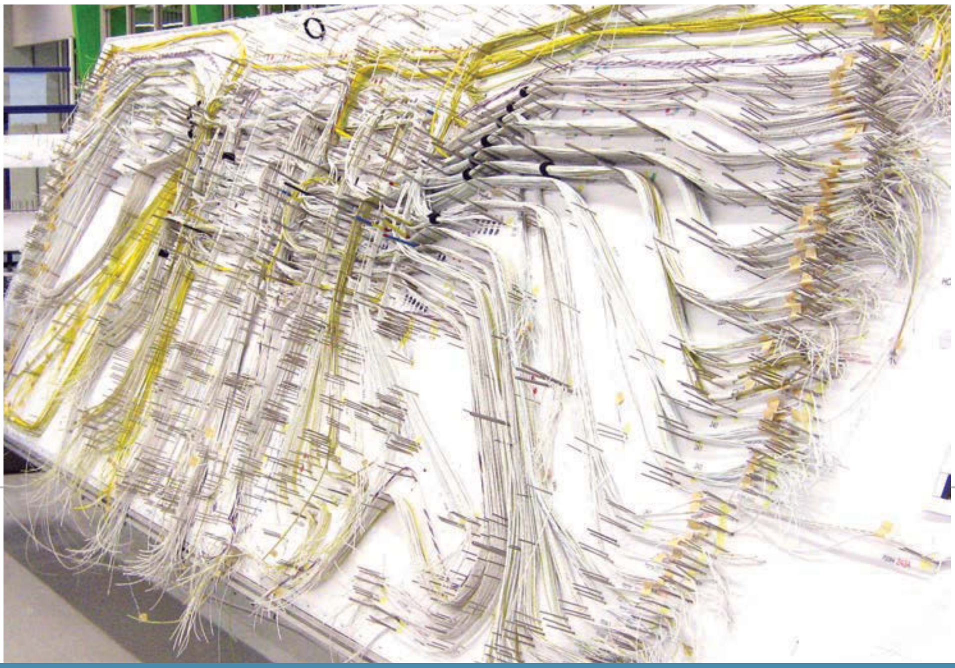
Today Fokker Technologies specializes in manufacturing for other global aviation and aerospace companies. Its Elmo division, based in the Netherlands, has developed a singular expertise in electrical interconnection systems for aircraft and aircraft engines. Fokker Elmo facilities in Holland, Turkey and China build wire harnesses and assemblies for companies throughout the world including Lockheed Martin (JSF), Airbus (A320, A400 and A380), Bombardier (CSeries) and Boeing (737 and 777) among others.

The company's Wiring Design and Manufacturing System (WDMS) is a highly efficient manufacturing software tool and process that greatly reduces overall costs, captures the design, and converts the information for all aspects of the production process. WDMS safeguards the configuration of the aircraft wiring and enables online change capabilities.

Bombardier, Canada, employs Fokker Elmo's range of services. "We are responsible for the design and production of the entire wiring and interconnection system for Bombardier's CSeries civilian aircraft, from start to finish," says Fokker Elmo manufacturing engineer Rinie van Gorsel. The company provides integrated design, manufacturing and a customer support package that includes several electrical panels. In addition, the company is designing and producing all flight test and instrumentation wiring required during the certification of the CSeries. It also handles all modifications before the aircraft is put into service. According to van Gorsel, "Fokker Elmo delivered the complete wiring system for the first CSeries flight test vehicle (FTV1) including all the flight test instrumentation, which was installed first time right and successfully enabled a 'Full Power On'."

The higher-volume production demands of Airbus and Boeing have been ideal for transforming much of the fabrication from centralized electrical testing to a model of lean production. DIT-MCO International, a supplier to Fokker Elmo for electrical testing, assisted in the transformation at the company facility in Langfang, China.

Fokker has long used a centralized test bench with a large DIT-MCO test system configured with 9,600 test points. This test bench, which incorporates the test interface directly above the work surface, provides greater flexibility by accommodating many different harness designs.



