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AEROSPACE TESTING INTERNATIONAL

SEPTEMBER 2011

Bird's eye view

An exclusive tour of the CATBird, the highly modified Boeing 737 avionics testbed for the F-35

Entry level

It's been a long haul but the Boeing 787 is now entering service with Japanese airline ANA

The Iron Bird

Advanced simulation, a fresh approach, and new technology for the A350

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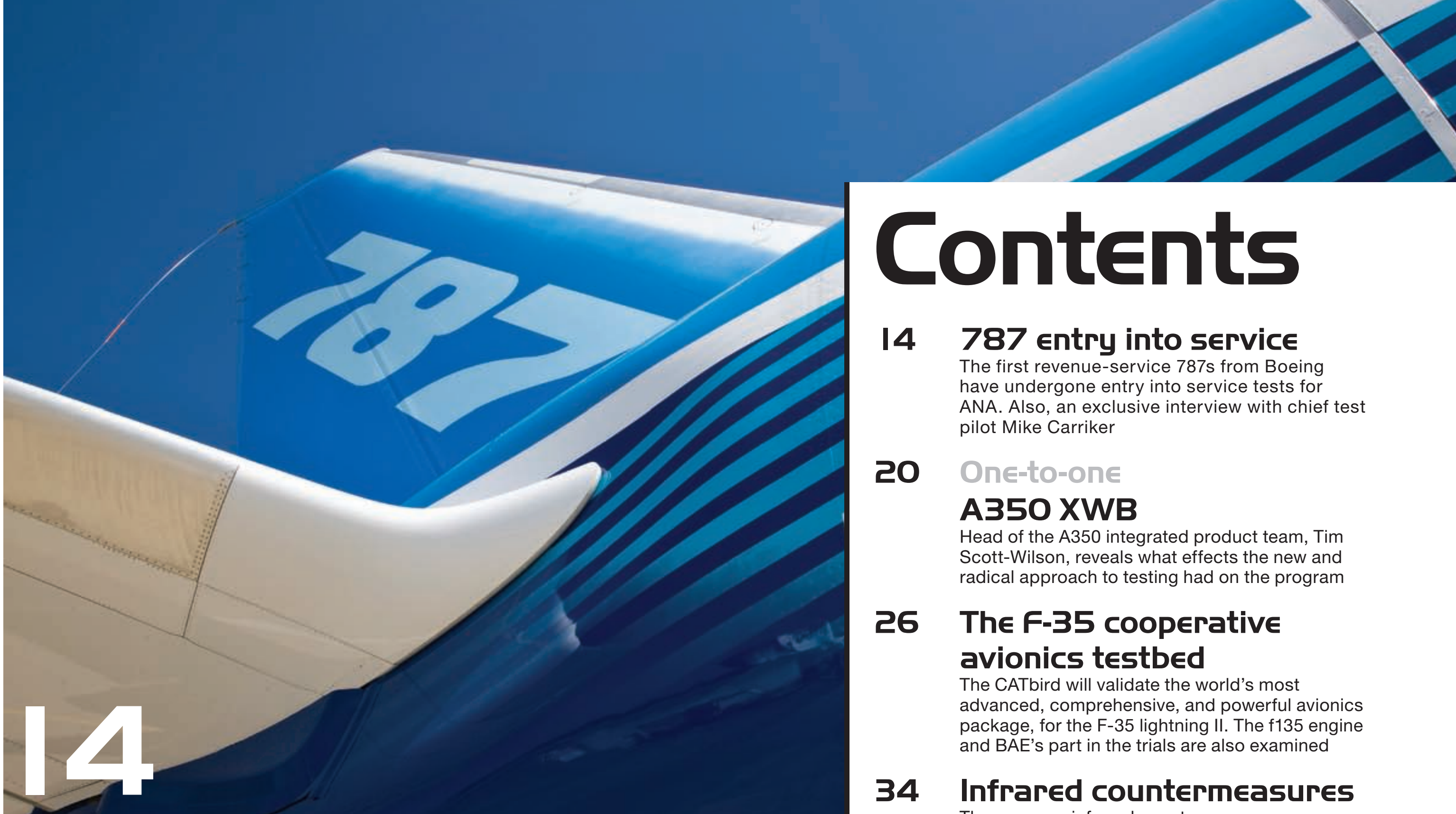

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For Testing Aircraft Subsystems, Honda Depends on dSPACE

The revolutionary HondaJet aircraft represents the new standard in light jet performance, quality and comfort – including the highest speed and greatest fuel economy in its class. To get HondaJet ready to fly into the new era, Honda Aircraft Company, Inc. will model its designs on dSPACE simulators for automated integration testing.

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Embedded Success dSPACE

Just a few weeks ago, I was witness to a very grim and sad spectacle being played out on television. It was the sight of a stunt wing walker climbing out of an aircraft and then hooking up to the skid of a helicopter above him. At the last moment the plane pulled away a millisecond too early. The man missed his grip and fell to his death in front of an audience of thousands at the airshow in the USA. His name was Todd Green.

The macabre images were hard enough to watch with the thought that so many children must have been enjoying the stunt, but it resonated even further because I had heard just the day before that one of the pilots of the most famous aerobatic team in the world had been killed shortly after a public display. His name was Flt Lt Jon Egging; it is believed the 33 year old tried to eject after guiding the RAF jet away from a built-up area and toward a field after it apparently suffered a failure following the display. He was killed when the jet plunged into a field near the River Stour, just outside Bournemouth, UK. Flt Lt Egging was the first Red Arrows pilot to die in a crash for 33 years.

On the very same day, stunt pilot Bryan Jensen was killed when his modified Pitts 12 crashed at the Kansas City Airshow at the Charles B. Wheeler Downtown Airport. I saw this on YouTube, sadly, courtesy of my son. The plane appeared to do a straight dive into the ground, and no obvious reason has yet surfaced. The full inquiry into the crash is expected to last months, and investigators have released no details on initial findings.

In the wake of these tragedies, I have observed a number of press stories suggesting that air displays and stunt flying should be consigned to the trash can, as they pose an unnecessary danger to human life (including spectators). With stunt pilots, this view may have some credibility, but to lump in a military display team is a very different story.

The Red Arrows has used the dual-control BAE Systems Hawk T1, which has a top speed of Mach 1.2, since 1979. The pilots are at the top of their game, all trained fighter pilots, and all have completed a highly rigorous selection and training process. I have met them. The Red Arrows team has more than 80 ground support personnel, all exceptionally trained who travel the world as one working unit. The specialist engineering technicians are drawn from three Royal Air Force trades: mechanical, avionics, and weapons.

During the seven-month winter training season, the Red Arrows' fleet of 13 Hawk aircraft is given an extensive overhaul. The aircraft are dismantled, inspected, and tested in turn to make sure that all hidden faults or damage are repaired.

Preparation of the aircraft begins each day at 07:00, when technicians arrive to prepare the aircraft for their first training sortie of the day. After the end of flying, the night shift carry on working into the early hours of the morning, until they have prepared sufficient aircraft for the following day. The avionics technicians have only recently installed new engine performance monitoring equipment, which enables their mechanical technician colleagues to manage the condition of each engine more efficiently.

One of my colleagues at work commented recently that, given the economic climate, military air displays such as the Red Arrows, Patrouille de France, and Thunderbirds are a frivolous luxury when military spending is being radically cut. My answer regarding the RAF is this: the Red Arrows is the public face of the Royal Air Force and is acknowledged as one of the world's premier aerobatic teams. Within the UK, the Red Arrows exists to demonstrate the professional excellence of the RAF and promote recruitment. The team supports wider British interests overseas by contributing to defense diplomacy efforts and promoting British industry. The Hawk aircraft flown are all British made. During international tours the Red Arrows demonstrates both British skill and British technology to millions of people.

Incidentally, the team also helps more than 500 UK charities every year. It flies the flag.

I have been to Farnborough and many other air displays in my capacity as editor of this magazine, and also in my spare time with my children. There is an immense sense of pride when the team swoops in low and fast.

Safety is paramount. After a very thorough investigation, the legacy of call sign RED 4 will be that safety can only be improved.

The Red Arrows has already performed another public display, but with the missing man formation: a diamond, minus one corner.

Christopher Hounsfield, editor

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COVER IMAGE: The underside of the CATB avionics testbed for the F-35 (picture courtesy of Lockheed Martin)

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Indian fighter decision looms

Toward the end of 2011 the Indian government is expected to pick its future medium-range multirole combat aircraft (MMRCA) in a deal reputedly worth US$10 billion and that has the potential to shape the global military aerospace industry.

It sees France's Dassault Rafale going head-to-head with the four-nation Eurofighter Typhoon in a competition that has already seen the Boeing F/A-18E/F Super Hornet, the Lockheed Martin F-16 Fighting Falcon, the Russian Mikoyan MiG-35, and the Saab Gripen fall by the wayside after failing to meet the test criteria and pass the technical evaluation conducted by the Indian Air Force earlier this year.

The depressed state of the European military aircraft industry means the competition is a must-win for both industry teams and it is highly likely that the 'losing' aircraft will be out of production by the end of the decade.

Added spin has been provided by the Libyan conflict, which has seen both the Rafale and Typhoon taking a frontline role in a high-intensity air campaign for the first time. The Rafale saw action from day one of the war in March, flying strike missions from bases in France and from the country's nuclear-powered aircraft carrier, the Charles de Gaulle. The 10 Rafale M of the French Aeronavale alone had flown some 445 sorties up to the end of June. An Armée de l'Air (ALA) even destroyed a Libyan combat jet landing at an airbase.

British Royal Air Force and Aeronautica Militare Italiana (AMI) Typhoons have played a high-profile role in NATO's Operation Unified Protector. The Italian Typhoons have flown purely air supremacy missions, while the RAF aircraft have flown air-to-air and air-to-ground missions with both laser and satellite guided weapons.

While the dogfight between the Rafale and Typhoon will focus on the respective capabilities of the two aircraft, particularly the ability to upgrade the two fighters to incorporate new technologies and weapon systems, the crucial determiner will be the potential for industrial cooperation to India offered by the rival bidders. It is expected that only the first 20 or so of the 126 aircraft required will be built outside India. The remainder will be built at production facilities to be established in India. It is expected that at first this will involve local assembly of kits dispatched from Europe and progressively increasing quantities of locally produced components will be incorporated over time.

Ultimately, India wants to become full partners and be able to offer technology for incorporation in the wider fleet of aircraft across the Eurofighter partner nations. A key requirement for India is the eventual incorporation of electronically scanned array radar technology in the aircraft they buy, or at least the ability to retrofit to the fleet once a mature radar is available.

Critical choice

The selection of the winner of the Indian MMRCA contest is critical for both Dassault and the Eurofighter partners. It will ensure the long-term viability of their production lines and supporting supply chains until well into the second half of this decade, providing a crucial safety net to keep their aircraft on the market for at least another decade. For India, it will transform its military aviation industry, opening the door for the introduction of some of the most advanced technology. India is particularly interested in the advanced production technology from the Rafale or Typhoon assembly lines, which will enable them to provide a launch pad for the next generation of India-built military aircraft.

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Loss of Air France Airbus still a mystery

Although in July French investigators released more information about the loss of an Air France Airbus A330 airliner over the mid-Atlantic in June 2009, the full report will not be completed until early next year.

The French air accident investigation bureau (BEA) caused confusion when it published its fourth report into the Air France crash on July 29 and then four days later had to issue a clarification.

A draft recommendation sent confidentially to the aircraft operators, manufacturers, and French airline aircrew union SNPL appears to suggest modification to the Airbus A330's stall warning system was needed. On August 1 BEA announced that, 'This draft was withdrawn because it appeared to BEA investigators that the recommendation was premature at this stage of the

View from the top

SNPL president Jean-Louis Barber said the pitot failure "constituted the trigger" and the pilots then faced a "delicate, unexpected" and "totally novel" situation.

The union insisted that the design of the stall warning "misled" the pilots. "Each time they reacted appropriately the alarm triggered inside the cockpit, as though they were reacting wrongly. Conversely, each time the pilots pitched up the aircraft, the alarm shut off, preventing a proper diagnosis of the situation."

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Space Shuttle legacy

In the dead of a July night a major chapter in the history of manned space flight came to an end with the landing of Space Shuttle Atlantis at the Kennedy Space Center in Florida.

The safe landing on July 21, 2011 of STS-135 was a fitting end to more than 30 years of space shuttle operations and a great relief to NASA chiefs who wanted to go out on a high. Pilot Doug Hurley brought Atlantis to a slow stop after a near perfect landing and returned the other crew members, Commander Chris Ferguson, and Mission Specialists Sandra Magnus and Rex Walheim, to their families.

This mission delivered more than 9,400 lb of spare parts, equipment, and other supplies in the Raffaello multipurpose logistics module – including 2,677 lb of food – to sustain International Space Station operations and its crew for the next year. The 21ft-long, 15ft-diameter Raffaello brought back nearly 5,700 lb of unneeded materials from the station. On its 13-day journey STS-135 traveled more than five million miles. It was the 26th night-time Shuttle landing (20th night-time and 78th landing (total) at Kennedy) and the 133rd landing in shuttle history.

"The brave astronauts of STS-135 are emblematic of the shuttle program, skilled professionals from diverse backgrounds who propelled the USA to continued leadership in space with the shuttle's many successes," NASA administrator Charles Bolden said after the historic landing. "This final shuttle flight marks the end of an era, but today, we recommit ourselves to continuing human spaceflight and taking the necessary, and difficult, steps to ensure the USA's leadership in human spaceflight for years to come."

Since STS-1 launched into space on April 12th, 1981, 355 individuals from 16 countries flew 852 times aboard the shuttle. The five shuttles traveled more than 542 million miles and hosted more than 2,000 experiments in the fields of earth, astronomy, biological and materials sciences. The shuttles docked with two space stations, the Russian Mir and the International Space Station. Shuttles deployed 180 payloads, including satellites, returned 52 from space, and retrieved, repaired, and redeployed seven spacecraft.

NASA's space shuttle fleet eventually comprised Columbia, Challenger, Discovery, Atlantis, Enterprise, and Endeavour, and they regularly carried people into orbit to launch, recover and repair satellites, conduct cutting-edge research and the entire program helped build the largest structure in space, the International Space Station. Both the Columbia and Challenger shuttles were lost in accidents, killing all crew members, which stalled the program, but the remaining four shuttles will be put on display at museums around the USA to benefit future generations.

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investigation. In fact, this subject will have to be explored more fully by the Airplane Systems group and completed by the work of the Human Factors working group, whose creation was announced during a press conference on July 29.

'This new working group, which will be made up of specialists in cognitive sciences, ergonomics, and psychology will have to examine all aspects linked to man-machine interactions and to the pilots' actions in the last few minutes of the flight,' said the investigating bureau. 'Only after all of this work has been completed and included in the Final Report will it be possible for a recommendation on the functioning of the stall warning to be made, based on reasoned scientific analysis. 'Finally, it should be noted that the warning sounded uninterruptedly for 54 seconds after the beginning of the stall, without provoking any appropriate reaction from the crew. This fact must be analyzed as a priority by the working group.'

Air France welcomes the moves by BEA: 'From the flight recorder data, it has been established that the combination of multiple improbable factors led to the disaster in less than four minutes: the icing of the pitot probes was the initial event that led to the disconnection of the autopilot, the loss of associated piloting control protections, and considerable roll movements.

'After the maneuvers carried out by the crew in deteriorated and destabilizing piloting conditions, the aircraft stalled at high altitude, could not be recovered, and struck the surface of the Atlantic Ocean at high speed.

'It should be noted that the misleading stopping and starting of the stall warning alarm, contradicting the actual state of the aircraft, greatly contributed to the crew's difficulty in analyzing the situation. During this time, the crew, comprising both first officers and the captain, showed an unfailing professional attitude, remaining committed to their task to the very end. Air France pays tribute to the courage and determination they showed in such extreme conditions. At this stage, there is no reason to question the crew's technical skills."

UK looks to field simulation network

Requirements for a tri-service distributed simulation network are expected to be confirmed soon by the UK Ministry of Defence.

The project, known as the Defence Operational Training Capability (DOTC), aims to link up all the simulation centers of the UK armed forces into a single network to enable inter-service training between units and personnel at separate locations. According to industry executives familiar with the project, a tentative target of 2020 has been set for the network and its air, land, and maritime components to be up and running.

Dr Chris Mace, the ministry's director general for science and technology operations, is currently leading a study into the viability of the project and once this is complete requirements will be set by 'customers' across the UK armed services and a procurement competition is expected to be launched.

The project is described by industry executives as potentially one of the most important UK procurement efforts over the coming decade, and one that will eventually require all the existing simulator devices in use by the UK armed services to be replaced or significantly modified. The main users will be tri-service frontline units rather than organizations carrying out basic or recruit training.

The cost of the project is expected to be several hundred million pounds over its life, say industry sources. It is expected DOTC would save the ministry several billions of pounds in fuel and other running costs by allowing live training events to be replaced by networked or distributed simulation. The concept also envisages links between simulated and live training events.

Contenders to bid for the project are expected to include BAE Systems, Lockheed Martin, and Boeing. QinetiQ has also already created a team of personnel to work on the project.

A Ministry of Defence spokeswoman said that the project was still at an early stage and no targets dates for Main Gate or contract award had been set. A ministry source suggested that the project might be rolled out incrementally but industry executives with knowledge of the project suggested that there could be benefits in appointing a prime contractor to oversee the supply hardware and software and then run the service once it is set up.

Linked in

The most mature element of the project is the DOTC (Air), which aims to link the Royal Air Force's Eurofighter Typhoon mission training center at RAF Coningsby in Lincolnshire with other air sector simulation centers, including the Joint Helicopter Command's AgustaWestland Apache AH.1 attack helicopter training site at Wattisham in Suffolk. The project also includes provision for a 'Red Air' or aggressor aircraft to fly live missions against pilots working in simulators and a suite of centrifuges to test the reactions and tolerance of pilots to acceleration above those experienced in the earth's gravity.

The air element is expected to begin work in 2013 and the land element by 2017, which will enable the army's Combined Arms Tactical Training center at Warminster, Wiltshire, and training facilities for forward air controllers to be linked with the air domain's simulators across the DOTC network. Links to maritime domain simulation centers with the full tri-service capability will be up and running by 2020.

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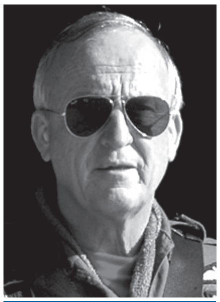


Taking science to the edge

MODERN DESIGN OF EXPERIMENTS IN FLIGHT TEST HAS MOVED SCIENCE FURTHER INTO THE WORLD OF FLIGHT TEST PROGRAMS. DES BARKER ARGUES THAT THIS SHOULD NOT PUT OFF SMALLER COMPANIES

BY DES BARKER

What does flight test and scientific research have in common? Well, to start with, both involve some degree of experimentation. There are several other similarities, but most importantly, both run the risk of failure and both are expensive methods of determining results. However, in research fields failure can be an acceptable outcome, while in flight test failure could have catastrophic effects and is obviously a less than desirable outcome.

It is from the considerations of safety and cost that flight test campaigns evolved as a rather elaborate and comprehensive matrix of test points. The huge volume of test points, most of which were included to 'tick the compliance boxes' stipulated in the certification standards incurred vast numbers of flight test hours and data reduction, all at the expense of cost and time.

Modeling and simulation capabilities were Spartan at best, and did nothing more than make the test pilot 'happy' that the engineering department had considered worst-case scenarios and had an approximation of 'what could go wrong'. On the positive side, a test pilot was slightly better informed and hence, better prepared in the event that things went wrong. Test points were planned to build up from the known 'middle of the envelope' and then progress out to the 'unknown' edge of the envelope in small increments. In retrospect, though, much of the testing was 'box ticking' and following a build-up test program to overcome engineering uncertainty.

However, because of the demands of cost and time, such processes are changing. The fidelity and integrity of computational fluid dynamics (CFD) and experimental methods (such as wind tunnels) have made possible relatively accurate aircraft behavior and performance predictions. This implies that it is now possible to use such tools to predict and identify the most likely areas of hazard and to develop test plans aimed at investigating the specific hazardous areas through a build-up program and then following up with spot checks throughout the envelope. A subtle but important philosophical change.

Flight test engineers, with increased confidence in modeling methods and computational tools, are now more willing to use research methodologies such as modern design of experiments (MDOE) to assist in developing leaner flight test programs at significantly reduced costs while retaining safety margins.

MDOE implies data is analyzed using each designed experiment, and the results are compared and contrasted as a cost-benefit relationship between flight test resources expended (i.e. flight hours) and system understanding gained (i.e. statistical confidence and power). The DOE methodologies generally shows a 50-70% reduction in flight test resources expended to gain similar levels of understanding of the system under test. In a recent development of a 'smart bomb' flight test clearance program, using DOE techniques the total cost of the program was reduced by approximately 45% through the reduction in the number of test points.

> **"Poorly designed flight test plans waste resources, increase uncertainty, and overlook important insights"**

Like all things in life, flight test plans are designed, some properly and some poorly. Poorly designed flight test plans waste resources, increase uncertainty, and overlook important insights that a well-designed flight test plan can detect. Major aircraft industries and aerospace organizations are increasingly relying on DOE methodologies to understand and address the complex problems that pose major challenges to quality improvement and bottom-line savings.