"There is still a need for a large test bench, but few assemblies require more than 1,500 test points, and most less than 1,000 points," says van Gorsel. The centralized process that was well suited to lower volumes had created such a bottleneck for higher volume runs that the plant operated two testing shifts to keep up with one shift of manufacturing.

There is no movement of the materials until the harness is completely finished, a basic lean principle that also minimizes handling damage. "From start to finish, one technician can build, test, fix and complete the process without moving the product around," says van Gorsel. Throughput is faster than before, there is less work-in-process, products spend less time in 'build' stages, and lead time has decreased.

Fokker Elmo's facility in Izmir, Turkey, is producing the JSF program. "We provide everything for the JSF, from test programs, which are developed in Holland, to fabrication and testing with DIT-MCO in Turkey," says van Gorsel. The company ships finished harnesses to other international locations doing full aircraft assembly and testing.

Initially, Turkey used a low-volume approach with standard centralized testing and the large DIT-MCO Model 2650. As production increased and more programs were added, Fokker Elmo Turkey moved to lean processes with small distributed test systems based on DIT-MCO's 2115 tester in the manufacturing cell, modeled on the plant in China. Fokker Elmo's operation in the Netherlands is home to extensive fabrication of aircraft and jet engine harnesses for civilian and military aircraft. It is also the heart of everything that happens before production at any Fokker Elmo operation.

DIT-MCO engineers developed a special interface to help transition the testing process in China from the centralized tester to the Model 2115 in the flow-shop environment. The interface, designed to accommodate existing test adapters, is interchangeable and supports existing data-generation processes. ∎

ABOVE LEFT/LEFT: **Visual inspection of each termination verifies the correct components and markings. Fokker designs form boards used to assemble the wire harnesses**

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TORQUING TURBOS

Integrated driveline solutions for helicopter turboshaft engine trials

The testing of modern helicopter turboshaft engines occurs across a wide spectrum, from initial and ongoing engine development, to production pass-off by the OEM through maintenance, repair and overhaul by both military and civil operators. Helicopter turbines generally have either a relatively low output speed, typically 6-8,000rpm, or a high speed of around 15-25,000rpm. In all cases, power absorption is by means of a dynamometer and, increasingly, to allow for full transient testing, via a high-inertia flywheel to simulate the aircraft's rotor.

The most common type of dyno is a water brake, but opinion is divided between the merits of having a reduction gearbox and a more reliable low-speed unit, or a direct-drive high-speed brake. Recently, consideration has also been given to electric dynos, which recover the otherwise wasted energy from the turbine and avoid the complexity of a water-cooling plant, and might to some degree allow inertia simulation. Another solution is the Varoc air dyno – used extensively by the US Navy and Army – which can readily be used outdoors, without external services, even at military theater level.

The most important requirement of helicopter turbines is an accurate measurement of torque – and therefore power. While dynos measure torque as casing reaction torque, having an in-line torquemeter between the engine and dyno greatly improves the accuracy, typically to 0.1%, and is essential if there is a gearbox and/or a flywheel in the driveline, not only to eliminate the uncertainty of the losses, but also for accurate measurement of torque during transient engine-handling tests.

UK-based Torquemeters has become established as a preferred supplier of high- and low-speed torquemeters for the testbeds that test many of the world's most popular turbo shaft engines, including GE's CT7/T700 and the new 7,500hp GE38; PWC's PT 6 and 210 families; and Turbomeca's Arriel, Makila and RTM322 engines.

Torquemeters' Torquetronic range of products use the phase-shift principle with no shaft-borne electronics, which gives them almost unlimited speed capability, very high accuracy and credibility, and a service life of more than 30 years.

ENGINE TO TESTBED

On high-speed turboshaft test benches, a critical factor is the mechanical interfacing of the engine to the testbed. This requires an integrated, rather than piecemeal, design solution, covering the high-speed coupling. This needs to respect the engine's coupling mass limits, and be sufficiently long to enable good access and efficient engine docking while respecting the space and mounting constraints of the engine's inlet or exhaust, and often the torque tube/gimbal support of the engine.

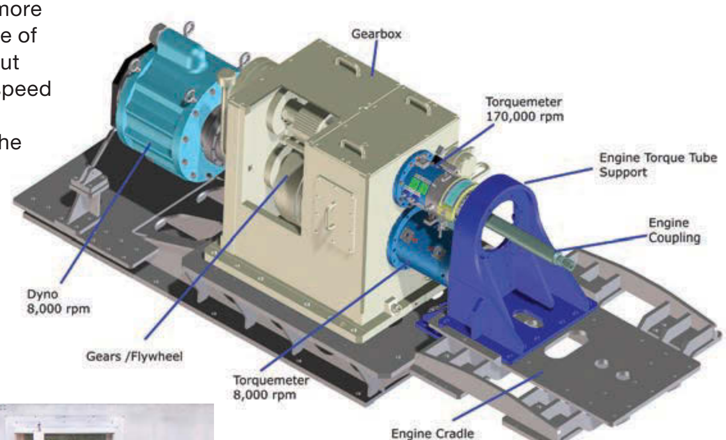
Working closely with engine manufacturers and also leading test cell system integrators, Torquemeters provides more than 30 years' experience of not only torquemeters, but also the complete high-speed transmission connecting them to the engine and the dyno interfaces.

For high-speed applications for helicopter engine and gearbox testing, rotor-dynamic considerations favor pedestal units coupled with very light Tordisc diaphragm or disc pack couplings. For low-speed applications, the torquemeter can alternatively be suspended between the engine and the dyno.

CASE STUDY

A recent example of Torquemeters' capability is the supply of a unique combined gearbox/flywheel unit, which has a case-mounted water dyno on the low-speed output shaft and flange mounted high- and low-speed torquemeters on the input side. These are suited to the speeds of low- and high-speed versions of the same engine type, making for a very compact driveline, with no need for time-consuming alignment and the sharing of a common oil system.

Torquemeters' experience in mechanical design, analysis and in-house precision manufacturing enables the company to supply high-speed test equipment, from standalone torquemeters to complete turnkey test stands. ∎



ABOVE: Dual output shaft gearbox with integral flywheel

LEFT: Varoc air dyno testing a T58 engine

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TWO TECHNOLOGIES FOR BETTER DUAL SHAKER VIBRATION TESTING OF MISSILES

Dual-shaker testing can be used to achieve more force than is available with any single shaker, so a system has been developed that can now accurately control complicated multishaker tests

As factory acceptance tests finish up, production personnel at Data Physics are preparing to ship their third high-force dual-electrodynamic shaker system in three years. These systems were made for the US Navy and organizations in Australia and Turkey. The large dual-shaker vibration test systems include two high-force SignalForce shakers each in the 180kN to 222kN range, large head expanders and slip tables, and SignalStar Matrix multishaker vibration controllers.

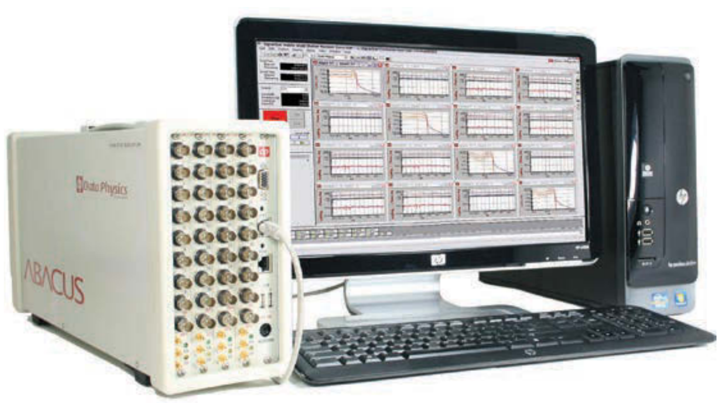
Dual-shaker testing can be used simply to achieve more force than is available with any single shaker. This configuration is also quite common when shock and vibration testing missiles or other large payloads that have a high slenderness ratio (a narrow cross section compared with length). In this case, a dual-shaker arrangement is a natural choice because the force is distributed more evenly and heavy head expanders are not needed.