The problem is that smaller companies and even those referred to as non-type certificated aircraft manufacturers and experimental home builders are not included in this rather elite grouping of MDOE users and are consequently losing out on the benefits of a more scientific approach to flight test design. Many of the smaller companies regard DOE as out of their league but it is certainly not that complex; if one can build an aircraft, one can master the art of DOE.

In an era of restricted budgets and timelines, careful design and thoughtful analysis of flight test experiments can make the difference between a failed or canceled flight test program and the successful fielding of a required capability. ∎

Des Barker is the former senior test pilot for the South African Air Force, and one of the world's leading figures in his field

Picture courtesy of NASA - Sean

Wind tunnels have advanced the test procedures for aircraft and programs. They have made a huge difference regarding MDOE

Suborbital space flight: hauling the mail

A NUMBER OF INDEPENDENT COMPANIES HAVE BEEN APPOINTED TO PROVIDE SPACE 'SERVICES'… AT NASA'S EXPENSE

BY MICHAEL BELFIORE

Years ago, when biplanes ruled the skies, government contracts to deliver mail provided an importance source of revenue that helped commercial aviation to get off the ground. Hauling the mail helped to prove the reliability and commercial feasibility of a new form of transportation.

A century on, suborbital spacecraft are doing the same thing. Recently they received a boost from NASA in the form of government contracts to fly researchers and their experiments into space. Call it spacemail.

In August, NASA announced its selection of seven US providers of suborbital space flight services for its Flight Opportunities Program. Researchers who meet the qualifications can fly on these privately developed vehicles as they become available, at NASA's expense (find details at https://flightopportunities.nasa.gov/).

Some of the providers are flying high-altitude balloons and more or less conventional sounding rocket designs; others, including Virgin Galactic, plan to take people up with their experiments. But all have one thing in common, according to L. K. Kubendran, the Flight Opportunities Program executive: "These are a different class of vehicles. These have to be reusable. They should be capable of flying twice within five consecutive days."

Preparing for take-off

NASA recently named seven US firms as providers in its suborbital Flight Opportunities Program, under which it will purchase flights for researchers who wish to test hardware, make observations, or conduct other research in a high-altitude, microgravity environment:

- **Armadillo Aerospace of Heath, Texas, will use vertical take-off/vertical landing (VTVL) rockets;**
- **Near Space Corporation of Tillamook, Oregon, will fly payloads on high-altitude balloons;**
- **Masten Space Systems of Mojave, California, has a VTVL design similar to Armadillo's;**
- **Up Aerospace Inc of Highlands Ranch, Colorado, uses low-cost sounding rockets;**
- **Virgin Galactic of Mojave, California, has the largest vehicle, an eight-seat rocket-powered airplane;**
- **Whittinghill Aerospace LLC of Camarillo, California, has another reusable sounding rocket design;**
- **XCOR Aerospace of Mojave, California is developing a two-seat spacecraft.**

The Masten Space Systems Xaero vehicle is a vertical take-off/vertical landing rocket Photo: Masten Space Systems

Getting off the ground

The several minutes of microgravity time that can be attained on a flight going up to 100km in altitude, compared with the mere 30 seconds available on a parabolic aircraft flight, can make a world of difference, without the multimillion-dollar price tag of orbital flight.

"We need some way to get in zero-g for four or five minutes to gather this data," says Nathan Silvernail, a graduate of Embry-Riddle Aeronautical University, who is working with mechanical engineering professor Sathya Gangadharan on an in-space refueling system. "Who knows if our experiment doesn't work? We don't want to have to spend all that money to get to the International Space Station to figure that out." The Embry-Riddle experiment will most likely first fly on a craft being developed by Masten Space Systems of Mojave, California. Although the company's Xaero will be unmanned, it aims to bring aviation-style flight frequency to space. Key to success, according to Masten business development director Colin Ake, is frequent testing. "We want to iterate quickly on hardware and software," he says. "The faster we can get back to testing, the faster we can iterate on it."

Passenger seat

One company developing a manned vehicle is XCOR Aerospace, also in Mojave. Its rocket-powered spacecraft, called the Lynx, includes a seat beside the pilot for a human researcher or space tourist. One of XCOR's customers, the Planetary Science Institute of Tucson, Arizona, plans to fly a telescope atop the vehicle for exo-atmospheric observations. "NASA has been flying suborbital observatories for decades, on unmanned, disposable rockets," Planetary Science Institute astronomer Luke Sollitt said in a statement announcing the missions. "The new manned, reusable commercial platforms will allow us to make repeated observations with a single instrument, but without the need to refurbish it between flights. "In addition, the short turnaround means we can do many observations or targets."

XCOR has been developing Lynx over several years, finding customers for each piece of the technological puzzle as it goes. One example is a novel piston-powered pump that replaces much more expensive turbopumps.

All this activity depends on a build a little, test a little development philosophy that takes maximum advantage of limited resources by innovative small companies. It is what makes it possible to pay the bills hauling the mail while continuing to develop ever more capable and affordable vehicles for passengers and cargo. ∎

Michael Belfiore is the author of Rocketeers: How a Visionary Band of Business Leaders, Engineers, and Pilots Is Boldly Privatizing Space. Web: www.michaelbelfiore.com

Enter the dream

JAPANESE AIRLINE ANA HAS TAKEN DELIVERY OF THE FIRST REVENUE-SERVICE 787s FROM BOEING, HAVING BEEN VERY MUCH INVOLVED IN THE PROJECT SINCE THE DESIGN PHASE

BY LORETTA GUNTER

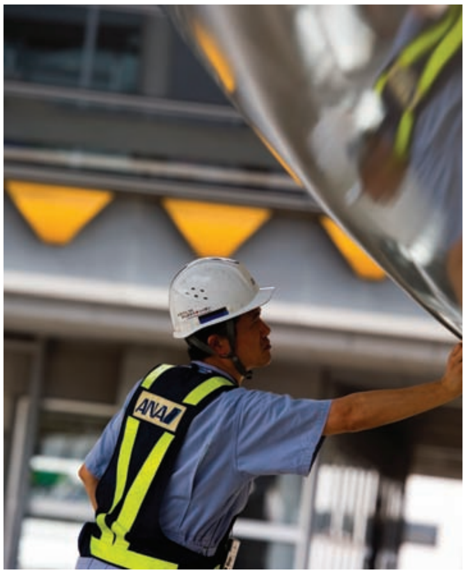
Long before December 15, 2009, when the 787 Dreamliner made its first flight, the Boeing team began considering what it would take to ensure a smooth entry into service for the jetliner. It happened before the airplane made its public debut at rollout and even before launch customer ANA placed its order for 50 of the all-new twin-jet airplanes.

"We began our efforts for entry into service at the same time we started the design of the 787 Dreamliner," says Mike Sinnett, vice president and chief project engineer for the 787 program. "Literally from the day we formed the program team we elevated the in-service experience to the same level as the design of the product and the development of the supply chain and production system."

The proof is in the earliest organization charts for what was then the 7E7 program. Under the moniker of 'Services' rested a program-level organization to represent the voice of the customer and ensure the design teams considered the in-service experience as they made technical decisions.

"It was clear from the earliest days that we had to take into account how this airplane would stand the test of time with our customers," Sinnett explains. "After all, Boeing has these airplanes only for a relatively short amount of time. Their lives are spent in the service of airlines around the world. Our decisions had to include a lifecycle perspective."

Mike Fleming, vice president of 787 Services and Support, leads the team responsible for representing the customer to Boeing and, in many cases, representing Boeing to the customer. "My team is in a unique position to understand the requirements of the customers and the realities of the design evolution," he says. "We often provide that bridge between the technical teams at Boeing and our customers."



All Nippon Airways Co expects to receive all 55 Dreamliner jets it has ordered from Boeing by March 2018

With ANA, the relationship is especially deep and stretches beyond the Services team. The airline sent a team to be part of the design effort and has maintained a group working at the Boeing facility in Everett, Seattle, USA, alongside the design team.

The Japanese team

"When the ANA team arrived in Everett, they told us we were 'reputation sharing partners,'" recalls Steve LeBaron, the lead Boeing customer engineer assigned to ANA. "Throughout the course of the program, we have seen how true that is. ANA has been right beside us as we made key decisions, it influenced the design, and stayed deeply integrated in understanding the progress, the challenges, and the solutions."

In addition to the design of the airplane, preparations are made to ensure the entire system is ready for service. Three key elements are defined for readiness: the airplane, which is put through a rigorous flight test and certification program; the airline, which must receive appropriate documentation and training; and the broader Boeing infrastructure, which must be ready to provide the same level of support already in place for well-established production lines such as the 777.

Flight test and certification go hand in hand but are not interchangeable. Only a portion of

Pilot light

787 chief test pilot Mike Carriker exclusively discusses the highs and lows of the flight test program

Captain Mike Carriker, chief test pilot for the Boeing 787 Dreamliner, has an impressive flying portfolio. After joining Boeing in February 1990 as a production pilot, and becoming senior engineering pilot for the 737 in the same year, he assumed the title of Sonic Cruiser chief project pilot, and in that role transitioned to the 787 program in January 2003.

He has participated in all Boeing flight test programs since he joined the company, including the completion of more than 500 hours of 777 testing. He served as assistant project pilot for the Joint Strike Fighter program during the design and proposal phases, was captain on the first flights of the Boeing Next-Generation 737-600 and 737-900, and first officer for the first flight of the Boeing Business Jet.

Carriker also flies the 1933 airliner the Boeing 247D and the B-17F for Seattle's Museum of Flight, the 1940 Boeing 307 and Boeing's Helio-Courier. He has more than 7,500 flight hours.

Prior to all this, Carriker was a US Navy pilot, flying A7-Es and F18s. He has more than 300 carrier landings in the A7-E.

He was a 1985 graduate of the US Navy Test Pilot School. After a tour as a Navy test pilot, he was an instructor at the US Navy Test Pilot School and also an instructor at the Empire Test Pilot School at Boscombe Down, UK. In 2002 he received the American Institute of Aeronautics and Astronautics Octave Chanute Award for outstanding contributions to aeronautics.

Carriker holds type ratings on all current production airplanes. So how did he get to be chief test pilot on the most significant and revolutionary medium-size airliner to enter service in decades? "Becoming chief test pilot for an all-new airplane is a career path that evolves over a period of many years," he says. "It involves a lot of hard work and a fair bit of luck. After all, we only develop an all-new airplane every 10 to 15 years so a lot of things have to line up. In 2001 I was selected to be the chief pilot for the Sonic Cruiser program. We assign chief pilots long before airplanes are designed because flying is really just a small part of the job. The chief pilot is part of the design decision-making chain, so early involvement is important. When Boeing shifted from the Sonic Cruiser to the 7E7, which became the 787, I shifted too."

From a technical point of view, what does Carriker think is the greatest breakthrough in the entire program? "That's a little like asking a father to single out one attribute of a child that they are proud of," he says. "The airplane as a whole is a breakthrough. It takes the integrated effect of all the improvements we've introduced to get there – from our use of composites, literally the way we build the airplane; to the advanced aerodynamics that you can see every time the airplane takes off; to the advanced systems.

"Most passengers will never see 90% of the advances that we've made with this airplane, and that's how it should be."

The initial test program on Rolls-Royce-powered planes is complete, as is the General Electric certification program

> "We conducted over 4,000 hours of flight test before the 787 was certified in August"

the flight test effort is directly related to certification. In addition, there are elements of the airplane that are validated using laboratory evaluations and mathematical analysis.

"We conducted over 4,000 hours of flight test before the 787 was certified in August," says Sinnett. "That testing showed how the airplane performed when it was pushed well beyond operating norms. It also showed how it performed within operating norms. We have to demonstrate both elements to the regulatory authorities before they agree that the airplane is ready for service."

The laboratory testing ranges from demonstrating the capabilities of the materials used on the airplane in the event of fire or high pressure to full-scale demonstrations of extreme loads and fatigue characteristics.

Among the documentation required for any new airplane is an array of manuals that spell out how it is to be operated and maintained. These manuals used to be delivered as stacks of notebooks. With the 787, they are delivered virtually as online sets of information that can be updated with new information throughout the life of the program.

787 preparation

Earlier this year Boeing validated the accuracy of many operations within the maintenance manual. Mechanics strictly adhered to the

Follow the plan

There have been a number of production retrofits due to flight test design changes, but Carriker will not be drawn on the subject. "I'm not going to discuss specific changes. That process of finding improvements and making them is just a normal part of flight test. The changes we found on the 787 are not significant or unusual when compared to any other program. Our testing and design processes are quite formal. When test results don't match our expectations, we get to work on understanding how to change the design. That's a combined effort that requires us to dig deep into the data collected during the test and to do a detailed review of the design and our objectives. As the chief pilot, I help explain what was experienced (or not) during the testing and help to generate and evaluate ideas for solutions. It's a very iterative and collaborative process – and very disciplined."

Carriker explains that the challenges on the 787 program were much the same as those faced on any other flight test program: "It's the balancing act of schedule and requirements. Requirements always win but we can't take our eye off the schedule. In addition to the technical requirements of the chief pilot, I can do a lot to help keep the team focused and motivated.

"Overcoming our challenges was largely a matter of working hard and never giving up. Again, it's not any different than any other flight test program. It's hard to be innovative and bring a new commercial jetliner to the market. There's a reason it doesn't happen that often and we knew that going in."

Back in November 2010, a serious inflight fire in the electrical equipment bay of a 787 test plane forced an emergency landing in Texas. All 30 to 40 people aboard were safely evacuated on slides.

The fire affected the cockpit controls, and the jet lost its primary flight displays and its auto-throttle, according to a person familiar with the incident. Some use of the flight and engine controls was lost by the pilot, which on the Dreamliner are electrically activated. Carriker says this was the low point of the test program: "Completing flutter and system stability was huge. Doing the test where we showed 777 landing commonality was huge. The runway work at Edwards AFB is always a highlight. The event in Texas was the low." As a result, there were some minor aerodynamic changes to things such as the position of the slats at various settings, and a vortex generator was added to the vertical stabiliser to improve rudder effectiveness at very high angles of rudder attack and low speeds.

A device was also added to the back of the auxiliary power unit to control fluid drainage, as well as minor changes to brackets and secondary structure.

Program setbacks

Delays in the test program have also had an effect, but Carriker says that this was the right way to go: "Innovation is hard work. Given the choice between being on time or being delayed, I'd pick on time. Given the choice between being right and being delayed, I'd pick being right, and that's exactly what we did. Ideally, we'd get both – on time and right. But that just wasn't in the cards for us. We made the right decisions when we held back on performing first flight when the side-of-body issue was discovered. Was it disappointing? Only for very brief moments. There's just not time to be disappointed when something like that happens. You have to roll up your sleeves and get to work."

Despite the all-new design and features from wing-tip to wing-tip, the similarities between the 787 and existing 777 are remarkable. "It's just like a 777. That's how we designed it. But, it's not as easy as it sounds. The 787 is made of different materials, it has significantly different systems. We had to create flight control laws that would force the commonality. We did that because it is of significant value to our customers. Now it takes only five days for a 777 pilot to be trained to fly the 787."

In August the 787 completed all flight tests required for type certification of the 787-8 Dreamliner with Rolls-Royce engines. The final flight occurred on board ZA102, the ninth 787 to be built. During the flight, the 14-person crew completed simulations of a dispatch with a failed generator and failed fuel-flow indication.

At the end of August the aircraft received certification from the US Federal Aviation Administration (FAA) and the European Aviation Safety Agency (EASA). The future for Carriker is fairly short-term in sight and philosophy: "I won't know where I am going until I get there. Right now we have certification of the first delivery configuration. We still have to get through the remaining conditions to certify the 787s with GE engines. And we've got the 787-9 coming up too."

written instructions to remove and install parts – including an air-conditioning pack heat exchanger, lower recirculation fan, ram air fan, and air separation module – on a flight test airplane.

In addition to testing the processes as they were written, it was essential to check that the ground service equipment specified performed as expected, adds Fleming.

Representatives from four airlines participated in the activity, helping to note areas where the directions could be improved to add greater clarity on tasks that are performed regularly when airplanes are in service.

In addition to participating in Boeing evaluations of the manuals, there is formal training for maintenance crews and flight crews. Both sets of training involve classroom learning and hands-on practice.

The Boeing 787 flight training program uses an innovative suite of training devices including a full-flight simulator, flight training device, and desktop simulation station to ensure that pilots are ready to fly the Dreamliner.

With the 787 pilot training courses, pilots can transition to the new airplane in five to 20 days, depending on pilot experience. Boeing 777 pilots can qualify to fly the 787 in as little as five days. The 787 recently achieved a common pilot type rating with the 777. In order to bring training closer to customers around the world, Boeing has installed a network of eight 787 training suites at five global campuses: Seattle, Singapore, Tokyo, London Gatwick, and Shanghai.

Cross training

Just like the validation exercise for the maintenance manual, Boeing and ANA used a flight test airplane to demonstrate that ANA is ready to begin operations with the Dreamliner.

In July an ANA crew, working alongside a Boeing team, brought a 787 from Seattle to Tokyo for a week's worth of demonstrations. Thousands of enthusiasts greeted the airplane each time it landed at a new airport in Japan. And dozens of ANA crews got the opportunity to practice their roles in supporting the 787; from the flight crews to the ground crews, a variety of tasks were conducted at five airports to put the people and the equipment through their paces. The airplane was towed to gates, fueled, and maintained using ANA's equipment, people, and operational procedures based on Boeing's manuals.

"Our service-ready demonstration in Japan really helped us prove to ourselves, both Boeing and ANA, that we're ready," says Fleming. "It's not that issues won't come up – they always do with machines. They do with airplanes that have been operating for many years. The key is knowing what to do to resolve issues quickly and efficiently. We have the tools, processes, and people in place to do just that. And, more importantly, we have built relationships with our customer that enable us to share information and find solutions together."

Revenue service

At time of going to press, Boeing was due to deliver the first 787 to ANA on September 25. ANA will conduct about one month's worth of preparations after receiving the airplane before it enters revenue service.

"It's almost impossible to adequately explain the detailed planning and preparation that is done to prepare for bringing an all-new airplane model into revenue service," explains Sinnett. "Each element is considered, planned, practiced, evaluated, improved, and implemented by a team of experts. We can talk about the broad categories – preparing the airplane, preparing the customer, and preparing the Boeing infrastructure – but really, only the people involved, the men and women who have spent years of their lives preparing for this, really understand how intricate and thorough this effort is.

"And even at that, most people are focused on a somewhat narrow band within the overall effort that is service readiness. Boeing has an outstanding history of working with its customers to introduce new airplanes; we are continuing that tradition with the 787." ∎

Loretta Gunter is senior manager, Boeing 787 Communications

The aim is that the lightweight jets will help ANA cut fuel costs by US$52-65 million a year. ANA plans to have 20 Dreamliners by March 2013

Air proof

THE DEVELOPMENT AND TEST PROGRAM OF A350 XWB IS DIFFERENT TO ANY OTHER IN AIRBUS'S HISTORY. THE HEAD OF THE INTEGRATED PRODUCT TEAM, TIM SCOTT-WILSON, REVEALS WHAT EFFECTS THE CHANGES HAVE HAD

BY JOHN CHALLEN

Back in the middle of the 2000s, with the development of a brand-new family of mid-sized passenger aircraft ahead of it, Airbus was thinking hard about how to improve the systems test regime for A350 XWB.