An added benefit of dual shaker testing is the ability to use the shakers separately and independently. Once removed from the constraints of a large table or device under test, the shakers can be used to test small payloads to higher frequencies. This versatility of configuration gives users more options and capabilities than a single large shaker can deliver.

One of the traditional challenges with using two or more shakers for testing in a single degree of freedom is ensuring a good phase and amplitude match across all the shakers. Past solutions to this challenge include using a phase delay circuit between amplifiers to produce two signals of equal magnitude with a fixed or slowly changing phase delay. With the introduction of current multishaker control technology, the vibration controller can now correct for magnitude and phase dynamically. More importantly, the phase and magnitude of the force from each shaker is determined at each frequency. This real-time approach accounts not only for system phase delay, but also for the dynamic response in the test article, fixtures and tables. Force appropriation across the shakers brings a whole new dimension to help manage the dynamic response of the test system.

While multishaker testing using two or more shakers is not new, the great performance improvement from the multishaker controller is relatively new. Phase matching two or three shakers for collinear motion now is a task of the vibration controller rather than complicated fixtures and marginally effective electronic circuits. The SignalStar Matrix controller offers true multiple degree of freedom (MDOF) control for multiple exciters and is able to control complicated multishaker tests with real-time control for sine, random, shock and time replication test types.

Missile and missile canister vibration testing is a good example of a test where high-level distributed force combines with the need for high-precision vibration control. Other aerospace applications include satellite and spacecraft testing. SignalForce electrodynamic shakers and accessories, combined with SignalStar vibration controllers, provide the of reliability and precision that small and large multishaker aerospace applications demand. ∎



ABOVE: The SignalStar Matrix Vibration Controller is capable of single and multi-exciter control and is scalable to over a thousand channels

RIGHT: SignalForce 5022 Electrodynamic Shaker System configured with a monobase slip table

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180°C UNIVERSAL ACCELEROMETERS

The more than 100 types of accelerometer offered by Brüel & Kjær have a new star among their ranks with the introduction of a high-temperature, general-purpose triaxial CCLD unit.

The Type 4527 suits continuous use at 180°C and comes complete with a high-temperature cable that safely copes with temperatures up to 250°C without distortion. The high temperature capability allows mounting close to hot sources, while the solid, proven construction ensures longevity and durability for everyday use. With wide dynamic, frequency and temperature ranges, a very low noise floor, and low sensitivity to electromagnetic interference due to low output impedance, it is ideal for structural testing.

Using the same design and offering the same range specifications, a similar high temperature accelerometer greatly reduces setup time using TEDS technology. The new Type 4528-B automatically self-identifies to supply calibration and sensitivity data to the data-acquisition hardware. The Type 4528-B is rated up to 165°C for continuous use.

Both new units give the user the flexibility to select the number of axes they want to measure – three, two or just one – avoiding the confusion of unnecessary data and reducing the number of measurement channels.

A range of mounting options allows secure setup using an M3 stud, an adhesive pad or a clip mounting that ensures easy positioning.

Every unit shipped from Brüel & Kjær's Danish production facilities is tested in a high-temperature oven for 48 hours, ensuring complete reliability, and pre-aging the materials to keep their performance consistently stable.

FURTHER INFORMATION
Brüel & Kjær Sound & Vibration Measurement A/S
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or go to online enquiry card 105

ONE DEVICE ACCESS TO ETHERNET AND CAN

Company Vector is introducing the VN5610 device, a compact Ethernet/CAN interface with USB. Developers in the automotive and aerospace industries will benefit from simultaneous access to CAN networks and Ethernet-based systems such as BroadR-Reach and AFDX with just one interface. The new hardware can be used in tasks ranging from remaining bus simulations to Ethernet monitoring and synchronization of Ethernet frames with other bus systems such as CAN. In particular, developers will benefit from highly precise time stamps with a common time base for synchronizing the various systems.

The VN5610 bus interface has two separate channels for Ethernet and CAN, which enables simultaneous operation of a remaining bus simulation with the CANoe.IP or CANalyzer.IP Vector tools. While two high-speed CAN channels are available in the CAN section, the Ethernet section supports BroadR-Reach and standard Ethernet IEEE 802.3 (100BASE-TX or 1000BASE-T). The advantage here is that the user can connect existing standard Ethernet loggers and accessories when the interface is used as an Ethernet media converter.