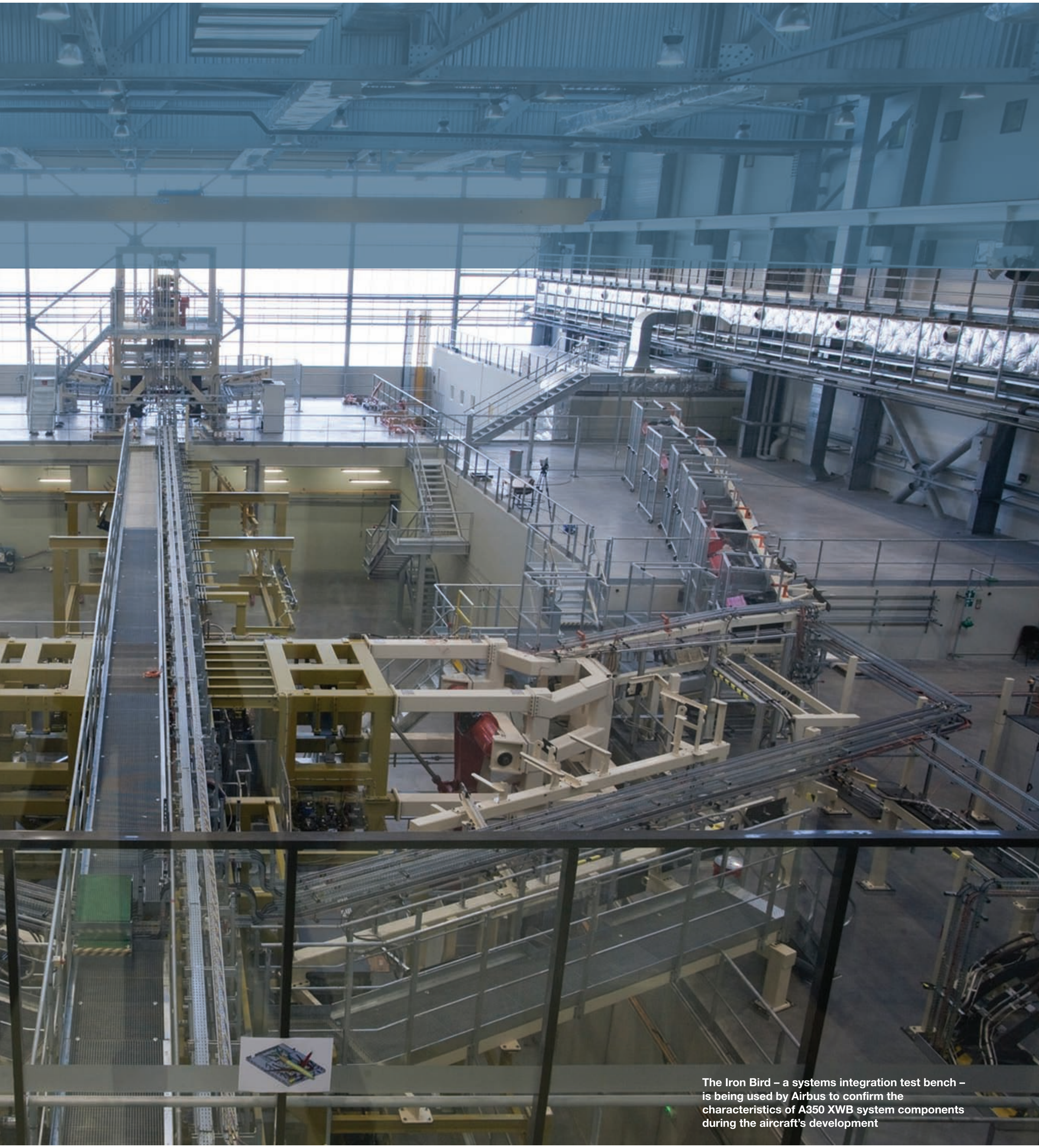
"From the beginning the discussion was about how we could achieve the highest level of maturity by the time we delivered the first aircraft," explains Tim Scott-Wilson, head of the integrated product team for A350 XWB Lab Test Means at Airbus. The concept became known as 'service ready at first flight'. The ultimate aim is to concentrate the flight tests on certification, rather than development testing. He does concede that achieving certification with no flight tests will never be totally possible as the plane and its systems need to be proved in the air, but he expects that systems testing will be increasingly performed on the ground through Airbus's use of more advanced simulation systems and test rigs.

"We had to find a way to finish the systems testing about 12 months earlier than we have done before," continues Scott-Wilson. "We changed our test approach in a number of ways. We wanted to focus Airbus's testing more on integration between systems, and we also made plans to perform more representative operational scenarios on the ground, rather than depending on the aircraft. To do this we asked the suppliers to do more equipment level testing and in some cases pre-integration with equipment from other suppliers, which was previously done by Airbus."

Scott-Wilson also reveals that the evolved and enhanced test program adopted for A350 XWB is already paying dividends. "It gives us the opportunity to identify problems that, in the past, airlines have experienced during their first six months of operation. It gives us more time to implement the fixes," he explains. "It is not so easy to achieve because we have to strike a balance between trying to test earlier, and being too early to have a representative system."

Simulation solutions

For now, though, all seems to be going to plan. Scott-Wilson explains that there are a number of reasons for making such efficiency gains. "We have put a lot of effort into getting the testing infrastructure right in the important areas, such as the Iron Bird." A mini simulator sits around the Iron Bird, he explains, which enables the systems being tested to fly in an environment generated by the equivalent of a training simulator. "On A380, we had a similar system but we were still developing it as we started testing," admits Scott-



The Iron Bird – a systems integration test bench – is being used by Airbus to confirm the characteristics of A350 XWB system components during the aircraft's development

Wilson. "For A350 XWB we've achieved a working level of completeness and maturity on the simulation environment much earlier. This time around, the testing will be a lot more efficient and representative."

The advanced virtual simulation environment on the A350 XWB Iron Bird represents another leap forward. To many it is perceived as representative of the technological improvements that the company is making with the aircraft as a whole, meeting the needs of the next generation. "Our new simulation package enables flight environment parameters to directly interface with the system we are testing, whether it be hydraulics, avionics, or electrics," continues Scott-Wilson. Airbus has used data from within its design offices to develop these airplane simulations, providing the whole development team with access to all of the flight dynamics and parameters. He explains that this development lets him and his fellow engineers feed representative information into any of the aforementioned systems that are fitted onto the airplane. "We are getting to the point where we can 'plug-and-play' real systems and simulated systems in a particular configuration so that we can, when necessary, run a complete virtual flight using a combination of the simulated and real environments.

"For A350 XWB we've achieved a working level of completeness and maturity on the simulation environment much earlier"

"What we also plan to do with the enhanced ground simulation is to introduce operational testing onto the test rigs," continues Scott-Wilson. "In the past we used to undertake systems testing on the ground and looked mainly at the system behavior in test conditions, but operational testing where we look at the way the whole aircraft is behaving was mainly done during flight tests.

"The enhanced simulations we now have on the test benches mean that we can test systems in operational flight scenarios on the ground too. This configuration not only enables us to conduct these assessments earlier, but they can also be undertaken using engineers that may not be test pilots, but who understand the systems and are qualified to fly the simulation. What we've achieved more completely on A350 XWB is the ability to run simulated flights for systems testing on the ground, rather than just running the systems test."

But, as Scott-Wilson points out, there is more to testing that relying purely on computers and simulation packages. A350 XWB's first major test bench, Aircraft Minus One, which was introduced around two years ago, still concentrates on the validation of the system specifications, particularly man/machine interface and display definition. "This test rig also helps us to evaluate cockpit operations, human factors, and the initial aircraft handling qualities and flight control laws that will be programmed into the flight control computers," he explains. "By having a representative cockpit really early we can get useful feedback on how the pilot will operate in the aircraft, which we use later as an input to the integration simulator when we have real hardware in the loop. Also, the flight crews can learn about the aircraft's systems, identify issues using their operational experience, and become involved early to help the continuity between ground and flight test phases."

Efficiency is key

Given the scale and importance of the A350 XWB program, an efficient test regime was imperative. With three versions of A350 XWB in production (the -800, -900, and -1000) and with a large emphasis on optimizing cabin comfort and the use of composite technologies, not to mention the

A350 in development numbers

Three A350 XWB family members;
25% lower fuel burn than today's equivalent aircraft;
150 simulation models (Iron Bird);
200 simulation models (integration simulators);
2,400 electrical wiring diagrams (Iron Bird and integration simulators);
12,000 workers involved in A350 development at its peak.

Tim Scott-Wilson, head of the integrated product team for the A350 XWB

A test of power

Trent XWB development preparations are currently being made for the engine's first flight in Toulouse, on Airbus's A380 flying testbed (A380 MSN1). More than 1,100 Trent XWB engines have been sold to 36 customers. The engine has now also completed a 150-hour endurance type test at INTA in Madrid, Spain

The development of Rolls-Royce Trent XWB is being led by the UK-based company. A major task for Rolls-Royce will be the development of a higher-thrust version of the engine for the flagship A350-1000. When it is completed, the engine will deliver around 97,000 lb maximum thrust, achieved through the inclusion of new high-temperature turbine technology, which increases the size of the engine core and advanced fan aerodynamics. This extra engine performance will enable Airbus to offer increased range and capacity for the aircraft.

need to reduce weight, noise, drag, and emissions, development time was at a premium.

Scott-Wilson notes that the A350 XWB testing has been subject to more automation than any other Airbus program in history, in order to achieve greater repeatability in testing. The switch has also meant faster development. "Automation has given us some real value in terms of the testing philosophy. We can use the early testing to develop a test script that can be repeated later on as systems maturity grows to verify that we still have the same results." Evidence of this early testing can be seen on the Iron Bird, as well as on High Lift Zero, a facility based in Bremen, Germany, that is home to a full-scale functional test rig of the A350-900's slat and flap system.

Advanced high-lift systems are key to the performance of A350 XWB, so the German facility represents a major investment and a vital part of the development jigsaw. One innovation applied to the A350 XWB wing's high-lift devices is the change to the new mechanical concept, adaptive dropped hinge flap (ADHF) design, as well as greater integration with the spoilers during all flight phases. The flight computer will perform in-flight trimming of the inboard and outboard flaps, creating a variable camber wing that adapts to different flight conditions. These new features require extensive testing to confirm that they will operate correctly.

"To start initial tests we are using metal dummy flaps designed to match the stiffness of the real flap [which are composite]," explains Scott-Wilson. "We will subsequently put the real flaps into the test rig to ensure the dynamic interaction between control system and the real flap structure is working correctly."

The inside track

As well as the facility in Bremen, another key location of A350 XWB development in Germany can be found in Hamburg. It is here that a constellation of test benches are responsible for cabin systems validation and verification, and it is also the location for a full-size (in terms of diameter) fuselage.

"The functional integration benches (FIBs) can work in parallel with the cabin rig," explains Scott-Wilson. "We are focusing not only on cabin control and in-flight entertainment, but also water and waste management, air distribution, and function controls. We also have a full-size skeleton frame of a fuselage that is used for testing the air distribution with full-size ducts, which enables us to check flow through the ducts before we do later testing with the cabin itself." This is also part of the approach of doing more tests on highly representative rigs rather than using the aircraft itself.

Other tests being conducted in Hamburg include smoke clearance checks, temperature balancing, and open frame testing. "The cabin is under construction, and between now and the middle of 2012 we will be updating and integrating cabin modules into the airplane, such as galleys, seats, and toilets," says Scott-Wilson. "The aim of the platform is to have it fully fitted around nine months before the first flight of the first cabin-equipped airplane."

Above: Computer rendering of the A350 XWB

Left: Nose landing gear (picture supplied by Liebherr Aerospace)

Below: Control room running a variety of tests on the A350 XWB mock-up

Testing through to take-off

"At the end of 2010, we had flying controls and hydraulic generation already running on the Iron Bird with simulations of some of the other systems," recalls Scott-Wilson. At the time of writing the A350 XWB Iron Bird was due to start the next phase of hydraulics and electronics testing shortly. "The first phase focused on the integration of the flight control computers and the flight surface actuators," explains Scott-Wilson. "The second phase is more focused on performance of all the different systems. It is a stepped approach that will continue through the rest of the program. There are a number of technologies included for the first time on an Airbus commercial aircraft, such as the Military 1553 databus standard for communication with the flight control actuators."

There are plenty of other tasks on Scott-Wilson's list for 2012 over and above that planned for the Iron Bird, such as landing gear testing, cabin integration, fuel system tests as well as the avionics and maintenance systems. "We believe that 2012 will be the key year for achieving the maturity we want to have for the systems," concludes Scott-Wilson. And the first real litmus test of the aircraft will come when the first A350 XWB takes to the air. ∎

The early bird

THE CATBIRD WILL VALIDATE THE WORLD'S MOST ADVANCED, COMPREHENSIVE, AND POWERFUL AVIONICS PACKAGE, FOR THE F-35 LIGHTNING II

BY ED DELEHANT

The southernmost run station on the Lockheed Martin side of the runway at Naval Air Station Joint Reserve Base Fort Worth, Texas, houses an aircraft that is one part airliner and one part advanced fighter. This curious combination is a Boeing 737-300 transformed into a flying test laboratory for the F-35 program, known as the cooperative avionics testbed (aka CATB or CATBird).

Built in 1986 and formerly operated by Indonesian Airlines, the converted 737 now sports a bright red vertical tail emblazoned with CATB in white block letters. Rather than transporting commercial passengers, the aircraft now carries a team of test engineers. It serves as a flying laboratory for developing and demonstrating avionics for the F-35 Lightning II, particularly avionics related to mission systems.

"Mission systems are best viewed as systems that enhance the combat effectiveness of the aircraft," notes Tony Nigro, deputy manager for the CATBird. Nigro has been associated with the CATBird since 2005. "This aircraft is all about reducing risk for the program. We want to uncover and resolve issues with the mission systems software as early as we can and before they reach the F-35 fleet. CATBird enables us to test mission systems in a dynamic environment against both fixed and moving targets. We can simulate situations in this aircraft that we can't simulate in a ground laboratory.

"Mission systems provide the pilot with situational awareness, through the processing, fusion, and display of data from both onboard and off-board sources. The advanced sensor suite on the F-35 collects vast amounts of information that is processed and presented to the pilot through the large color flat panel displays in the cockpit. Certain flight-critical and tactical information is also projected onto the helmet-mounted display. The overall process allows pilots to make faster and more effective tactical decisions. Pilots can also transfer sensor information to other aircraft as well as to maritime and ground forces.

The mission hardware

Mission systems-related hardware on the F-35 includes the APG-81 active electronically scanned array radar; electronic warfare; an integrated communications, navigation, and identification system; the integrated core processor; the electro-optical targeting sensor; the electro-optical distributed aperture system; and the pilot's helmet-mounted display.

Not coincidentally, this same hardware is found externally and internally on the CATBird. In fact, the most noticeable feature from the outside of the flying laboratory is the F-35 integrated forebody, or nose section, mounted

With the completion of the Stage 7B modification in April 2011, the CATBird is now configured with the full F-35 sensor suite and is currently supporting Block 2A mission systems software integration and testing

The flying test lab is configured with data links to support key sensor and fusion capability enhancements incorporated in the F-35's Block 2 software version, it is currently conducting ground testing in Fort Worth, and has recently begun transitioning to flight testing

Taking the best bits

BAE Systems has taken a major role in last-stage F-35 manufacture, test, and evaluation

BAE Systems is teamed with prime contractor Lockheed Martin on the F-35 program. BAE is leading the manufacturing of the aft fuselage, vertical and horizontal tails, and wing tips, and is responsible for the fuel system, crew escape, life support, prognostics health management, and support for UK aircraft carrier integration. It also provides static and fatigue testing capabilities to the program.

The company's flight test expertise is invaluable. It is coordinating readiness and sustainment capabilities for the benefit of Team JSF. Focusing on the test and development on the aircraft, BAE Systems plays a significant role.

Role in the STOVL flight program

BAE Systems leads the short take-off and vertical landing (STOVL or F-35B as it is also known) flight science flight testing at Naval Air Station Patuxent River, Maryland, USA. In this role BAE Systems has led the test operations, planning, and execution activities on three F-35B test aircraft. Flight science testing consists of basic aircraft envelope expansion through the assessment of flying and handling qualities, measuring loads, and flutter margins in order to establish the airframe operational limitations for the aircraft.

The company has used its legacy Harrier experience to lead the detailed test planning for the unique STOVL capabilities of the F-35B variant and successfully achieved the first Vertical Landing for the F-35 program in March 2010, after only 42 test flights. BAE Systems currently has some 45 employees working at Patuxent River.

Lead role in UK naval carrier integration

An advanced synthetic environment based at BAE Systems Warton, Lancashire, is used to investigate and prove operations of the F-35 carrier variant aboard the UK's future Queen Elizabeth Class (QEC) aircraft carriers years before they enter service. The sophisticated simulation, the only one of its kind in the world, integrates accurate models of the aircraft and the ship, including the flight deck markings and visual landing aids used by pilots during take-off and landing, as well as the motion of the ship under various sea conditions and the turbulent airflow around the unique twin-island superstructure design – referred to by naval aviators as the ship's 'burble'. Earlier this year test pilots from both the UK and USA used the facility to perform a joint exercise to evaluate the latest QEC design fitted with an angled deck and equipped with 'cats and traps' (catapults and arrestor wires).

F-35 structural testing

The Structural & Dynamic Test facility at Brough, Yorkshire, UK, has the capability to perform static and fatigue testing on a large scale (F-35 tests have up to 170 actuators and 4,000 strain gauges); dynamic testing and birdstrike testing are the main elements of the capabilities. These are all supported by a team of engineers covering the key disciplines of design, control, instrumentation, dynamics, and integration.

As part of the F-35 system development and demonstration (SDD) program work share, BAE Systems has the responsibility for carrying out a large share of the structural testing required to qualify all three F-35 variants. The testing at Brough includes a full-scale static and fatigue test of the conventional take-off and landing (CTOL) variant, fatigue testing of the horizontal and vertical tails for all variants, static testing of the horizontal tails for all variants, plus thermo acoustic environment work for the STOVL variant.

Testing to date has been completed on the CTOL full-scale static test and all the horizontal tail static tests. Fatigue testing is complete (two lifetimes) on the CTOL and STOVL horizontal tails and is half complete on the CTOL and STOVL vertical tails. The CV variant tails have not started their fatigue testing yet.

The full-scale fatigue test is also part of the way through its first life of testing.

Total test system

The CATBird represents a new industry benchmark in integrated avionics testing technology. It will test the entire F-35 Lightning II integrated sensor suite, including the electro-optical targeting system, electro-optical distributed aperture system, advanced electronically scanned array radar, and electronic warfare system. The CATBird is also designed to: monitor and measure the in-flight performance of various installed sensors; incorporate a high-fidelity F-35 cockpit that will enable pilots to operate the fighter's integrated sensor suite in an airborne environment; and fuse all sensor information on a tactical situation display that will provide total situation awareness on a single screen.

on the front of the 737. The nose contains the active electronically scanned array radar and the front top sensor and two side sensors for the distributed aperture system, or DAS.

Designated the AN/AAQ-37, the DAS consists of six electro-optical sensors placed at various positions on the outside of the aircraft. The system, developed by Northrop Grumman, provides situational awareness in a 360° spherical field around the aircraft. As such, it warns the pilot of incoming aircraft and missile threats and provides day and night vision, fire control capability, and precision tracking of wingmen and friendly aircraft for tactical maneuvering.

Moving back from the nose of the CATBird to just behind the cockpit, the sides of the forward fuselage sprout a pair of fixed canards. The nose-to-canard spacing is geometrically identical to the nose-to-wing spacing of an actual F-35. The canards contain forward-facing sensors that are part of the electronic warfare system.

A spine measuring 8.23m, running on top of the fuselage, contains two more of the six total DAS sensors; the GPS receiver; antennas associated with UHF, VHF, and satellite communications; and several datalinks, including assemblies and interface units associated with the F-35's multifunction advanced datalink. The MADL, as this sophisticated datalink is called, enables the aircraft to communicate within and between flights to share a common view of the battle space.

A structure on the underside of the fuselage, called a canoe, contains additional MADL hardware, another UHF antenna, and the remaining two DAS sensors. Two smaller wing-like surfaces, called strakes, protrude from the fuselage between the main 737 wing and the empennage. These structures contain rear-facing sensors that are part of the electronic warfare system as well as part of the F-35 radar altimeters.

In addition to a fully functional F-35 crew station, the interior cabin boasts 16 work stations that allow system operation, performance monitoring, and data collection

Less visible appendages are two tail cones of the 737 engine fairings. These fairings contain two more aft-facing electronic warfare sensors.

On the flight deck

The flight deck of the 737-300 was mostly untouched, with the exception of the addition of an electronic flight bag. The flight bag, a common upgrade for commercial 737s, consists of a color moving map that aids navigation and a system that provides satellite weather downloads, flight charts, manuals, and other files for the pilots.

A large area just behind the cabin is devoted to hardware racks and a high-fidelity F-35 cockpit sits to the right rear section of these racks. Twenty workstations fill the back half of the aircraft, and the rear lavatories were removed to make room for additional hardware racks and storage. The aircraft retained the forward lavatory and the galley area.

Minimum pilot crew consists of one pilot and one co-pilot. All four CATBird pilots are Lockheed Martin Aeronautics employees. The CATBird engineering team spent a lot of time refining the external design additions of the aircraft to ensure that the aircraft retained the standard flying qualities of a commercial airliner. After the 737 was modified, a short flying qualities test program was flown in the spring of 2007 to validate that the CATBird retained those flying qualities.

The pilots fly with flight test engineers involved in the development and testing of the mission avionics. The crew also has a designated test director and a test conductor, as well as personnel who monitor the network and instrumentation.

The typical duration for a mission systems test flight averages 2.5 hours, with the longest mission systems flights lasting almost five hours. All 11 of the four-hour-plus flights, including mission systems sorties, were flown on the CATBird's deployment to Edwards Air Force Flight Test Center in California. The CATBird has the ability to fly four-hour missions routinely.

"The most complex mission systems testing we perform involves multiship, air-to-air fusion scenarios," explains Ron Kolber, head of the CATBird mission systems testing. "These missions require a tremendous amount of coordination and logistics. They are also some of the most challenging for the F-35 systems.

"Sensor fusion testing is a key advantage that the CATBird brings to the table," continues Kolber. "Although the static infrastructure of fusion software can be tested in ground labs, navigation systems and various sensors require moving inputs to test the fusion algorithms."

The future of fighter aircraft

CATB, or CATBird, is a highly modified 737 aircraft designed to integrate, test, and validate the functionality and performance of the entire F-35 Lightning II sensor suite before it ever flies in an F-35 aircraft. This methodical system of technical risk reduction ensures that the F-35s delivered to US and allied forces provide an unprecedented level of battle-space situational awareness while greatly enhancing combat effectiveness and survivability. The F-35 will have the most comprehensive and powerful sensor suite of any fighter in history, and rigorous testing on board the CATBird verifies that it is dependable and capable, mission after mission.

Next-stage development

CATBird testing will follow a block build-up for mission systems software through the current 'system development and demonstration phase of the program, which finishes with Block 3 software. Given its unique capability, CATBird can also function as an additional static test laboratory when it is on the ground.

First flight of the modified aircraft occurred at Mojave Air and Space Port in Mojave, California, as long ago as January 23, 2007. As of

September 12, 2011, the CATBird has completed 179 flights in the modified configuration, with 114 of these flights in direct support of mission systems testing for the F-35.