In what is known as Ethernet monitoring, the interface offers a transparent connection (in/out/monitor) between two nodes with precise time stamps.

In the interplay of the new VN5610 with the Vector tools CANoe.AFDX and CANalyzer.AFDX, it is now possible to access the Ethernet-based AFDX protocol that is widely used in the aerospace industry.

The new interface can also readily handle the new CAN FD standard with its reconfigurable FPGA hardware architecture, and rounds out the VN5610 product range.

FURTHER INFORMATION
Web: www.vector.com/vn5610
or go to online enquiry card 106

LATEST DUAL-BRIDGE STRAIN-GAUGE LOAD CELLS

PCB Piezotronics is launching a new product line of dual-bridge, fatigue-rated, strain-gauge load cells specifically for airframe structural, lifetime and fatigue testing applications on wings, fuselage, landing gear, iron bird and other airframe components.

PCB Series 1400 includes a dual-output feature that offers sensor redundancy and the ability to provide control feedback from one bridge while the other is used for data acquisition.

These load cells are available in multiple ranges and have an A2LA accredited calibration to ISO 17025 in both tension and compression directions and include thermal compensation.

An additional feature – moment compensation – helps to maintain accurate output from the sensor in the presence of the eccentric loading and side loads often experienced during high-cycling load testing. A single shunt calibration resistor is provided with each load cell for ease of calibration at the test site.

PCB dual-bridge, fatigue-rated, strain-gauge load cells are available with standard capacities ranging from 5000 lb to 100,000 lb (22kN to 445kN) with combined accuracies from <0.04 % to <0.06% – using the best fit (least squares) method – for linearity, hysteresis and non-repeatability. Many other ranges are available and these fatigue-rated load cells are guaranteed for 100 million fully reversed cycles.

In addition to dual-bridge load cells for airframe structural test, PCB Piezotronics produces load cells including low-profile, rod-end and S-beams for applications such as weighing, material testing, press monitoring, process automation, rocket thrust, component testing and flight-control durability.

FURTHER INFORMATION
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STANDS FOR ACTUATORS

The reduction of turnaround times will have a major impact on the MRO community in 2013-2014. Reducing setup and test times is a very important factor in economizing. Delivering value for money must not be neglected, however, so the reducing of turnaround times must be accomplished without cutting the quality of maintenance.

Test-Fuchs, the global expert in innovative test solutions, has launched new test stands for electrical, linear and rotating actuators. These solutions focus not only on test precision, but also on usability and quick handling. The customer requirement for extremely high precision in measurement is always the Test-Fuchs focus, but these new solutions ensure that the units under test use the very latest technologies as well as including strategies to reduce cost.

Test-Fuchs therefore designed a method to mount the units to be tested without any tools or time-consuming screwing, using a number of modular adaptors to fix the units easy and quickly. Access to the test chambers has been made very easy, and a perfect concept of transparent test chambers enables the user to control what is going on at any time.

Safety doors with polycarbonate sheets protect the user and are also interlocked and observed via the software, providing a maximum of safety for the personnel.

The test stands work with extremely user-friendly software and allow fully automatic test programs as well as manual test sequences, always providing test reports automatically. The software also integrates user administration and a calibration tool. For optimum flexibility for the user, the test stands are operated via extra large touchscreen panels on extractable swivel arms. Mounting and testing has never been so easy.

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ELECTROSERVICES COMPANY ACQUIRES MICRO MOVEMENTS

On January 11, 2013, Electroservices Enterprises of Telford announced that the full acquisition of the shares of ADS and Micro Movements had been completed.

Simon Plant, managing director commented, "The Electroservices Directors feel this diversification through the purchase of ADS and Micro Movements gives the company an excellent opportunity to increase growth within the aerospace industry particularly, while utilizing our excellent skill base across overlapping fields of engineering."