A majority of the test flights are from the aircraft's home base in Texas. "In addition to using Edwards AFB, we have also visited Eglin AFB in Florida," notes Dan McDaniel, flight test engineer for the CATBird. "At these government ranges, we can test the F-35 mission systems against high-fidelity threat emitters and various airborne targets. We have also conducted low-level radar altimeter and navigation testing in the mountains near Holloman AFB in New Mexico."

Sister in the sky

CATBird has flown against one and two air adversaries so far. The targets, both in the air and on the ground, will increase in number and complexity as the software blocks progress.

The airborne testbed has successfully demonstrated air-to-air and air-to-ground target detection and tracking with multiple sensor types including radar, electronic warfare (EW), electro-optical targeting system (EOTS), and communication navigation identification (CNI) system. In addition, the radar has successfully performed synthetic aperture radar (SAR) mapping functions and has been used to provide targeting information for joint direct attack munition (JDAM) and GBU-12 guided weapons.

The CATBird is currently supporting the development and test of the Block 2 mission systems avionics hardware and software. Block 2 brings additional sensor, datalink, and sensor fusion capabilities to the F-35 Lightning II sensor suite.

"Even in these early software releases, the F-35 mission systems avionics have proved to be very capable," notes McDaniel. "The capabilities we are refining with CATBird will provide the warfighter with a weapon system that is second to none." ■

Ed Delehant, is the project pilot for the F-35 Cooperative Avionics Test Bed (CATB) with Lockheed Martin Aeronautics

Changes to the aircraft included modifying the nose of the 737 to replicate the F-35, the addition of fore and aft sensor wings to emulate the F-35 wing and control surface edges and the addition of external structure on top and bottom to hold F-35 avionics equipment

F135 production trials

Ground testing of the F135 engine that powers the F-35 joint strike fighter has been ongoing at Arnold Engineering Development Center's C-1 test cell since 1999.

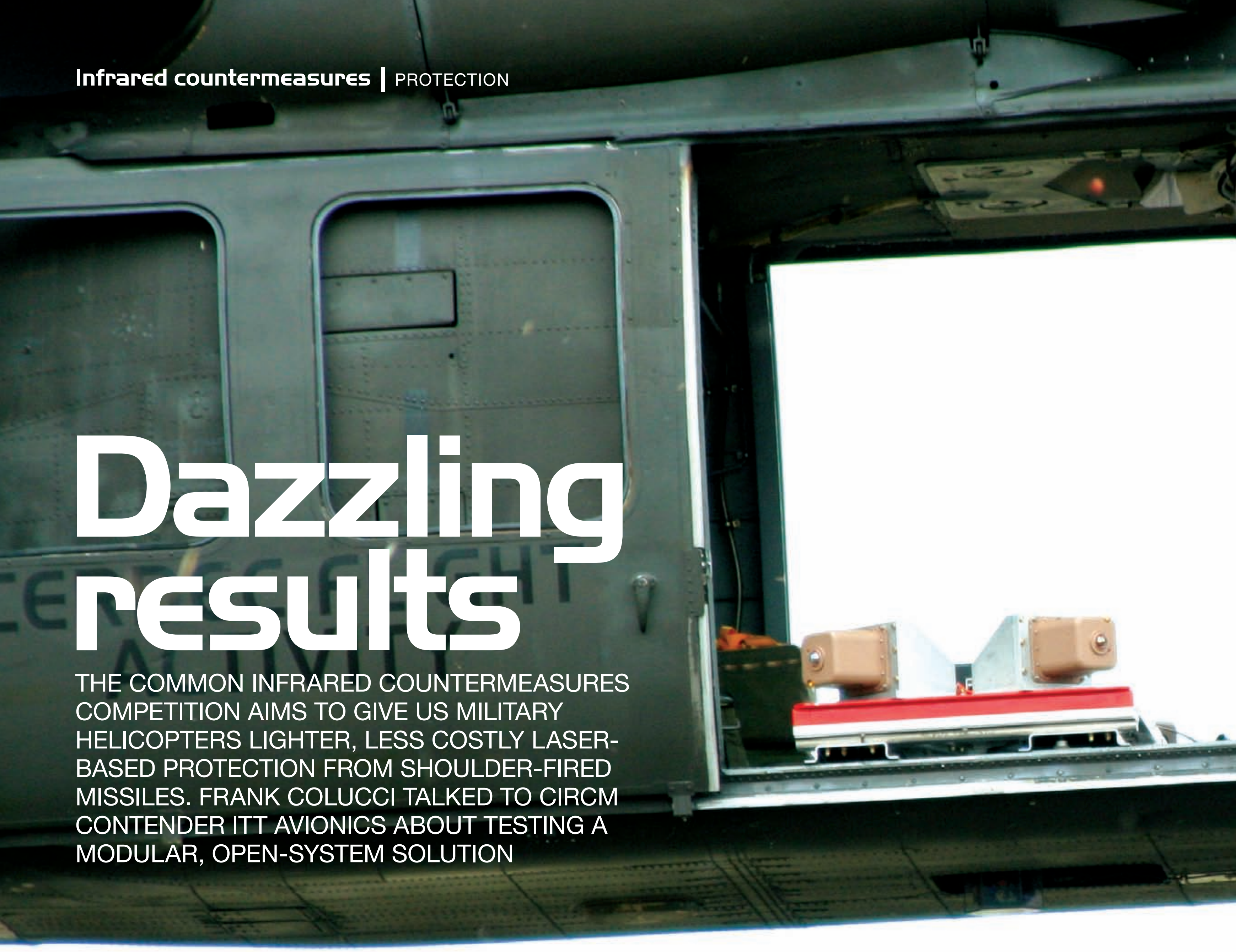
According to John Kelly, AEDC's program manager for the tests, the earliest work performed on the F135 was concept testing. Development testing on the F135 took place in AEDC's Test Cell C-1, beginning in 2004; qualification testing started on the F135 in Test Cell J-2 in early 2009. Ground testing on the F135 has covered a wide range of objectives, from evaluating the engine on alternative fuels to validating engine modifications on both conventional take-off and landing/carrier variant (CTOL/CV) and short take-off/vertical landing (STOVL) variants, some of which are designated for low-rate initial production to the US government for the F-35 Lightning II program.

In October 2010, a test team at AEDC achieved a significant milestone with the F135 STOVL variant of the engine when it successfully completed one of the most rigorous, demanding tests in the entire qualification program. This project was another critical step toward government certification.

The high-temperature margin test which took place at AEDC involved intentionally running the engine to turbine temperatures beyond design conditions while simultaneously operating the turbomachinery at or above 100% of design conditions.

Kelly said with the current testing at AEDC, the Pratt & Whitney F135 continues its steady progress through validation testing to full production and sustainment.

Pratt & Whitney's F135 engine powers the F-35 Joint Strike Fighter for the US Air Force, Marine Corps and Navy, as well as for eight international partner countries.



Dazzling results

THE COMMON INFRARED COUNTERMEASURES COMPETITION AIMS TO GIVE US MILITARY HELICOPTERS LIGHTER, LESS COSTLY LASER-BASED PROTECTION FROM SHOULDER-FIRED MISSILES. FRANK COLUCCI TALKED TO CIRCM CONTENDER ITT AVIONICS ABOUT TESTING A MODULAR, OPEN-SYSTEM SOLUTION

BY FRANK COLUCCI

The last US helicopter claimed in Afghanistan by a shoulder-fired, infrared-seeking surface-to-air missile was a US Army CH-47 Chinook, which was shot down in May 2007 with the loss of seven lives. Since then, Chinooks in combat theaters have fielded an advanced threat infrared countermeasures (ATIRCM) quick reaction capability (QRC) that aims modulated laser energy directly at the incoming missile seeker to dazzle the threat and confound its guidance system.

Other directed infrared energy countermeasures (generically, DIRCMs) protect US Marine Corps CH-53s and Air Force CV-22s. The Army now wants a lighter, less costly, more readily integrated common infraRed countermeasures (CIRCM) system to protect a range of rotorcraft, including those of the Navy, Marine Corps, and Air Force. ITT Avionics in Clifton, New Jersey, is competing for the CIRCM Technology Development phase. Lead engineer Dr John Janus explains, "These systems operate in a truly dynamic environment." Lasers, pointer-trackers, and integrated controls have to contend with the vibration and temperature extremes of a maneuvering helicopter and the behaviors of supersonic missiles. "It's almost impossible to recreate all those things simultaneously in the laboratory or the test range," he acknowledges. "We take pieces of these systems and test them throughout the environment."

Testing in the CIRCM Technology Maturation phase tried competing systems in industry and government laboratories and on aircraft. The ITT TM system, for example, flew four times at Lakehurst, New Jersey in June 2010 on a Black Hawk belonging to the Army Communications-Electronics Research Development and Engineering Center (CERDEC) Flight Activity (see *Inside the Megabase,* June 2010 issue). The CIRCM prototype tracked and laser-jammed captive missile seekers on the ground.

Equally important, it exercised an essential modular open system approach (MOSA) by using two different lasers in different test flights. "That both demonstrated our MOSA architecture and validated that we have multiple laser sources," explains Bob Ferrante, vice president and general manager of ITT Electronic Systems' Airborne Electronic Attack Division.

ITT Avionics, BAE Systems, Northrop Grumman Electronic Systems, Raytheon Missile Systems, and Lockheed Martin Missiles and Fire Control have submitted proposals for the 21-month CIRCM technology demonstration (TD) phase. Two TD winners will ultimately compete for one engineering and manufacturing development (EMD) contract and subsequent production. The Army alone has a procurement objective of 1,076 CIRCM systems to protect Apaches, Black Hawks, Chinooks, and a Kiowa Warrior successor with a First Unit Equipped in 2017.

The Navy and Air Force collaborated with the Army on joint CIRCM requirements, and the Navy looks for a missile jammer that is lighter and more integrated than the large aircraft infraRed countermeasures (LAIRCM) which currently protects Marine CH-53s.

Blind the threat

First-generation man portable air defense systems (MANPADS) including the old SA-7 homed only on helicopter hot metal parts in IR Bands I and II. Later missiles seek Band IV emissions from helicopter exhaust plumes and other sources. The Russian SA-24 exported to Venezuela and the Chinese QianWei 2 made in Pakistan are both credited with dual-band seekers able to reject decoy flares. Against such smarter threats, the effectiveness of MANPADS countermeasures depends on maximizing the ratio of jammer signal strength to target source signature.

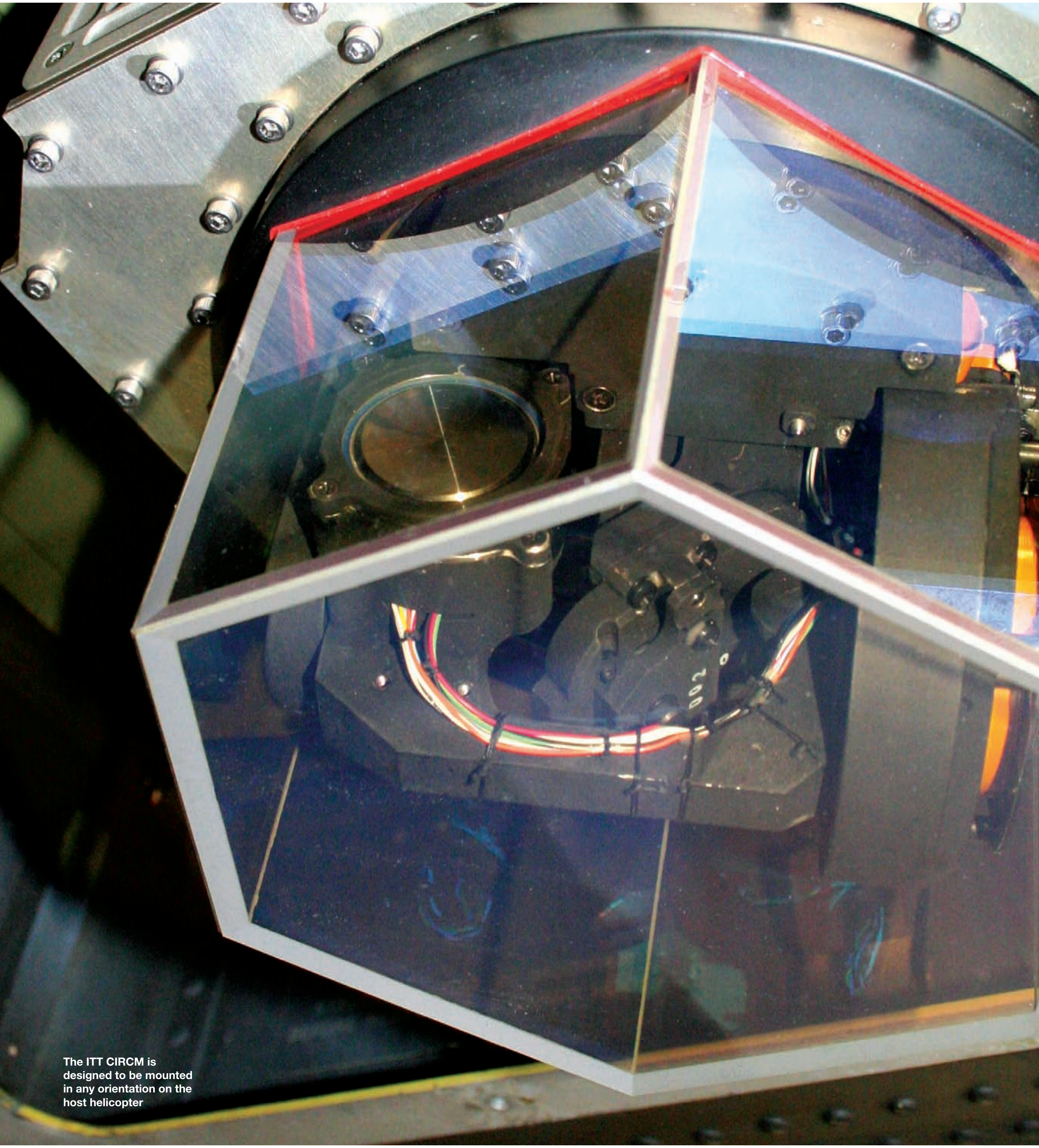
ITT flight-tested its CIRCM system on a Black Hawk of the Army Communications-Electronics Research Development and Engineering Center (CERDEC) Flight Activity (Pictures: ITT)

Omnidirectional flash-lamp jammers that have long been used on combat helicopters broadcast weak IR energy in a protective sphere. Cued to the threat by separate missile warning Receivers, DIRCM systems use precision pointer-trackers to aim lasers that put more than 1,000 times as much energy directly on the approaching missile seeker. CIRCM requirements emphasize MOSA so the system can work with different warning receivers, cockpit displays, flare dispensers, or aircraft architectures.

MOSA standardizes hardware and software interfaces to let CIRCM incorporate better, lighter, or cheaper components without lengthy re-qualification of the entire system. ITT engineers initially based their CIRCM offering on an optically pumped semiconductor laser, but MOSA enabled them to switch seamlessly to single-chip quantum cascade laser technology. "That's a much more efficient and reliable technology to use," says Dr Janus. The modular approach also made it possible to fly quantum cascade lasers from both Daylight Solutions and Northrop Grumman.

MOSA may accommodate smarter processors and new lasers over time to adapt CIRCM to do more than jam missiles. It also has powerful implications for testing. "In our approach to system design, we took a top-down engineering

> **"Two TD winners will ultimately compete for one Engineering and Manufacturing Development (EMD) contract and subsequent production"**



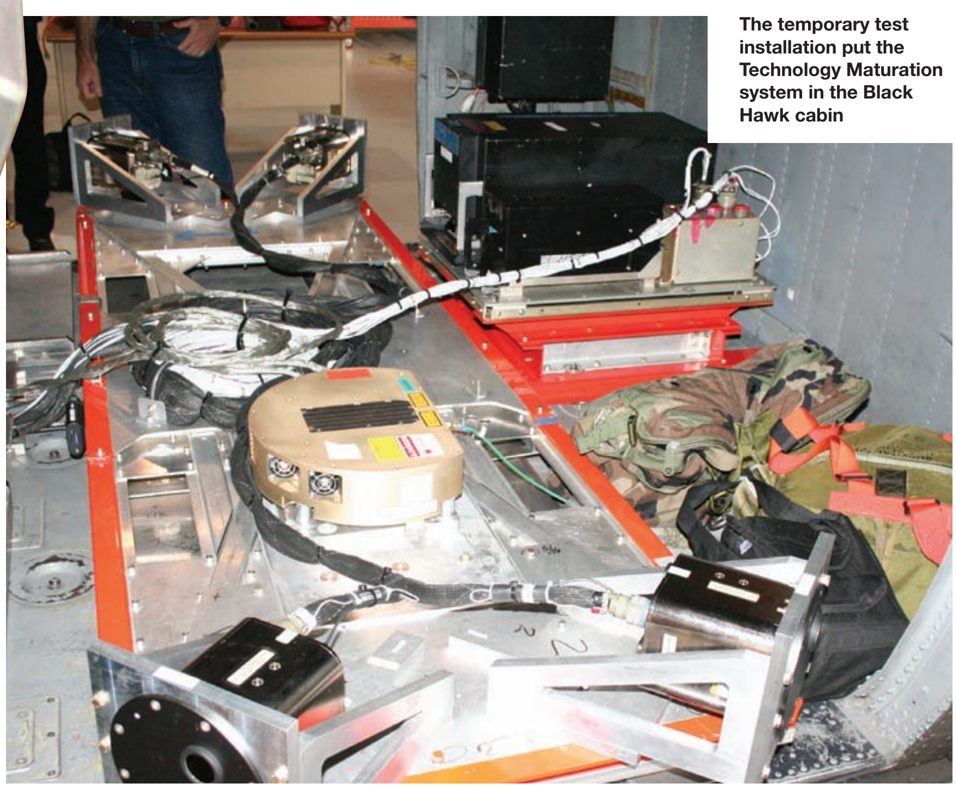
The ITT CIRCM is designed to be mounted in any orientation on the host helicopter

Objective: Integrated ASE

MANPADS attacks in Iraq and Afghanistan quickly drove the US Army to improve and standardize its helicopter aircraft survivability equipment (ASE) with the AN/AAR-57 common missile warning system (CMWS) and ALE-47 improved countermeasures dispenser, a 'smart' dispenser that sequences a flare 'cocktail' to defeat today's more discriminating IR missile seekers. The ALQ-144 and other legacy jammers that broadcast infrared energy will give way to the laser-pointing CIRCM. MANPADS countermeasures nevertheless remain only part of the Army's balanced survivability approach to infrared, radio frequency, laser, and unguided ballistic threats. The Army Aviation Center at Fort Rucker wants additional capability in an integrated, common, modular self-protection suite around 2015. Truly integrated ASE systems can also be networked to locate threats for other members of a combined arms team.

New ASE still adds unwanted weight and requires expensive integration, despite the databused architectures and digital cockpits in new Black Hawks, Apaches, and Chinooks. The OH-58D Kiowa Warrior only recently received CMWS protection, but true integration awaits an OH-58F cockpit and sensor upgrade in service around 2015. The APR-39 radar warning receiver and coupled AVR-2 laser warning receiver remain essentially strap-on devices with their own cockpit controls and displays. The 30-year-old APR-39 is receiving a processor upgrade by 2013, and the new AVR-2B adds an additional laser band. Though new CMWS hostile fire indicator software promises to detect rocket-propelled grenades and small arms flashes, Block III Apache Longbows will field an electro-optical (EO) ground fire acquisition system (GFAS) quick reaction capability in Fiscal 2012. A new hostile fire detection system is due to commence development in Fiscal 2012, and the definitive hostile fire indicator (HFI) solution may include EO and acoustic sensors.

The need to protect helicopters comes at a time of expected budget cuts, and the current research trend is toward CIRCM-like Open Systems without proprietary software, and potentially able to have more functions added without new hardware. Such systems can potentially protect new aircraft and adapt to new threats without excessive cost and weight. The truly integrated ASE vision may have to wait for a totally new aircraft, and the US Army does not expect the joint-service multi-role (JMR) successor for the Black Hawk and Apache in service before 2030.



The temporary test installation put the Technology Maturation system in the Black Hawk cabin

approach from the beginning," says Dr Janus. "We really embraced a MOSA architecture. By using that modular architecture, it enabled us to break the system up into components and test those components separately as subsystems."

ITT developed the AN/ALQ-211 Suite of Integrated Radio Frequency Countermeasures that controls Aircraft Survivability Equipment (ASE) on the Air Force CV-22 Special Operations tilt rotor, including the Northrop Grumman AN/AAQ-24 DIRCM. The company began researching lighter-weight, higher-reliability solutions to infrared countermeasures around 2004 and evolved CIRCM technologies in the Technology Maturation phase. "We started investing in this business area roughly five years ago," says Ferrante. "We're in about the third iteration of the system."

CIRCM analyses began with a broad survey of the industrial base and with engineering trade-off studies to identify candidate technologies. "Using that information, we determined that the concept of using lasers to counter heat-seeking missiles was an established technology that had been proven," recalls Janus. A team of industry consultants who are familiar with the fielded ATIRCM and LAIRCM focused ITT on higher reliability, lighter weight, and lower lifecycle costs. "When we looked at what was out there from a legacy standpoint and where difficulty arose," recalls Ferrante, "one area was certainly reliability, and the point of design from the pointer-tracker and the laser and all the alignment difficulties that go along with them."

ITT first tested a stabilized gimbal, key to a fast-moving pointer-tracker that would maintain line-of-sight to a missile seeker. At the Clifton facility, a simple rotary table provided mock aircraft motion while a linear track carried an off-the-shelf infrared source about 60ft away. "As we developed the system, we implemented more sophisticated test systems where we introduced a multi-axis motion simulator to really recreate a full aircraft dynamic environment," explains Janus.

Government agencies provided MANPADS threat data, and a Systems Integration Laboratory (SIL) set up at Clifton performed short-range dynamic tests of tracking capability and laser propagation. Simulated target engagements in the ITT SIL from June 2006 to April 2007 led to risk-reduction flight tests in 2007 to validate the laser pointer-tracker design. Also in 2007, the Navy's Advanced Tactical Aircraft Protection Systems facilities at Naval Air Engineering Center Lakehurst ran systems-level tests against captive seekers in a representative environment. ITT built a number of brassboard and prototype systems for tests. "It's staged, but many of these tests were conducted concurrently in rapid succession," says Janus.

"Our test facility here at Clifton and our initial flight tests revolved around the pointing accuracy and generating laser energy on a missile target in the threat environment." Laser makers and other suppliers leveraged their own test facilities. "Once those subsystems were tested, we integrated them in a staged approach," says Janus. "It's a combination of subsystem tests leading up to a temporary installation on a helicopter in the flight test environment."

Crane Naval Surface Warfare Center in Indiana built the multi-seeker missile simulator used for CIRCM live fire test

Reliability and live firing

US government engineers also oversaw reliability testing at Clifton through the full temperature and vibration environment specified for CRICM. The Technology Maturation system spent around 700 hours in temperature and vibration chambers. "Let me tell you, that government guy got really tired after 700 hours of sitting there," notes Bob Ferrante, vice president and general manager of ITT Electronic Systems' Airborne Electronic Attack Division. The convection-cooled system nevertheless proved capable of operating in temperatures to 71°C with no air movement. "That's a key design point for the system," Ferrante adds. "You can maintain operational performance in that environment with no fans. That increases reliability in dust and sand." Similar environmental testing in the Technology Development phase will stretch to more than 2,000 hours.

Live-fire flight testing on a Black Hawk in 2008 at Lakehurst put the demonstration CIRCM in a more dynamic environment against simulated missile ground launch signatures. "In our first flight test, we used relatively short range, and had a large target board and an off-the-shelf hot-plate as an IR source," recalls Janus. The airborne system tracked the stationary ground source with the helicopter in hover, rapid ascent, and cruising flight. "Later, we used a modulated IR source and integrated radiometer from Scitech. We measured laser power on the ground-based source." In 2010, the target was a government test van built by Crane Surface Warfare Center with an IR source, a radiometer, and multiple missile seekers tracking the aircraft through different flight profiles. The fiber-optic system employed countermeasures in less than one second from simulated missile launch. "Those seekers are instrumented so they can validate that they lost guidance," explains Janus.

Live-fire testing also extended to ranges in Tonaph, Nevada and White Sands, New Mexico where the CIRCM system acquired and tracked real missiles. The system proved able to follow missile signatures from launch through their full flight profile. The ITT system changed little with testing, says Janus. "Surprisingly, it was more just the detail of the implementation and doing the final tweaks to meet some specific requirements."

Subsystem testing and trade studies validated an early ITT decision to adopt a fiber-optic system architecture. "We recognized fiber-optics was an industry with a strong heritage," says Janus. "We were able to leverage that to decouple the laser from the pointer-tracker." Optical fibers carry laser energy from source to apertures to increase reliability, hike Mean Time Between Failure, and lower Mean Time To Removals with corresponding reductions in life-cycle costs.

Ferrante adds, "By using infrared fiber to transmit that light, we're able to decouple those two and keep that boresight without highly complicated correction servo mechanisms." Decoupling the pointer-tracker from the laser also provides a pathway to integrate future subsystems and use CIRCM for laser communications, rangefinding, and hostile fire countermeasures. "Another benefit was that we could reduce weight substantially by not having a mechanical connection between the pointer-tracker and the laser."

With two laser heads for all-round protection, the BAe ATIRCM on Chinooks today weighs around 160 lb. The Northrop Grumman LAIRCM on CH-53s weighs more than 190 lb. Cable and supporting hardware boost installed weight of either system to more than 350 lb. Joint-service requirements put CIRCM target weight at 85 lb for the jamming B-kit with two turrets. The supporting A-kit is limited to 70 lb for large rotorcraft such as the Chinook and Osprey, or 35 lb for smaller helicopters like the Black Hawk with less wiring.

> **"We could reduce weight substantially by not having a mechanical connection between the pointer-tracker and the laser"**

EnLITEned testing

The Army CERDEC opened its own Laser Infrared Countermeasures Test and Evaluation (LITE) facility at Eatontown, New Jersey in 2009 to advance competing CIRCM technologies. Inside the lab, an "own-ship" motion table carried each vendor's pointer-tracker while a simulated threat rode a Cartesian table 60ft away. Infrared and closed-circuit TV cameras documented simulated engagements. The LITE lab coupled CIRCM candidates with the Army's current Common Missile Warning System (CMWS), and it measured tracking accuracy, pointing precision, and laser power received on the seeker dome. "It was an end-to-end system test that was completely autonomous and cued by external stimuli," explains Dr Janus. ITT ultimately integrated its CIRCM solution with the BAE CMWS, Elisra PAWS (Passive Airborne Warning System), and Lockheed Martin candidate Joint and Allied Threat Awareness System (JATAS). The LITE lab and an identical CERDEC facility at Aberdeen, Maryland will test CIRCM competitors in the Technology Development stage.

With their proposal submitted, ITT engineers are already testing their first Technology Development system. Ferrante concludes, "If our assertion is correct that our system is ready for Prime Time, and we move into the EMD phase, a lot of the testing the government is going to do for the TD phase is probably applicable to the EMD phase." ∎

Frank Colucci has been an aerospace journalist and industry writer for 30 years. He routinely covers aircraft design, operations, and test, and writes about avionics integration and other advanced technologies. He has been a contributor to Aerospace Testing *since its inception*

Green with navy

THE US NAVY HAS MOVED ANOTHER STEP TOWARD ACHIEVING ITS RENEWABLE ENERGY GOALS, WITH THE LATEST USE OF BIOFUELS ON THE T-45 TRAINER

Rick Kamin, the US Navy's fuels and lab team leader. Left: The T-45 Navy trainer

BY CHRISTOPHER HOUNSFIELD

The US Navy's alternative energy program went a stage further when a T-45 training aircraft completed a successful biofuel flight at the Naval Air Station (NAS) Patuxent River.

The 'Salty Dogs' of Air Test and Evaluation Squadron (VX) 23 flew the jet trainer on a biofuel mixture of petroleum-based JP-5 jet fuel and plant-based camelina.

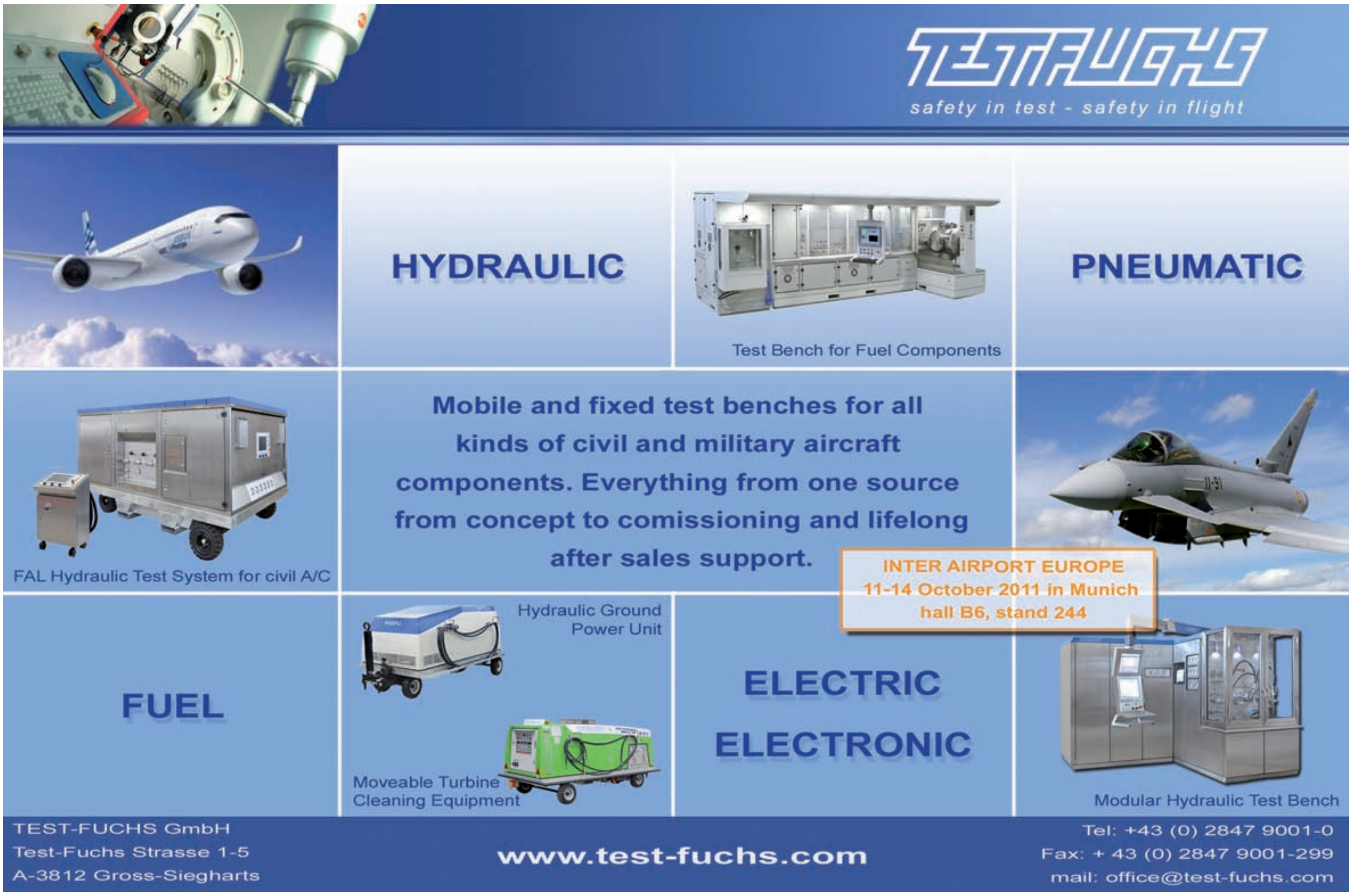
The T-45 'Goshawk' is a tandem-seat aircraft used by the Navy and Marine Corps to train pilots on carrier and tactical mission operations. This is the fifth aircraft successfully tested using biofuel at NAS Patuxent River and showcases the Navy's commitment to achieving energy independence by reducing the need for foreign oil.

Previous aircraft tested include the F/18 E/F, MH-60S, F/A-18 D, and most recently, the MV-22. Navy Secretary Ray Mabus's goal is to cut the Navy's oil usage in half by 2025. Three additional Navy aircraft are scheduled for biofuel test flights before the end of the year. This initiative is one of many throughout the US Navy and Marine Corps that will enable the Department of the Navy to achieve Secretary Mabus's energy goals to improve energy security and efficiency, increase energy independence, and help lead the nation toward a clean-energy economy.

The man behind the mission is Rick Kamin, a civilian. His title is Naval Air System Command Research and Engineering Fellow, which translates as the guy in charge of the entire program for the US Navy's alternative fuel efforts. "The program was instigated about two years ago when Navy Secretary Mabus announced his energy goals for the Navy and his desire to move the Navy off its dependence on petroleum.

"The T45 was just one of the aircraft in the platform that we are moving forward, testing and demonstrating the 50/50 blend of petroleum and renewable fuel," explains Kamin.

The Navy works closely with the other services and even the commercial sector, and cross-border as Kamin describes: "We share



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11-14 October 2011 in Munich
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The Honeywell-operated G450 business jet was the first aircraft to cross the Atlantic using a 50/50 blend of Green Jet Fuel made from camelina seeds and petroleum-based jet fuel

Commercial trial leader

Since the launch of its technology to produce Green Jet Fuel in 2008, Honeywell's UOP has steadily worked to prove the viability of this option in a variety of commercial and military applications. Airlines are facing considerable operational challenges that place their profitability – the one business priority that drives everything else they do – in question. The driver in this issue is the volatile cost of fuel, reducing profit margins. Juxtaposed against profitability is a greater need for efficiency and a sustainable source of energy that will help airlines reduce emissions while allowing them access to a fuel source with predictable prices. At this critical juncture in the airline industry, new sources for energy have never been more imperative.

Global governments and the US military are also aiming to reduce overall energy consumption and increase their energy security. Renewable energy initiatives enable an increase in energy efficiency on platforms and at facilities to reduce adverse impacts on the environment, improve the energy efficiency of existing infrastructure, design-in energy efficiency to new infrastructure, expand renewable options, and help militaries to manage their energy costs.

Technology can help. From advanced avionics to energy-efficient jet engines and innovative and sustainable biofuel, innovations from Honeywell are helping address these needs today with an eye to the future.

In just three years, Green Jet Fuel made using the process technology from Honeywell's UOP has been tested on a wide range of military and commercial applications to help airframers, airlines, and the military to meet their goals. This includes more than nine demonstration flights with commercial airlines or business jets, and every US military flight testing flight to date. Some of the test highlights include:

- The first aircraft to break the sound barrier using Green Jet Fuel on the Navy F/A-18 "Green" Hornet on Earth Day 2010;
- The first biofuel helicopter flight on an Apache helicopter flown by the Royal Netherlands Air Force;
- The first transatlantic biofuel flight, from Morristown, NJ to Paris in June 2011;
- The first boat demonstration on biofuel on a Navy Riverine Combat Boat (RCB-X);
- Successful ground testing of the TPE331 turboprop and TFE731 jet engines as well as a commercial auxiliary power unit;
- The first commercial, passenger-bearing flight to travel across the Atlantic flow from Mexico City to Madrid by Aero Mexico.

The Green Jet Fuel program was a major part of the testing and eventual approval of Green Jet Fuel by ASTM International for commercial flight. Using data collected throughout ground and flight testing initiatives, ASTM, the international governing body for product standards, was able to approve this fuel for commercial, passenger-bearing flights in a 50/50 blend with petroleum-based fuel on July 1, 2011. This approval means that airlines around the world can now begin using the biofuel on regular routes to begin addressing their energy challenges. It also means that the companies and individuals who have worked tirelessly to grow these plants and supply them to equally hard-working refining partners will now be able to move forward with expanding operations up to a commercial scale.

information, and coordinate results; we try to minimize duplication and we're all in this together. It's to qualify fuels across the board, and from an Air Force and Navy perspective it's a joint operability issue. So all the information that we put together we share amongst the other players in the alternative fuels efforts.

"We have shared our information with our allies. We try to pass on anything that we test both in aircraft and ship, because it is an interoperability issue. When we are on exercise together or in various places in the world, we are sharing fuel. So anything that we do as a country to look at alternatives, we have to make sure that everyone who could potentially use the fuel also understands the efforts and the processes, so they're comfortable that if they pick up the fuel during a coordinated mission, that they're good to go."

The big challenge

When questioned on the major challenges that faced the fuel development team, Kamin reveals that it wasn't a technical issue, but rather the approach to fuel usage. "It's in the culture. We're in a culture that uses petroleum. All our fuels come from petroleum, we have always used petroleum. So to demonstrate an equivalent of something other than petroleum is an education process and an evolving process that allows people to become comfortable and realize that we can make fuel that's acceptable for naval applications, whether it be aircraft. It is something that doesn't come from oil taken out of the ground.

"It takes a process to educate and understand that the finished product is really all that the operator's concerned about. The fuel that goes into their aircraft, how it is produced, and where it comes from is an important point, but it's really the performance of the fuel that is the only important thing that the pilot cares about.

"The whole intention of our program is to demonstrate that the performance of a fuel produced from a renewable source, a jet fuel, is equivalent in operation to others, and I think that is what we've seen to date, with our laboratory testing and our engine testing and our aircraft flight tests. We were running the Blue Angels (the Navy display team) a couple of weeks ago here at Pax River on biofuel. The performance was similar and the pilots could not notice the difference," Kamin says.

Setting standards

Any technical problems were dealt with at an early stage in the development process, pre-T-45 tests. "The technical hurdle we faced in the process was early on and that was to make sure that we developed a systematic and robust process to test the fuel, especially in the laboratory. That meant developing confidence that the fuel coming out of the laboratory when we go to engine and flight testing would not have any issues. You have to realize that, as the Navy started this process. It must be understood that we did not have a protocol in place about how you test an alternative-source fuel. So we had to develop that process and get the cooperation and coordination from the various stakeholders across the Navy of what we're going to test, and how to do it. The key was to develop the process."

Neste Oil produces NExBTL diesel at two units at the Porvoo refinery in Finland and at one plant in Singapore. A fourth NExBTL plant is under construction in Rotterdam

Fuel quality

Airlines are becoming increasingly interested in biofuels, as the industry needs to reduce its greenhouse gas emissions and dependence on fossil fuels. Neste Oil's cooperation with Lufthansa in the area of aviation biofuels saw Lufthansa begin commercial flights using Neste Oil's NExBTL renewable aviation fuel on July 15 this year.

Lufthansa is currently using NExBTL renewable aviation fuel on four daily return flights between Hamburg and Frankfurt. One of the engines of the Airbus A321 operating these regularly scheduled services is powered by a blend of 50% NExBTL renewable aviation fuel and 50% fossil fuel; the other is powered by regular fossil-based jet fuel.

The use of Neste Oil's NExBTL aviation fuel became possible on July 1 following the decision by ASTM International, formerly known as the American Society for Testing and Materials, to approve the use of renewable aviation fuel produced by hydrotreating vegetable oil and animal fat.

Production of NExBTL aviation fuel

Neste Oil's renewable aviation fuel is based on the company's NExBTL technology, and is produced by hydrotreating animal fat and various types of vegetable oil. The end-product is used as a bio-based blending component for conventional JET A1 fuel.

Neste Oil is currently one of the only companies in the world capable of producing renewable aviation fuel on a commercial scale. Its four NExBTL plants in Finland, Singapore, and the Netherlands can produce both NExBTL renewable diesel and NExBTL renewable aviation fuel.

Aviation fuels need to have a high energy content and be capable of operating at very low temperatures. As a pure hydrocarbon comparable to fossil aviation fuel, Neste Oil's NExBTL renewable aviation fuel meets these criteria.

Neste Oil works in close operation with ASTM and was involved in developing the new D756 standard. Extensive fit-for-purpose tests were carried out on NExBTL renewable aviation fuel as part of this work. The fuel meets the D7566 standard and is fully compatible with all current aircraft engines. It also offers a lower level of environmental impact, due to its considerably smaller carbon footprint and lower levels of other airborne pollutants, such as nitrogen oxide (NOx).

What makes the process unique to the US Navy is based on application, which is why it has its own test laboratory, with a development crew of 12 and an expanded team of up to 50 when you include the engine, flight test, and component experts. "We all have different, unique applications. A commercial airplane doesn't fly the same as a jet fighter, the sea environment isn't the same as a land-based environment, so we all have little differences that we have to make sure are acceptable," notes Kamin.

Possibly the most incredible fact is that there has been absolutely no need to adapt the engines. Although engine tests are an essential part of the procedure, this is all just part of the fuel test program, not the engine. As Kamin states, "The biggest success is every time we run a flight test, the pilot's initial comments have been that they could not tell the difference. So it proves the work we've done in the laboratory and the work that we've done to get the flight test has been correct, and has been successful because our ultimate goal is the end user; the pilot shouldn't know the difference between these fuels from what they've been traditionally flying on.

"We fill up the plane using petroleum-based JP5 one day; the next day it started its flight test program with the biofuel – we fill it up with the 50/50 blend of the bio-petroleum and it runs, it operated, it conducted its flight test program as designed and when it was done, we just put back petroleum-based JP5 and it went back to its business. It's a true drop and replacement, no changes.

"You can mix and match; it's not like the current bio-diesel that you have for your cars or your trucks, it's true mix and match. No modifications to getting the fuel to the aircraft, or the aircraft itself," notes Kamin.

The next step

The US Navy does not get involved with the commercialization of the biofuel product, which is an essential element and the next stage in the development process. The system has to be proved, and it will have to have a solid customer base before that step can be taken, as Kamin explains, "The Navy's role is a test and evaluator, we're not a role in developing the fuel technology or making the fuel technology better. Our role is to demonstrate that it can be used successfully in our aircraft and ships. So for the fuel we're looking at now, these hydrotreat renewable jets or HEFAs."

What is interesting to note is the source of the fuel. I was expecting it to come from farmed crops, but Kamin is very keen to distance the Navy from this: "We do not go with corn fuels. The key goal for the Navy program is we do not want to tie into food crops. We do not want to interfere with food crop production, we don't want to use food crops, we don't want get into a food versus fuel issue.

"There are other sources besides algae and besides plant crops. There are people making fuel from municipal solid waste.

"There are processes to look at other sources of biomass to make fuel, and I think the next step in the Navy process is to look at these other sources and these other ways to make fuel and see which of them has the greatest potential to start looking at doing laboratory and eventually flight testing."