Micro Movements has a worldwide reputation for its expertise in data acquisition, signal conditioning, recording and analysis products and their application. It has instrumented, measured, recorded and analyzed results for its customers on projects from large structures such as bridges and power pylons through to airframes and jet engines, in addition to many automotive tests. The company has distribution outlets in Europe, the Far East and the USA.

For over 40 years Micro Movements has supplied signal conditioning and recording systems to a wide range of industries. Recently the company designed, developed and manufactured complete test stands.

FURTHER INFORMATION

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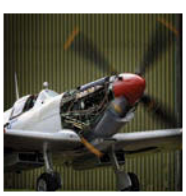
Fire burns bright

Squadron Leader Duncan Mason, OC Royal Air Force Battle of Britain Memorial Flight, talks to *Aerospace Testing* about the unit's fighter air test procedure

In October 2012, Squadron Leader Ian 'Smithy' Smith, outgoing officer commanding, flew the Royal Air Force Battle of Britain Memorial Flight's 'new' Supermarine Spitfire Mk XVI, TE311, for the first time in almost 60 years. A couple of undercarriage issues aside, he described the air tests as following standard procedure for any BBMF fighter – Spitfire or Hawker Hurricane.

So how is an air test on a 60- or 70-year-old fighter approached? Squadron Leader Duncan 'Dunc' Mason, who now commands the BBMF, explains the air test schedule: "First the airplanes have to perform high-power engine runs and jump through a few other hoops on the ground. I like to get involved in these if I can, because ground runs give you a sense of confidence in the airplane and engine. You can sit in an aircraft and take things in, but it's only when it's running that you can take in the smells, sounds and extra-sensory stuff that goes on at high power."



FIRST TAKE-OFF

"Before an air test, the engine is run to high power against the chocks, while temperatures and pressures, including brake pressure, are assessed. Correct brake pressure is no guarantee of brake effectiveness, however, and with differential braking vital for taxiing, an early brake test is crucial.

"If the engine rpm, temperatures and pressures aren't where you expect them on taxi or during the take-off run, you aren't going to fly. TE is very smooth and 'the needles' are rock steady, but on some of the earlier Spitfires there's far more gauge variation and it's working out whether that's something to do with the engine – you can feel it and hear it in terms of engine pitch variation – or the gauge; a gauge may be wandering around by 200rpm, but there's no change in the engine.

"Once you're airborne, the first thing that can go wrong is the gear. With the Spitfire, the worst case is if one leg comes up and the other doesn't. They're not too bad to put down on their bellies, but one up and one down is a very dangerous situation.

"After a major service the airplanes often have new or modified ailerons and trim can be quite significantly out. If it is, we go around and land. Then our 'tin bashers' use a big mallet and a piece of wood, beating the aileron to produce more or less lift. It's done engine running. You come round, they batter it until they're happy, and off you go again. If you're happy, great; if not, you come back and they batter it again."

TIMED CLIMB

With the gear up, power is set for a timed climb to 7,000ft in 4.5 minutes. There is a small margin for variation, but Dunc says that now he gains a real feel for how well the engine is working: "During the climb you test your squawk (IFF) and check that the ASI, altimeter and other instruments are working sensibly. The first thing you do at 7,000ft is stall the airplane and make sure the stalling characteristics are as you expect. In a Spitfire they're very benign, but a Hurricane will tuck a wing under pretty quickly and the stall can be quite dramatic. Then it's undercarriage and flap checks, generally three seconds for extension and four seconds on the way up for the gear, and checking for asymmetry in the flaps.