Right now, biofuel being used for the T45 program has been 'Camelina', a mustard seed crop. But as Kamin explains, the prime goal has been simple: "The good news story is that you can make fuel from something other than petroleum, [and] that fuel can be used in the Navy's high-performance aircraft, whether it be a T45 or an F18 or, you know, a Harrier." ∎

LEAK from the top

STRINGENT SAFETY AND QUALITY REQUIREMENTS MEAN THERE IS NO MARGIN FOR ERROR IN THE AEROSPACE INDUSTRY

BY AUSTIN WEBER

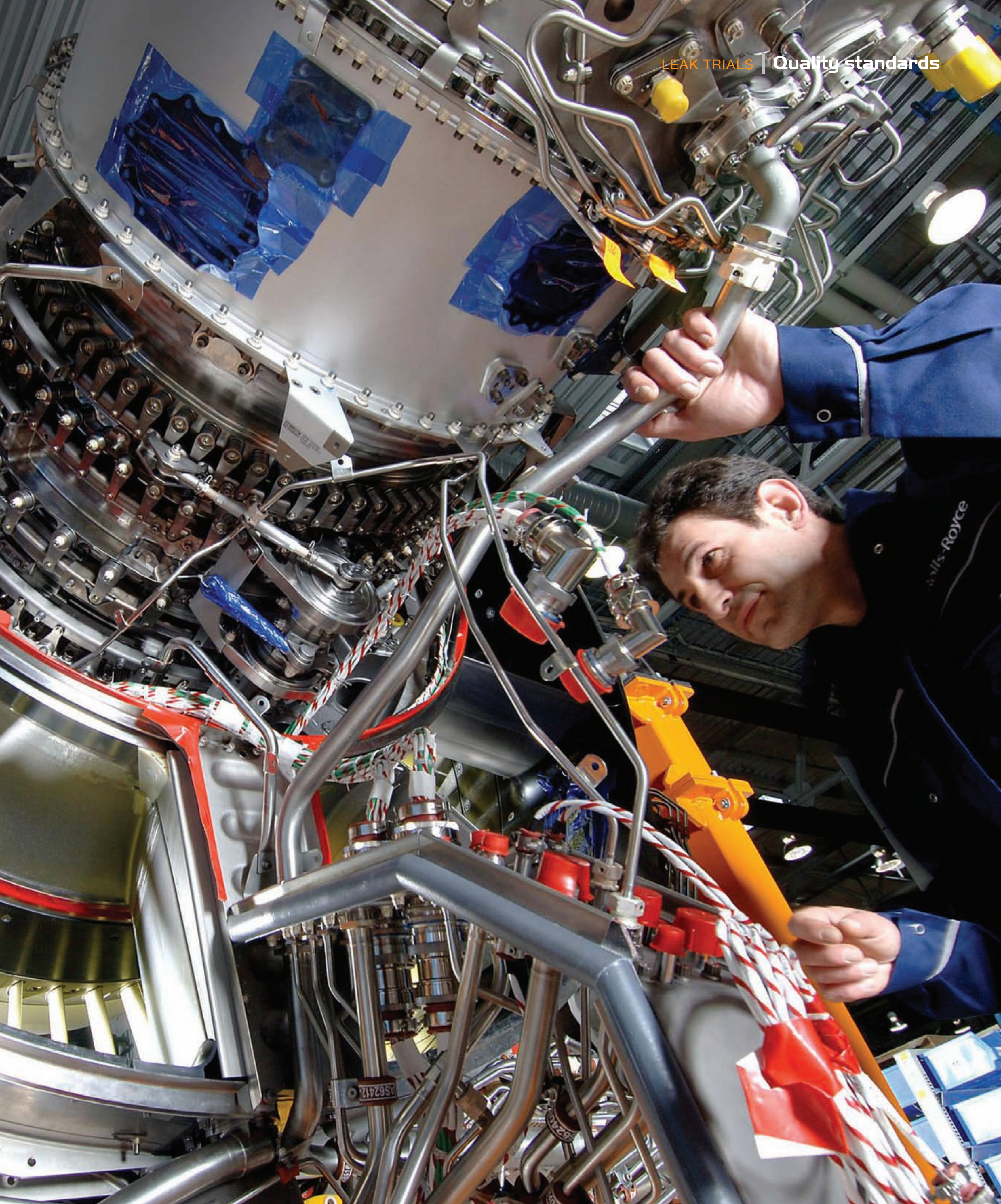
Leaks are never good. They're even worse if you're flying in an aircraft at 40,000ft. That's why aerospace manufacturers and suppliers spend countless hours testing critical components. Fuel systems, engines, landing gear, ventilation systems, and other aerospace devices that rely on numerous tanks, pumps, actuators, lines, and fittings must be tested for tightness during both assembly and maintenance applications.

Sometimes, no amount of preparation can prevent irritating leaks occurring in flight, as engineers at Lockheed Martin Aeronautics Company recently discovered. The problem-plagued F-35 Joint Strike Fighter program was grounded a few months ago by an oil leak during a test flight in southern California.

Fighters, jetliners, cropdusters, helicopters, satellites, rockets and other things that fly are prone to many types of gas and liquid leaks. They're also subject to different stresses, atmospheric pressures and quality standards than down-to-earth products such as automobiles, dishwashers and inhalers. That puts unique challenges on aerospace engineers.

"We are dealing with the safety of large amounts of passengers in a black-and-white type of situation," says Thibault de La Grandville, a sales engineer at ATEQ-Omicron. "Either things go well and you arrive safely, or they go wrong and the consequences can be highly tragic. Things rarely go half right or half wrong in this field and lives are at stake."

While fuel lines and hydraulic systems are obvious candidates for leak testing, it's also essential to test cockpit instruments, such as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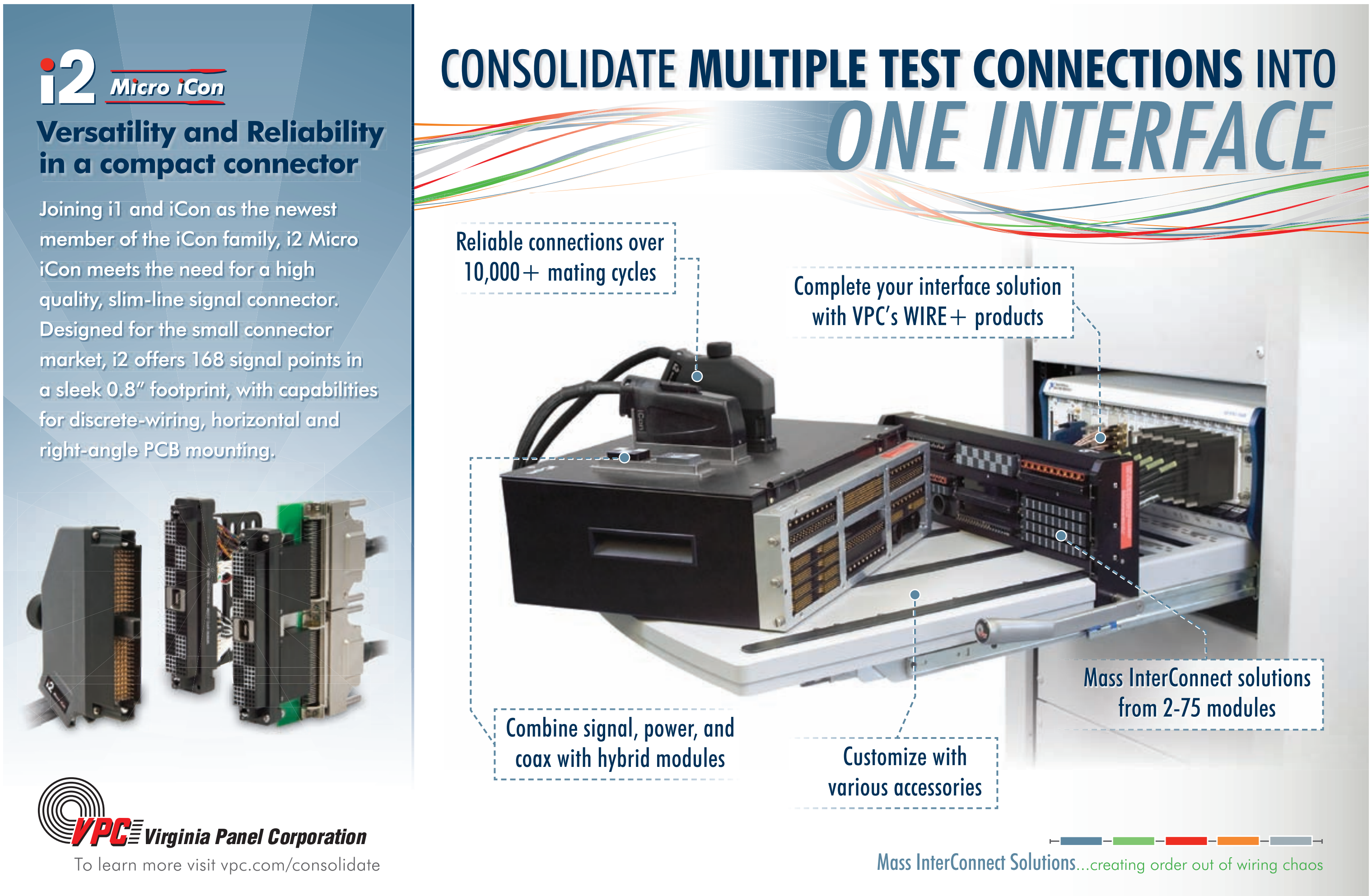
i2 Micro iCon
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Mass InterConnect solutions from 2-75 modules
Mass InterConnect Solutions...creating order out of wiring chaos

altimeters. If there's a leak in the circuit, pilots will get an erroneous reading of altitude, speed, or rate of climbing.

"At every stage (of aerospace assembly) everything needs to be checked with the utmost care," de La Grandville points out. "The pressure to deliver a reliable product is very high. Safety comes before cost more in aerospace than in any other industry."

Stringent standards

That's why aerospace manufacturers require high levels of quality certifications with leak-testing equipment, such as ISO 9001 and AS9100, in addition to safety certifications, such as UL 913. Many companies are also subject to stringent standards, such as MIL-STD-750, Method 1071, which covers hermetic seals, and IP67, which covers leaktight enclosures.

"The specifications for aerospace can be tighter than some other industries," says Martin Bryant, vice president of sales and marketing at Uson LP. "Aerospace manufacturers require high traceability and, therefore, leak testers and systems should be able to comply with data collection and part identification requirements such as barcode, 2D matrix or RFID reading."

"Aerospace leak testing is similar to the medical industry, but compared with automotive, it is slower to change procedures," adds Dave Morris, marketing manager at Alcatel Vacuum Products. "Aircraft or systems on board aircraft are tested manually. Smaller components are more automated, but compared with the automotive industry, batch sizes are quite small."

Manufacturers and suppliers are often held to a much higher standard. They're also subject to random spot checks and various red tape related to International Traffic in Arms Regulations.

"This industry is required to adhere to military standards, which mandate a tremendous amount of record keeping and data retention," says Chris Goebel, senior director of component sales and marketing at ULVAC Technologies Inc. "Aerospace is more demanding and asks more questions than any other industry we work with. When we've been working on projects for NASA, people from the FBI have arrived at our door, unannounced, to check records."

Smaller production volumes and throughput speeds also set aerospace apart from other industries. Traditionally, aerospace manufacturers move at a leisurely pace. In sharp contrast, automotive fuel lines, radiators, brake lines and other components typically need to be tested in 20 to 30 seconds per part. Some disposable medical devices must be tested even faster, as quickly as one part every two seconds.

"The typical medical device manufacturer makes thousands of parts a day," says Gordon Splete, account development manager at Cincinnati Test Systems Inc. "On the other hand, a helicopter manufacturer may be assembling just one vehicle a week. A company making fuel pumps for aerospace applications might only assemble 2,000 a year; an automotive supplier might build 2,000 units daily or weekly.

"Production-rate-wise, certain components may have less throughput requirements in

Leaks in space

Spacecraft present even bigger challenges to aerospace engineers. For instance, companies that manufacture space instrumentation, satellites and other devices have to subject their products to a battery of prototyping, flight qualification and flight verification phases.

"Before launch, the products must experience space-like temperatures and vacuum levels, and be shown to not only survive the extreme ranges, but also operate within specification before, during and after," says Margaret Bishop, business development manager at Abbess Instruments. "Space simulation chambers are key to these tests." The custom-built equipment simulates launch-to-space pressures, focusing on space vacuums at altitudes above 100,000ft.

Innoventor also works on out-of-this-world leak-testing applications. For instance, it recently designed a one-of-a-kind helium leak test system for Boeing's launch vehicle facility in Decatur, AL. The automated system tests 110 different locations on the Delta IV upper stage propulsion system, which carries heavy payloads, such as satellites, into orbit.

"We developed a helium mass-flow detection system that [enables] the upper propulsion system portion to function at maximum operating pressure," explains Kent Schien, CEO of Innoventor Inc. "Using a dual vacuum system design and a mass spectrometer, it can measure individual helium leaks in 15 to 20 seconds." The device reduced a 16-to-20-hour test cycle to less than one hour.

"As technology advances both in heavy lift capability in the aerospace sector and the higher usage of technology in the automotive sector, the technologies for leak testing are converging," notes Schien. "New aircraft systems are using more and more automation in leak testing.

"For example, Boeing's 787 program uses much more automation than any past programs," Schien points out. "The ultimate end goal [for the aerospace industry] is a universal system that could test and give back quantifiable data of a component, a subsystem or a system."

Left: The F-35 Joint Strike Fighter was grounded recently due to an oil leak (Photo courtesy Lockheed Martin Aeronautics)

Below: Leak detection is an essential part of aircraft manufacturing (Photo courtesy Bombardier)

aerospace compared with automotive," adds Splete. "This affords more time for testing and for considering technologies to be used in the production timeframe allowed. Low production rates enable some manual intervention with the parts, rather than fully automated processes."

Smaller production volumes can also pose bigger leak-testing challenges. "It's unlike the automotive sector, where you are talking about thousands or millions of parts per year in volume, and leak-testing systems can be afforded," notes Kent Schien, CEO of Innoventor Inc, a design-build engineering firm that has worked on numerous aerospace leak-testing applications.

"The aircraft industry only has [to test] hundreds or dozens of parts per year," Schien points out. "It's even less in the spacecraft sector; maybe only one or two parts annually. Therefore, standardization is difficult."

Size matters

Most aerospace parts are larger and heavier than automotive and medical components. Pumps and other hydraulic components typically operate under much higher pressure and are physically larger and stronger than devices used for automotive application.

That poses some leak-testing challenges. For instance, it's hard to put a jet engine or a landing gear in a test chamber. As a result, most testing usually occurs during subassembly instead of final assembly.

Leak testing is critical to the performance of avionic and flight deck instruments (Photo courtesy Honeywell Corp)

"Trace gas, helium, hydrogen and even sulfur hexafluoride, seem to be more popular in the aerospace industry than in others"

"Our customers are leak checking components, such as fittings and bellows, rather than complete systems," says Steve Blair, product manager for leak detection and gauges at Pfeiffer Vacuum Inc.

"Everything is unique in aerospace," adds Splete. "The hardest parts to test are those with irregular shapes and seal surfaces, such as fuel lines and landing gear."

Aerospace manufacturers often prefer test systems mounted on carts for portability. "They typically bring the instrument to the component, because of size and weight restrictions," notes Jacques Hoffmann, president of InterTech Development. "In automotive and medical device applications, you bring the part to the leak-testing equipment."

"Larger components, such as landing gear and ventilation systems, offer challenges due to their size," adds Goebel. "That requires unique leak detection methods, such as using sniffer probes. Smaller, hermetically sealed electronic components are [often] tested using automatic leak-testing systems."

The aerospace industry uses a wide variety of leak-testing equipment and methods. "Helium and hydrogen are typically used when testing large volumes, such as fuel tanks," says Hoffmann. "Actuators and other components use hydraulic testing."

The types of testing methods used are often dictated by the test measurement criteria, such as flow rate and pressure, and the type of part to be tested. "Pressure decay or vacuum decay testing methods are used for leak rates of one standard cubic centimeter per minute (sccm) and higher," says Splete. "That's typically used for pumps and fluid devices, and for radio enclosures that undergo atmospheric changes.

"When approaching high flow rates, such as measurements between 100 and 1,000 sccm, then mass flow testing is considered," adds Splete. "Helium mass spec testing methods are used when leak rates are lower than 0.5 sccm, such as high-pressure fuel lines and oxygen systems.

"We still see some bubble testing in the aerospace industry," Splete points out. But, many manufacturers are moving toward more sensitive methods that use helium and hydrogen tracer gases.

"Trace gas, helium, hydrogen and even sulfur hexafluoride, seem to be more popular in the aerospace industry than in others," explains Bryant. "This is due to specifications and production volumes which permit longer test cycle times."

According to Alcatel's Morris, "leak detection on aircraft fuel systems can be very tricky. The leak entry point inside the tank is often far away from the leak exit point on the outside of the aircraft. Tracer gas leak detection is the fastest and most reliable way to find and repair the leak by back-tracing the gas."

As a rule of thumb, the larger the aerospace part, the more intricate it is inside. And, the higher the pressure, the more difficult it is to test the part. For example, a wing can be challenging to pressurize. Because it has different compartments, it is difficult to ensure that all these parts are actually pressurized at the same rate.

"For such parts, pressure decay is almost impossible to use, because no instrument in the world can detect minute leaks on a large volume," explains ATEQ-Omicron's de La Grandville. "On a 1,000-liter part, for example, the minimum leak that you could detect with a pressure decay instrument would be 600 sccm. This test is not reliable for a large fuel reservoir. In that case, we use a hydrogen sniffer. But, since the part has a large surface, you have to really sniff it thoroughly.

"Landing gear, on the other hand, offers another challenge," adds de La Grandville. "To test hydraulic parts, you have to test them at their working pressure, which is very high. With such high testing pressures, you have to be very careful when you build your testing jig in order to avoid [explosions and other] accidents." ∎

Autin Weber is senior editor of ASSEMBLY magazine. This is an excerpt from the original article, reprinted with permission by ASSEMBLY Magazine, BNP Media, USA. Copyright 2011

Photo finish

NEW DIGITAL CAMERAS MAKE IMAGE CAPTURE SWIFTER AND EASIER AT ARNOLD AIR FORCE BASE BALLISTICS RANGE

A laser photo of an older erosion test conducted at Range G. The test was to see how a graphite nose cone would be affected by snow, which can be seen in the picture

BY PATRICK ARY

Until recently, obtaining new parts for the laser camera system at AEDC's Hypervelocity Ballistic Range G was a lot like antique shopping.

In a time when it is difficult to buy a new camera that is not digital, workers at Range G have been stretching their resources to keep their film-based camera equipment viable.

But now, after six years of planning, they have a new digital system that brings them into the 21st century and makes the process of capturing high-velocity images more user-friendly, both for them and for the base's test customers.

The digital system is more of a necessity than a luxury, according to instrumentation engineer Ed Erickson: "The cameras had been around for about 40 years, and the system as it existed up until now was around for about 20 years," he says. "Needless to say, spare parts aren't available for it anymore."

Range G is used to conduct kinetic energy lethality and impact phenomenology tests. Its two-stage gas-gun launcher is the largest in the USA, firing projectiles down a 930ft long instrumented tank.

Impact tests

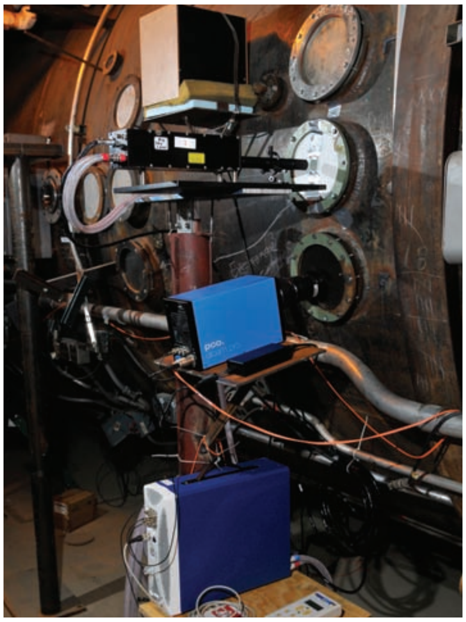
Impact testing and examining aerodynamic features of projectiles are primary functions of the tunnel and it is important to have a camera capable of capturing an image as the projectile flies by.

Erickson began looking for funding to implement a new system in 2005, which was the last chance he had to purchase spare parts for the old system. The man who made the illumination lamps for the laser system was retiring, so Erickson stocked up with as many as he could get. The ruby laser used in the system is no longer available, and there is only one remaining source of the image intensifiers used to achieve a sharper image in the old cameras.

The previous system was a box-shaped film camera. Because projectiles fired through the tank travel as fast as 18,000ft a second – six times faster than a bullet – a flashbulb is not capable of illuminating the tunnel for a photo. A laser is used instead.

The ruby laser employed in the old system sat inside a custom high-intensity lamp, which had a water cooling system and a 20,000V power supply. The old rig was the size of a steamer trunk, and because of the way it was built, a series of mirrors had to reflect the laser beam from one side of the box into the tank. If a customer wanted a photograph from a different section of the tank, it could take a full day to reposition the camera.

By contrast, the three new camera and laser systems are only about the size of a briefcase, with the laser capable of firing directly into the tank. If it needs to be moved, the new system



Above: A successful check-out test at AEDC's Hypervelocity Ballistics Range G captured this image of a projectile traveling at 18,000ft a second

Above left and left: New equipment installed at AEDC's Hypervelocity Ballistics Range G consists of a Dicam Pro camera (Photo by Rick Goodfriend)

can be repositioned and operational in about two hours. "Previously, I'd tell Ed or some of the other folks I wanted to move the laser camera," says project engineer David Woods. "They'd look down and they'd just start shaking their heads. Now, it's not so bad."

The new systems are "everything we need in a compact package", according to Erickson. They consist of a Dicam Pro camera made by the Cooke Corporation and a Quantel Laser CFR200; both off-the-shelf commercial items that have easy-to-replace parts. The only part that was built in-house is the triggering system.

"We chose a YAG (yttrium aluminum garnet) laser because they're common and relatively inexpensive," says Erickson. "The camera is sensitive to the same wavelength of light that the laser puts out, so the selection of one drove the specification of the other."

Instant imaging

The digital imaging system is also faster than the previous film system, according to Erickson. They have a photo of the projectile upstairs from the range as soon as the camera snaps the picture and stores it. It enables instant viewing rather than having to wait hours for the chance to go into the facility and physically retrieve the film.

"When they fire the launcher, carbon monoxide is generated," says Erickson. "Hydrogen could leak out of the tank. They have to take steps to purge the tank and make the downstairs safe for a person to re-enter. So it takes about an hour and a half to two hours before the service tunnel is ready for entry. Then it would take another half hour to develop the film."

Once the film was developed, negatives were placed between plates of glass and projected onto a large table. Datapoints were digitized into a software program that output a list of coordinates. Those points were fed into yet another data reduction program. The new system speeds up that process. "Because this is digital, we can use software with our data reduction to help us," explains Rick Rushing, the Air Force's ballistics range lead at AEDC. "It's more efficient."

Woods likes another aspect of the digital system: it eliminates the possibility that the film could be accidentally dropped or exposed to light, destroying the data. "The thing I like about this system is as soon as it's done, it immediately gets transferred into memory and saved, and we don't have to worry about what happens if there are extenuating circumstances," he says. "We have our data."

Laser photography expands the capabilities of the ballistics range at AEDC. It can be used to determine erosion data and the recession rate of a projectile. Images captured at every photography station could be colored and overlaid to determine changes at the stations when a projectile is fired through dust, rain, or ice. It can also be used in lethality testing to capture the first touch of a projectile on a target.

"Back when we had the old TV-based, quick-look camera, it gave the customer a good indication that things hadn't gone too terribly awry," recalls Woods. "After they saw that their model was still intact, the first thing they always asked was 'Where is it and what angles is it at?' The next thing you know, people are holding protractors up against the TV and trying to find good reference lines.

"With this system, as soon as we get two images of the same field-of-view saved, we've already done the calibration, so we can throw it into the software and draw a line between two points to get the pitch, the yaw, and how far it is from the center line."

Customer test

The range cameras are ready to go; their readiness was confirmed by a final check-out recently. A customer test is lined up for October. By then, Range G workers may be able to use their equipment to measure the attitude and positions of a projectile within a 3D field-of-view. That will allow them to look at aerodynamic stability information and determine hit point for lethality customers.

"I expect that as we continue to move forward with using these things on our test shots, we will continue to improve," says Woods. "These images are pretty good, but there are some things I'd like to see more clearly, and that's just the sort of thing that's going to come with time as we continue to use the systems." ∎

Patrick Avry is a public affairs specialist at Arnold Engineering Development Center (AEDC) located within Arnold Air Force Base

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Alex Mattos and Steve Uhrmacher

Heads of engineering and sales, Ultra Electronics – Electrics

Two guys, two jobs: Alex Mattos and Steve Uhrmacher are head of engineering and head of sales respectively for the Test Solutions business unit of Ultra Electronics Electrics. They answer to the managing director of Electrics regarding the performance of the Test Solutions business. Mattos is responsible for all technical and support activity within the business and Uhrmacher ensures that new business is secured and the customer base is maintained and developed. Aerospace Testing Technology spoke to them about the company's latest developments.

What does Ultra Electronics provide to the aerospace test industry?

Our business unit specializes in the full lifecycle of electronic test equipment and harness systems for fault-finding, subsystem integration, and production line testing. This includes design, development manufacture, installation, commissioning, training, and in-service support to all our customers and end users.

Our equipment serves the international defense and civil aerospace sectors, and we have a strong presence in the field of fuel and databus system testing. Our expertise and knowledge in the test equipment market enables us to offer our customers full support from concept through to the delivery of bespoke test solutions, providing a capability that COTS equipment simply cannot offer.

What is your latest development in test equipment for the aerospace industry?

We are currently developing a new system that will test the integrity of electronic wiring interconnect systems (EWIS) and optical fibers. The technology is a big step forward from existing technologies providing information such as the distance and type of the fault. It will be compatible with many types of wiring configurations and will be able to detect 'soft' faults such as insulation damage, intermittency, and corrosion.

As increased life extension programs are forcing platforms to be operated far beyond their original design life, this equipment will provide fast and accurate testing to ensure the EWIS remains compliant with safety legislation and the platform achieves the desired levels of availability.

Can you describe some of the applications where your systems have been used?

Our core products are designed to be robust and deployable in harsh environments. This makes them ideal for first line/O-level use with military users. Through 20 years of product development and platform integration we have become very experienced in designing cost-effective solutions for all types of applications.

Our equipment is also frequently used within production environments where accuracy and reliability are important factors. Systems integrators and OEMs use our products to assist with fault finding and verification of system performance.

Finally, aircraft maintenance and repair organizations (MROs) use our equipment to perform routine maintenance on behalf of the operators, who demand quick and effective test procedures to improve platform availability.

Integrating onto aircraft platforms must involve many stakeholders. How do you ensure that the solution is approved by all parties?

As an example, we have recently completed the integration of the 'fuel system test set' onto the Tornado GR4. This involves stakeholders from the MoD, RAF, DSG, FAST IPT, BAE Systems, Cassidian, and Autoflug GmbH. Our success in this area is based on bringing all stakeholders together and ensuring that a collaborative, focused approach is maintained through relationship management.

Is there one piece of test equipment you would like to highlight in particular?

We have embarked on a recent upgrade program with our RF Filter test set series. The frequency range will be extended to widen the variety of filters that can be tested. Additionally the HMI will be significantly enhanced. This patented technology enables the user to test the performance of RF filters in-situ, without the need to dismantle the system to gain access to the filter. This means embedded filters within LRUs can be tested easily. We will also be attending the EMC UK exhibition at Newbury Racecourse, Berkshire, on October 11-12 to explore further interest from the industry.

Why is it important to work closely with platform OEMs? Can you give a brief case of where this has worked?

Earlier we mentioned our success on the Tornado platform; in the commercial market we developed a fuel system test solution for the Airbus A380 production environment which was delivered successfully to meet the customer's requirements in 2007.

Earlier in 2011 we were awarded a contract to provide a similar solution for Airbus A350XWB production-line testing, which has now been delivered. Throughout the development of this solution we worked closely with the customer to ensure that the contract was executed on time and to budget despite various changes and modifications that occur during new aircraft developments.

What are the latest systems or developments on the company drawing board?

The company's Fuel System Test Set has been very successful and is in-service across

> "The ability to perform health checks on aging systems is becoming mandated"

the international defense communities. This system enables AC and DC fuel systems to be tested; these are the predominant fuel measurement and gauging methodologies found on board aircraft today. However, recent aircraft designs have become more complex and now include active probe and ultrasonic fuel systems.

In order to integrate with such platforms the company is developing an interface that will process and translate the data directly from the aircraft, giving users the flexibility to test various fuel systems with a single test set. We are also about to initiate production of our Jet Pipe Overheat Detector (JPOD) test set for temperature sensor testing on the BAE System Hawk. This solution is far more accurate and controlled than the current solution and is fully compliant to ATEX Zone 2 Category 3.

Where do you see the future of ground test equipment?

In recent times we have seen the impact of austerity measures within defense spending, which has also seen an increase in the price of raw materials. At the same time life extension and platform modernisation programs are now becoming a common theme within the land, sea, and air domains.

The ability to perform health checks on aging systems is becoming mandated. Test systems that can identify a weakness rather than waiting until fault or accident occurs will ensure safety records are maintained and aircraft availability levels are achieved.

Test systems that enable fault diagnosis on aircraft will significantly reduce the costs associated with no-fault-found scenarios. Software configurable systems enable cross-platform usage, and modular design will mean multiple test capabilities can be contained within a single box, all of which helps to reduce the logistical and cost footprint associated with aircraft.

Is there anything else readers should know about your company?

Ultra Electronics Electrics is undergoing some structural changes to accommodate a merger with another Ultra business, Precision Air Systems, which is currently based in Gloucestershire, UK.

The new business will be called Ultra Electronics Precision Air & Land Systems and will provide business units covering land systems, air systems, new product development, and customer support services. These changes allow Precision Air & Land Systems to provide a wider capability with a more integrated and customer-focused service to our existing and future customers.

King of the air

ENCOURAGED BY THE BURGEONING MARKET FOR OFF-THE-SHELF MISSION AIRCRAFT, LED BY THE UBIQUITOUS BEECHCRAFT 350ER, SAAB IS ENTERING THE MARKET BY OFFERING A RANGE OF SPECIAL MISSION VARIANTS OF ITS SAAB 34 AND 2000 COMMUTER AIRLINERS

BY DAVID OLIVER

Developed from the eight-seater Beech Super King Air 200 corporate transport that first flew almost 40 years ago, the King Air 350ER (Extended Range) is unquestionably the special missions platform of choice. More than 350 military versions of the Super King Air 200 were delivered to all four US forces, and military variants of the 350ER have been rolling off the production line since it was introduced in 2005.

Powered by two 1,050shp Pratt & Whitney PT6A-60A turboprops driving four-blade Hartzell propellers, fitted with NASA winglets, engine nacelle fuel tanks, heavy-duty landing gear, and ventral sensor pannier, the 350ER is the intelligence, surveillance, and reconnaissance (ISR) aircraft of choice for many countries.

Under project Liberty, the US Air Force has acquired a fleet of 37 MC-12W aircraft equipped with INMARSAT communications, L-3 multiband datalink, Wescam MX-15i EO sensor, and an advanced defensive aids suite (DAS). The US Army has selected Boeing to build a fleet of enhanced medium-altitude reconnaissance system (EMARSS) aircraft

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> **“Saab is actively promoting a range of military variants of the twin-turboprop commuter aircraft”**

based on the King Air 350ER, and the US Naval Air Systems Command (NAVAIR) has plans to source contractor-operated King Air 350iER ISR and electronic support (ES) aircraft for operations in South America.

Twenty-four ISR variants are being delivered to the Iraqi Air Force, equipped with synthetic aperture radar and L-3 Wescam MX-15 EO/IR system; the UK MoD has acquired five Raytheon Systems Ltd-developed King Air 350CERs (named Shadow R.1s) for RAF ISR operations in Afghanistan; the Royal Navy has taken delivery of four King Air 350ERs under a UK Military Flying Training System (MFTS) contract for training RN helicopter observers. The latter, designated Avenger T.1s, are equipped with a 360° Telephonics RDR1700A radar in a ventral sensor pannier. The special missions packages for both the UK aircraft were installed and integrated by Cobham Aviation Services, which also undertook flight testing for airworthiness clearances for carriage of the equipment.

Latest demonstrator

L-3 Communications has launched a new King Air demonstrator to test its Spiral 1 SPYDER mission suite, which includes a Wescam MX-15Di FMV OE imager and COMINT capability. Meanwhile, IAI/Elta Systems has flight-trialed its EL/I-3120 Compact Multi-Mission ISR package on a King Air. Service tests of the first modified King Air Multirole Enforcement Aircraft (MEA) for US Customs and Border Protection (CBP), equipped with the Selex Galileo 7500E AESA radar and an EO turret, started this summer.

Saab is actively promoting a range of military variants of the twin-turboprop commuter aircraft, of which Saab Aircraft Leasing has more than 100 in its portfolio. In addition to the steady-selling AEW&C variants, Saab 340 and 2000 aircraft are operated by several air arms – including those of Argentina, Sweden, Pakistan, and Thailand – in transport or training roles. In the USA, Calspan Corporation has modified a Saab 340 for training students at the US Naval Test Pilot School in Patuxent River, Maryland.

Two new aircraft are on offer: the Airtracer and Maritime Patrol Aircraft (MPA) variants of the Saab 2000. Airtracer is a long-range, high-endurance SIGINT aircraft equipped with COMINT and ELINT systems, SATCOM, wideband datalink, and ESM. Saab claims that a typical mission profile would be to transit 100 nautical miles, patrol at 160kts IAS for eight hours, and reposition back to base with 15 minutes’ holding at 5,000ft, or fuel for a 100 nautical mile diversion.

The MPA variant is designed for maritime surveillance and reconnaissance (MSAR) missions, maritime border security, counter smuggling and piracy surveillance, SAR and fisheries

Right: The latest version of its King Air 350ER ISR aircraft was displayed by Beechcraft at the 2011 Paris Air Show

Below right: The RAF’s secretive Shadow R.1 aircraft operated by No 5(AC) Squadron perform ISR missions over Afghanistan. (Credit: Peter Foster)

Below: The Iraq Air Force is taking delivery of 24 ISR King Air 350ERs plus 24 transport versions. (Credit: USAF)

> **"The aircraft is fitted with an airdrop door, a sono-buoy launcher, and SAR life-raft stowage"**

protection. Equipped with AESA radar and Saab RBS 15 anti-ship missiles, it is being offered for the Indian Navy's Medium Range Maritime Reconnaissance (MRMR) program and South Africa Air Force's Project Saucepan to replace its elderly fleet of C-47TPM aircraft in the maritime surveillance role.

Although there is currently no MoD requirement, Saab is one of several companies that could offer a cost-effective interim solution to the perceived gap in the UK's maritime surveillance capability following the cancellation of Nimrod MRA.4 following the government's 2010 Strategic Defence and Security Review (SDSR). Equipment developed and tested for MRA.4, such as the Thales Searchwater radar and the Northrop Grumman Night Hunter II EO/IR turret could be easily installed in the 2000 MPA as well as ESM wingtip pods.

The Selex Seaspray 7000 AESA radar provides the aircraft with IFF capability with customized interrogator functions. The radar is supported by a Saab R4A AIS transponder receiver/transmitter system for locating and identifying any naval activity, and an encrypted datalink. The MPA incorporates electro-optic (HDTV) and thermal imager sensors, ELINT and ESM systems, and a comprehensive DAS. A C2 system provides the user interface to mission operators via four workstations installed side by side in the cabin facing starboard, and to the pilots via a dedicated tactical cockpit display. The aircraft is fitted with an airdrop door, a sono-buoy launcher, and SAR life-raft stowage under the rear fuselage.

Mission profile

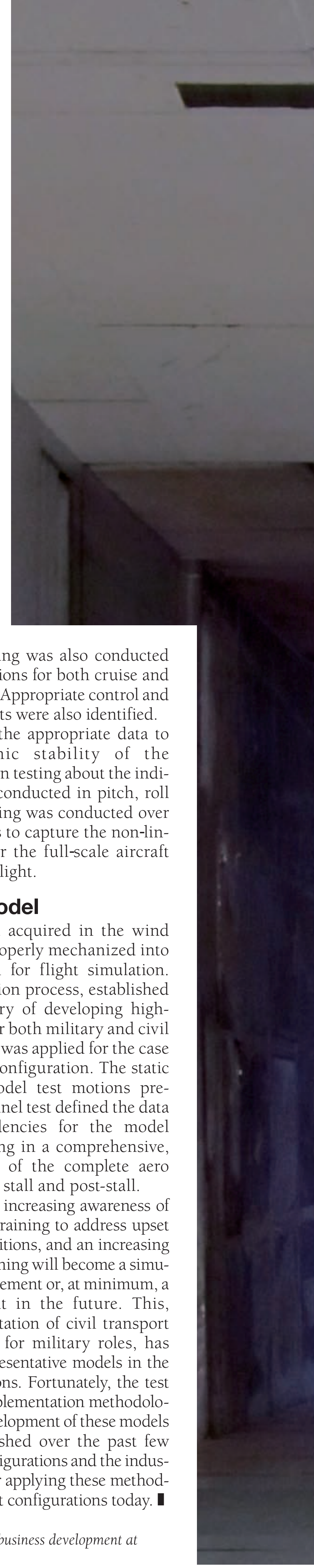
A typical mission profile for the MPA is to transit 200 nautical miles to an EEZ, patrol at 2,000ft at a speed of 160 knots for 5.5 hours, and reposition back to base with fuel for 45 minutes' holding, or a 100 nautical miles diversion. The MPA is equally suited to working in close cooperation with the Saab AEW&C equipped with the Erieye radar, which has a sea surveillance mode capable of tracking very small vessels such as a jetfoil or pirate skiff at a range of 250 nautical miles.

Extensive flight testing of the military variant has been carried out during the development of the Saab 2000 AEW&C version. Powered by two 3,096kW Rolls-Royce AE 2100A turboprops driving six-bladed Dowty propellers, the Saab 2000 has a maximum cruising speed of 370kts, a ceiling of 31,000ft and a range of 2,000 nautical miles.

Although manufacturer Saab ceased production of the Saab 2000 in 1999 after producing only 63 aircraft, more than 50 are extant and any modified Special Mission aircraft will have a guaranteed 35,000 flight hours life, including at low level, and a 25-year support package. ∎

Right: The Erieye-equipped AEW&C variant of the Saab 2000 has been sold to Pakistan and Saudi Arabia

Below: The Maritime Patrol Aircraft (MPA) variant of the Saab 2000 (Credit Saab)



Recovery position

A NEW TOTAL FLIGHT ENVELOPE MODELING APPLICATION FOR TRANSPORT AIRCRAFT IS DESIGNED TO SIGNIFICANTLY IMPROVE STALL PROCEDURES

BY BRIAN WACHTER

In recent years, the civil aviation training community has seen increased attention on pilot training in the prevention of and recovery from upsets, including stall. This interest has arisen partly because of disasters such as Colgan Air Flight 3407 in February 2009 and Air France Flight 447 in June 2009, both of which have been attributed in part to pilot error in response to an aerodynamic stall condition. Consequently, there is a growing need for flight-representative modeling of the stall and post-stall characteristics, modeling that is currently lacking or approximated with 'effects' models in civil transport simulators.

As those in the aerospace testing arena understand, the aerodynamic characteristics are complex and interrelated as stall is approached and exceeded, and consequently, these simplified models are insufficient for representative training.

The need for full-envelope modeling also arises from the adaptation of commercial transport aircraft configurations for military applications where the operational mission of these aircraft necessitates the use of more aggressive maneuvers. It also expands the normal operational envelope of these transport aircraft to include the large angular excursions that can be experienced during stall and post-stall motions.

Aerodynamic data

One of the challenges with implementing full-envelope flight models in piloted simulators, however, is the lack of dynamic data used to characterize the stall and post-stall behaviors of these aircraft. This data is critically important, as limitations in the dynamic coverage of the aerodynamics model may lead to unrepresentative aircraft response to adverse conditions or post-stall recovery. To meet this growing demand for flight-representative models, Bihrle Applied Research Inc (BAR), leveraging its experience with high angle-of-attack testing of military aircraft, established a low-cost dynamic wind tunnel test capability and flight model development methodology. This methodology captures the appropriate aerodynamics data of the stall and post-stall regimes for large transport aircraft and mechanizes this data for application in piloted simulators.

A factor that comes into play when considering dynamic data collection for large transport aircraft is Reynolds Number effect. In order to minimize the scaling effects associated with Reynolds Number, it is desirable to conduct testing using a large model scale and high dynamic pressure. However, dynamic testing requires that the model weight and inertial effects be small. Consequently, it is imperative to develop a test capability that optimally balances these opposing test rig and test technique requirements.

In order to collect the appropriate data, a test rig was designed and fabricated to fully support both static testing and forced-oscillation test motions in pitch, roll, and yaw on a single test stand.

The dynamic test rig was designed specifically for large-scale model static and dynamic testing at higher dynamic pressure. Its simplified mechanical configuration uses a facility turntable for angular displacement and a precision motor/gearbox for accurate attitude control for large angle-of-attack and sideslip static excursion as well as precise motion control for dynamic forced oscillation. The flexible design accommodates a number of strain gauge balances for measurement as well as a separate lower support, upper stand, and model sting for adaptation to the particular facility and model size. For the recent demonstration of this capability, testing was conducted in the Lockheed Martin Aeronautics Company large, low-speed wind tunnel (LSWT) facility in Smyrna, Georgia, USA.

Data collection consisted of static testing to acquire force and moment data across the angle-of-attack, sideslip, and speed range consistent with the normal operational envelope of the aircraft, plus expansion into the stall and post-stall regions. Testing was also conducted with slat/flap combinations for both cruise and landing configurations. Appropriate control and control interaction effects were also identified.

In order to collect the appropriate data to identify the dynamic stability of the aircraft,forced oscillation testing about the individual body axes was conducted in pitch, roll and yaw. Dynamic testing was conducted over a range of angular rates to capture the non-linear behavior and cover the full-scale aircraft rates typically seen in flight.