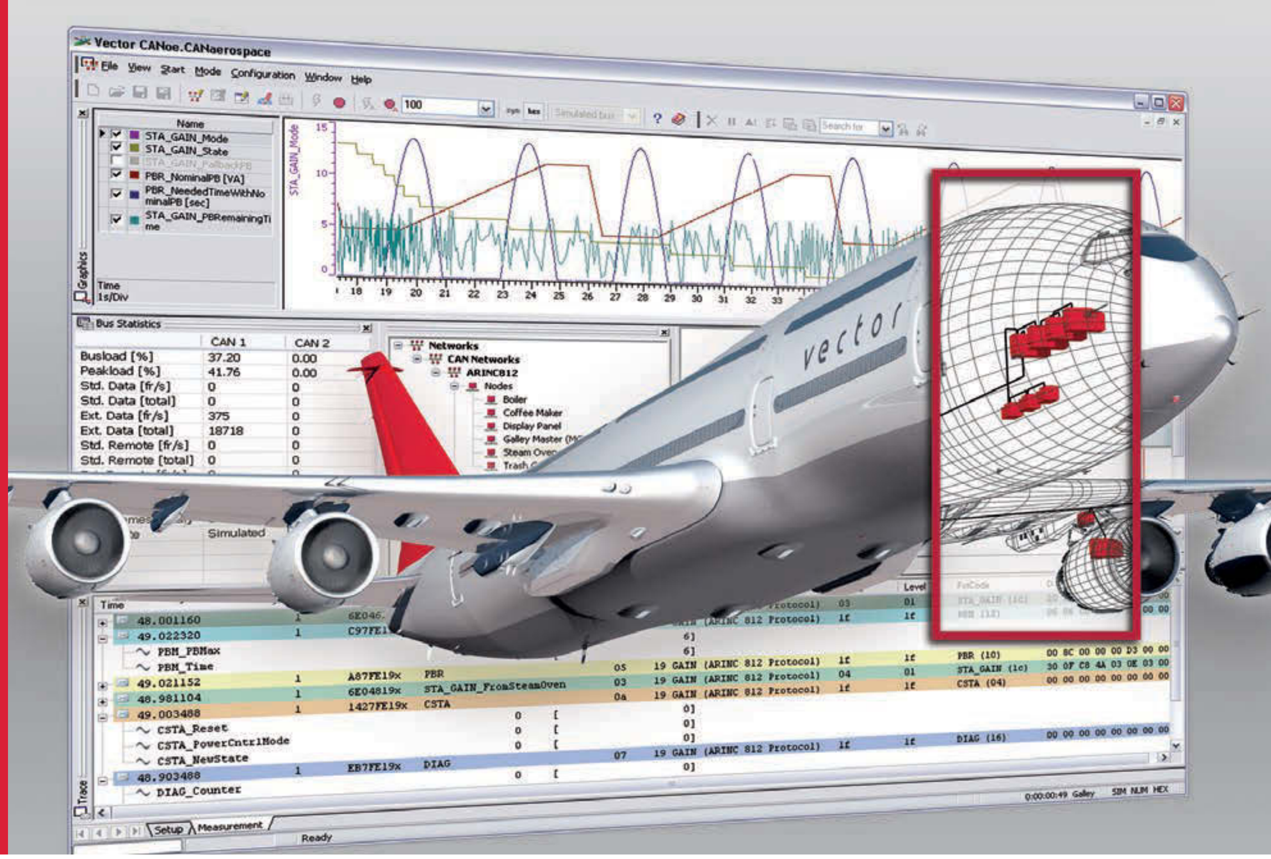
"Cruise and high-power figures are checked next, running the engine at cruise settings for five minutes before taking temperature and pressure readings. Then go to the maximum power and boost that we operate to and record data again. A handling check follows, using display maneuvers and looking for anything unusual with the engine. A high-speed dive from 7,000 to 1,000ft allows the engine's automatic controls to be checked.

"If all's well," concludes Dunc, "a further brake check on taxiing-in is usually carried out, as well as checking that all the pieces that were there when you taxied out are still there after you land. It's essentially a very simple air test for a pretty simple airplane."

SPITFIRE TE311

Spitfire TE311 is a low-back/bubble-canopy Mk XVI with 'clipped' wingtips. Some 58 years after it last flew, TE311 flew again in 2012, having undergone a rebuild to flying condition by BBMF technicians, which started in October 2001.

TE311 was taken on charge by the Air Ministry a month after the war ended and was placed in storage. From October 1945 to February 1946, it was flown by the Handling Squadron of the Empire Central Flying School. TE311 was transferred to non-effective stock in 1954. Subsequently the aircraft was a 'gate guardian' at Tangmere for 12 years and then, for 30 years, used as a static display at airshows.



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