Mathematical model

The full-envelope data acquired in the wind tunnel test was then properly mechanized into a mathematical model for flight simulation. BAR's data mechanization process, established through its long history of developing high-fidelity flight models for both military and civil aircraft configurations, was applied for the case of the large transport configuration. The static definition and the model test motions prescribed by the wind tunnel test defined the data structure and dependencies for the model mechanization, resulting in a comprehensive, non-linear description of the complete aero characteristics through stall and post-stall.

Basically, there is an increasing awareness of the need for civil pilot training to address upset and loss of control conditions, and an increasing likelihood that such training will become a simulator qualification requirement or, at minimum, a simulator endorsement in the future. This, together with the adaptation of civil transport aircraft configurations for military roles, has fueled the need for representative models in the stall and post-stall regions. Fortunately, the test techniques and data implementation methodologies required for the development of these models have been well established over the past few decades for military configurations and the industry is well-positioned for applying these methodologies to large transport configurations today. ∎

Brian Wachter is director of business development at Bihrle Applied Research Inc

Dynamic Duo

Dynamic wind tunnel testing provides the ability to collect aerodynamic data for characterizing the flight response of aircraft in the stall and post-stall region. When combined with traditional static testing, the result is a comprehensive data set that can be used to develop full-envelope models which properly characterize aircraft behaviors in both normal and abnormal flight conditions, and raise the bar for fully flight representative pilot training. The Bihrle Applied Research Inc dynamic test rig, shown here in the Lockheed Martin Aeronautics Company Low Speed Wind Tunnel (LSWT), is specifically designed to accommodate the large model sizes required for testing civil transport configurations.

Large transport aircraft model undergoing dynamic testing

Bolt from the blue

ADVANCES IN AIRCRAFT MATERIALS REQUIRE NEW STANDARDS TO BE DEVELOPED. ONE SUCH AREA IS FOR IMPULSE ENERGY, OR INDIRECT LIGHTNING TESTS

BY NICHOLAS WRIGHT

The latest aircraft designs that roll down the runways of the world include huge technology improvements over the past decade or two, but also offer operational enhancements and environmentally friendly solutions.

Across the globe, new designs are emerging that promise better passenger comfort, combined with higher fuel efficiency and lower operating costs.

Traditionally, large passenger aircraft were constructed mostly from metal, principally aluminum alloy for its strength and lightness. The obvious trend now is toward structures made from carbon fiber reinforced plastic (CFRP) materials, which offer all the strength of previous materials but with a significant weight saving. Both Airbus A350 and Boeing 787 include more than 50% CFRP materials.

The indirect lightning testing for equipment mounted within these aircraft represents a major sea change. Indirect lightning tests are defined in the RTCA DO-160 and EUROCAE ED-14 documents under section 22. Both documents are based on experience gained over many years with metal-skinned aircraft.

The new generation of aircraft require tests to the avionics equipment for which no experience exists. The responsibility is very much on the aircraft manufacturer to ensure that appropriate testing is performed. Because of this, separate standards are emerging for specific aircraft types with test requirements based on DO-160/ED-14, but modified to take account of specific construction materials and electronics used in a design.

DO-160/ED-14 defines a series of waveforms that simulate indirect impulse energy entering an aircraft and being induced into cable bundles within the structure. Six waveforms are defined and applied as damage assessment (PIN) tests or disturbance (single stroke, multiple stroke and multiple burst) tests.

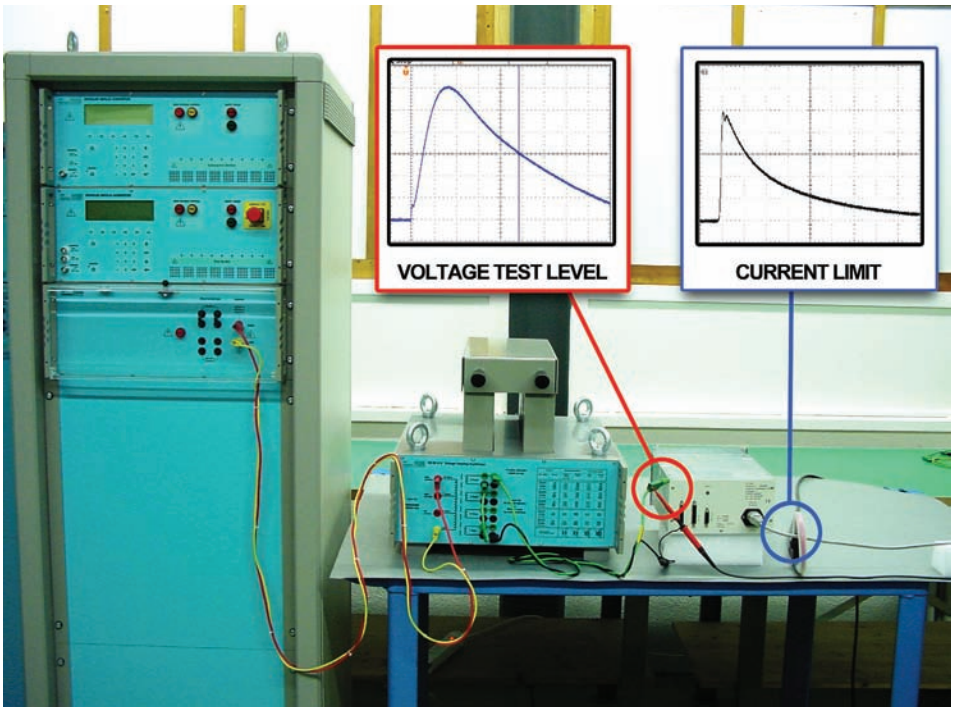
The method employed in the DO-160/ED-14 standards for cable bundle testing specifies a test level that should be achieved in the cable. This is coupled with a limit level for either current or voltage that must not be exceeded. There is no definition of test equipment impedance and the cable bundle impedance can have a significant influence on the test result. Both Airbus and Boeing deviate from this technique.

What does this mean for the test engineer? The DO-160/ED-14 method requires constant monitoring of the impulses as the test signal is increased to the desired level. This is labor-intensive and there is a risk that the cable impedance could prevent either the test level or limit level from being reached.

This situation requires a further test process and much more time. As these test types can already run for many days or even weeks, a further extension is undesirable.

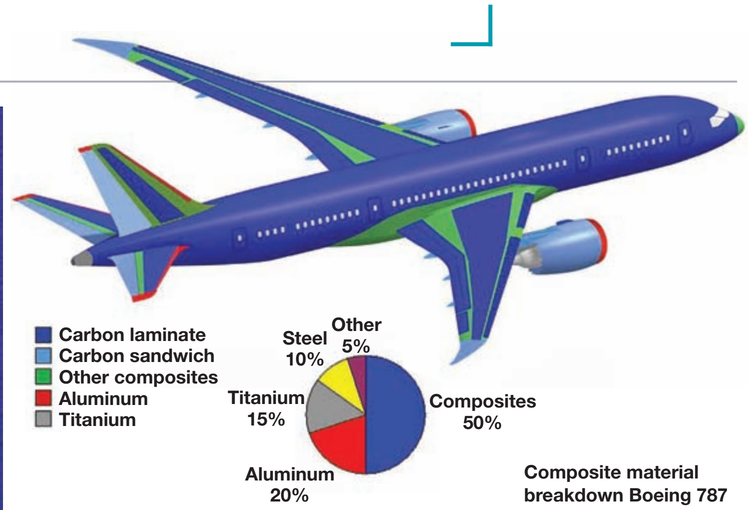
Impulse standards

Boeing test requirements set a voltage level that should be reached in the cable, even if



Indirect lightning test monitor points

> “There is no definition of test equipment impedance and the cable bundle impedance can have a significant influence on the test result”



Composite material breakdown Boeing 787

Lightning simulation

Studies by the Federal Aviation Administration reveal that the average civil aircraft is struck by lightning every 1,000 flight hours. It is therefore imperative that all aircraft should be tested to withstand the effects of lightning.

Lightning events differ mainly in current amplitude, in the transferred charge, and in the impulse shape of the lightning current. Two lightning events need to be simulated: the direct strike (current and voltage) and the induced currents and voltages within an aircraft resulting from a direct strike.

Induced lightning current, voltage waveforms, and impulse generator impedance values required to create these waveforms have been measured on avionics systems within aircraft subjected to direct strike events.

Test standards including MIL-464 and DO-160 specify both direct and induced strike pulse sequences and levels.

Standard	PIN injection	Cable bundle	Test verification
DO-160/ED-14	V_{OC} / I_{SH}	V_T / I_L or I_T / V_L	Voltage and current must be monitored during test process
Boeing	V_{OC} / $_{ISH}$	V_T / I_L only	I_L can exceed specified value to achieve V_T in cable
Airbus	V_{OC} / $_{ISH}$	V_{OC} / I_{SH}	After calibration no monitoring

it means exceeding the current limit. This is, of course, still dependant on the cable impedance and may necessitate changing test equipment.

Airbus has arrived at a solution that is independent of cable impedance and in fact in line with most international impulse standards. The test system (generator, coupler and cables) is calibrated with fixed impedance as for PIN injection. After calibration, the test can be performed without monitoring impulse levels in the cable bundle.

A hybrid generator is a circuit design where the dynamic behavior is well known. The impulse waveform is specified in open circuit and again in short circuit. The advantage of this design is that independent of the load impedance (for example, cable length, aluminum, or carbon fiber structure), the test results are repeatable and comparable. A hybrid solution is the only generator design that gives comparable test results over the complete EUT load range.

Although indirect lightning test requirements are changing, based on the latest technologies employed in aircraft designs, the basis is still the DO-160/ED-14 standards. These are also being revised and amended to take account of the new test requirements.

The latest version, G, already includes one additional impulse, the Multiple Burst Waveform 6. The next version, H, is being worked on currently and will include further changes, together with a detailed users’ guide to assist with test applications. ∎

Nicholas Wright is international sales manager for EMC Partner, based in Switzerland. Email: sales@emc-partner.ch

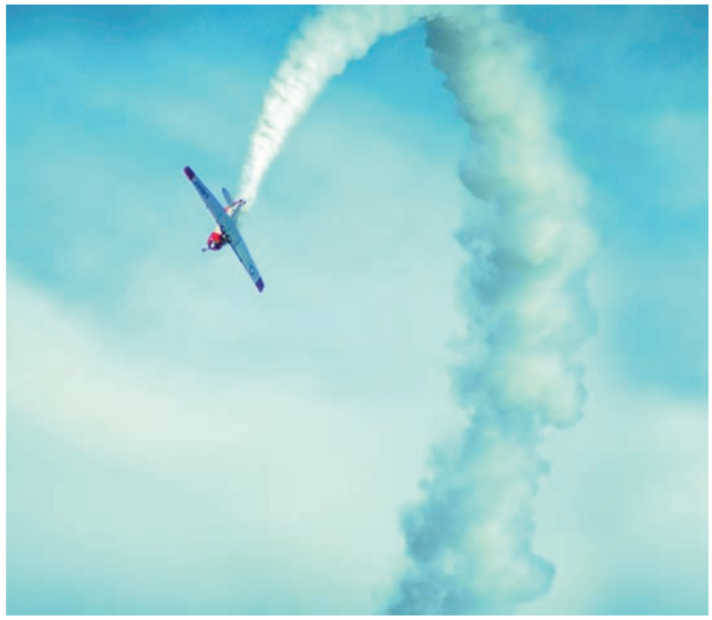
NASA's top model

A SUBSCALE UAV IS IDEAL FOR STUDYING TEST FLIGHTS UNDER EXTREME CONDITIONS

BY DR GERHARD REISS

In an effort to improve aviation safety, engineers at NASA are looking to understand flight dynamics in abnormal and upset conditions and to design automation systems that can help to maintain safe, controlled flight.

Loss of control can occur when events such as structural damage, hydraulic failures, or icing build-up have so changed the vehicle's performance that traditional autopilots fail, and pilots are faced with highly coupled controls and oscillatory or even divergent handling characteristics. To study these flight conditions, a subscale UAV (scaled down to 1:18 the size of a full-scale transport aircraft) was designed and integrated with a highly automated ground station for piloted testing. The UAV enables experiments to be conducted that are riskier and may incur much larger structural loads than would be feasible on a full-scale aircraft.



Aerobatic displays thrill spectators with maneuvers that push the aircraft to their limits. NASA is researching even more extreme flight situations with its UAV

Flight control system

Advances in control theory and real-time system identification are typically made at the researcher's desktop, with algorithm prototypes implemented in a model-based simulation tool such as MATLAB/Simulink.

One goal of the AirSTAR (Airborne Subscale Transport Aircraft Research facility) program was to reduce the amount of time required to rehost these algorithms to a real-time system for flight testing and to provide ample computing power for researcher code. By carrying out this rehosting process quickly, it is possible to provide real-world test results during an early stage of technology development, where they can inform and influence the direction of ongoing research. This capability was provided by employing a ground-based dSPACE system that communicates with the UAV over a high-bandwidth telemetry link. In addition to the UAV itself, the AirSTAR test facility includes a mobile ground station for piloting and monitoring the vehicle. The ground station's computer systems consist of a multi-CPU dSPACE unit and several connected workstations for display generation and datalogging.

The test pilot's station. Communicating with the UAV by radio, the dSPACE system performs all the ongoing real-time computation tasks so that the test pilot can fly any desired maneuvers realistically from the ground

The telemetry stream provides over 70 channels of raw data at 200Hz, but with real-time calibrations, corrections, and the calculation of derivative variables, the volume of data grows considerably. Over 500 variables at 200Hz are streamed to disk through the dSPACE host PC optical link, including 75 variables that document internal variables for studying the control algorithms during flight.

Extreme flight situations

The UAV can make flights lasting about 15 minutes. A second pilot, the safety pilot, in visual contact with the vehicle, performs the take-off and landing phases and hands off the UAV to the test pilot only after a specific altitude has been reached.

The test pilot runs through the flight program in the remaining time, piloting the vehicle from the simulator-like displays in the mobile ground station. To avoid exceeding the UAV's structural strength, a load protection algorithm monitors thrust and control surface settings and can limit inputs in emergency situations. In addition, the safety pilot always has overriding control of the test flight – the ability to intervene at any time and take over control of the UAV from the test pilot. ∎

Dr Gerhard Reiss is the marketing editor for dSPACE GmbH based in Germany

Cut inspection time with Laser Radar

THE NEW MV330/350 LARGE-SCALE METROLOGY SYSTEM FROM NIKON METROLOGY FEATURES NEW ELECTRONICS THAT DOUBLE MEASUREMENT SPEED AND PERFORMANCE

BY ROB SNOEJIS

The latest Laser Radar instrument enhances hole and edge measurement. Its propriety laser reflection technology obsoletes tedious positioning of targets at difficult-to-access locations, as is the case with laser trackers or photogrammetry systems. Through accurate non-contact measurements running manually or fully automatically, Laser Radar is a productivity multiplier that is very appealing to manufacturers in aerospace and beyond.

Large-scale metrology

Although similar from the outside and in achievable measurement accuracy (0.025mm), a Laser Radar and laser tracker house completely different technology. Incorporated into the first is frequency modulated coherent laser radar technology (FM CLR). The Laser Radar instrument directs a focused laser beam to a point on the part to be measured and recaptures a portion of the reflected light. The single large-aperture optical path maximizes signal strength and stability.

As the laser light travels to and from the target, it also travels through a reference path of calibrated optical fiber in an environmentally controlled module. Heterodyne detection of the return optical signal mixed coherently with the reference signal produces the most sensitive radar possible. The two paths are combined to determine the absolute range to the point. Combined with the measured horizontal and vertical laser beam angles, the 3D coordinates of the acquired points are determined in real time.

Equipped with more powerful electronics, the Laser Radar MV330/350 drastically increases the measurement speed from 500 to 2,000 points per second. This means that manufacturers can proceed twice as quickly with their large-scale metrology workload, while acquiring higher-quality data. The Laser Radar G3 allows them to double productivity when they align large parts during assembly, certify tooling and then monitor its repeatability during production, and measure metal, plastic, and composite parts, then compare them to their CAD models.

Laser Radar vs photogrammetry

The productivity gains that can be achieved with the new Laser Radar system are impressive. A wind turbine blade project encompassed the surface inspection of the 45m blade, which was required to be completed in a single shift. The Laser Radar automatically measured 48,000+ inspection locations with 0.025mm single point uncertainty in the requisite eight hour time period. Completing the same single-shift inspection assignment using laser tracking technology would require at least three laser tracker systems and operators as well as large overlay templates and additional tooling.

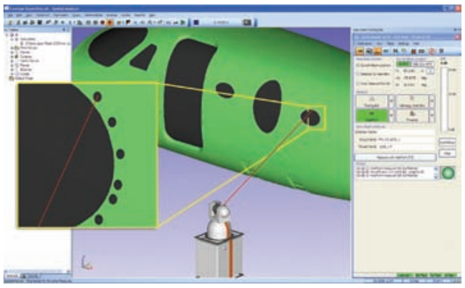
The comparison between Laser Radar and photogrammetry was the subject of a recent study. The conclusion was that Laser Radar significantly reduced the recurring labor required to characterize the surface profile of medium-sized carbon fiber reflectors. In addition to matching the required accuracy, the Laser Radar system achieved significant cycle time reduction through automated inspection.

Laser Radar MV330/350 trials

The non-contact and target-less Laser Radar system requires only one operator to set it up, then it runs unattended. It requires no special environment or expensive tooling. The system works indoors or out, in any lighting, and on any material or finish surface with a reflectivity of even less than 1%. Laser Radar is capable of measuring both freeform surfaces and geometric features.

With regard to hole inspection, the MV330/350 system increases inspection speed, accuracy and reliability. To measure critical sharp edges with accuracy, the MV330/350 has a dedicated edge-measurement mode available. The major strength of Laser Radar is that it can scan complex geometry that was impossible to scan previously because it was too large, too hard to reach, too complex, too delicate, or too labor-intensive.

Laser Radar's capability to accurately and efficiently measure supersize parts used in aerospace has garnered interest from many leading manufacturers. Aircraft fuselage section inspection with Laser Radar systems is three to five times faster compared with laser trackers, and requires up to 10 times fewer personnel. Other aviation metrology applications include fuselage, wing, wing/body connections,



> "Laser Radar serves as an award winning metrology component in the production of right-first-time composite parts"

Laser Radar serves an array of applications

As a versatile metrology system offering unique measuring capabilities, Laser Radar supports numerous applications:

- Quality assurance applications, including part-to-CAD comparison, feature and gap and flush inspection;
- Routine and event-driven inspection such as first-article inspections, incoming and outgoing inspection, troubleshooting, failure investigations;
- In-process applications, such as component alignment and robotic positioning;
- Tool building and alignment, including locating and adjusting tool features in real time;
- Tool digitalization and documentation of as-built tools and die surfaces;
- Model digitalization, including scanning artistic models and performing design layups for in-process and outgoing quality assurance;
- Routine maintenance, including static and dynamic inspections of aircraft, automotive and heavy-equipment tooling assemblies.

Left: Laser Radar automates accurate inspection of holes

Right: Large objects such as satellite dishes are impossible to inspect without non-contact technology

landing gear door and jet engine blade, and inlet cowl. A space application example covers the measurement of a space telescope's mirror features and large mechanical structures holding sensitive flight hardware.

In response to composite manufacturing challenges, Laser Radar serves as an award winning metrology component in the production of right-first-time composite parts. The integration of Laser Radar into innovative composite manufacturing methods illustrates the impact of metrology-assisted production on composite part production quality and throughput.

The successful adoption of Laser Radar metrology by the aerospace community has assured acceptance throughout many other industries, including nuclear, solar and wind energy, shipbuilding, large castings and antennae. One example is the fast-growing solar energy business, where Laser Radar is used to check the geometric integrity of parabolic and flat solar mirrors to accurately and efficiently trace incorrect bending and misalignment. ▮

Rob Snoejis is the senior editorial writer for Nikon Metrology in the UK

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Catolog of events

As a designer and manufacturer of sensors for dynamic acceleration, force, and pressure sensing, Dytran Instruments has published a new commercial brochure, Piezoelectric and DC MEMS Sensors for Measurement and Monitoring, a 172-page full-color catalog highlighting the company's most popular off-the-shelf models of acceleration, acoustic, force, pressure, shock, and vibration sensors for use in demanding aerospace and defense, automotive, power generation, and test and measurement industries. Products are presented in a series of technical specification charts, along with a line drawing and a partial list of the most popular applications.

The new catalog highlights many examples of Dytran's sensors, which are capable of reliably performing within demanding aerospace environments, while providing the high levels of durability and accuracy that can be found across the company's standard product line. Dytran sensors are specified for use in a variety of aerospace applications, including flight and flutter testing, health & usage monitoring systems (HUMS), ground vibration testing (GVT), satellite testing, landing gear assemblies, rotorcraft and fixed-wing aircraft monitoring, and high *g* shock testing.

DC sensors

For flutter testing and in-flight vibration testing, Dytran offers a variety of new DC sensors, including models 7500M and 7600B. The 7500M is a high-precision variable-capacitance accelerometer and combines an integrated VC accelerometer chip with a high-drive, low-impedance buffer for low-level acceleration measurements. Tailored for zero to medium-frequency applications, units contain a MEMS capacitive sensing element and four-pin radial Mighty Mouse connector.

The 7600B was designed as a drop-in replacement for piezoresistive units in new or existing zero to medium-frequency applications. Incorporating a MEMS capacitive sensing element and an advanced ASIC to simulate piezoresistive bridge operation, units also house an integrated VC accelerometer chip.

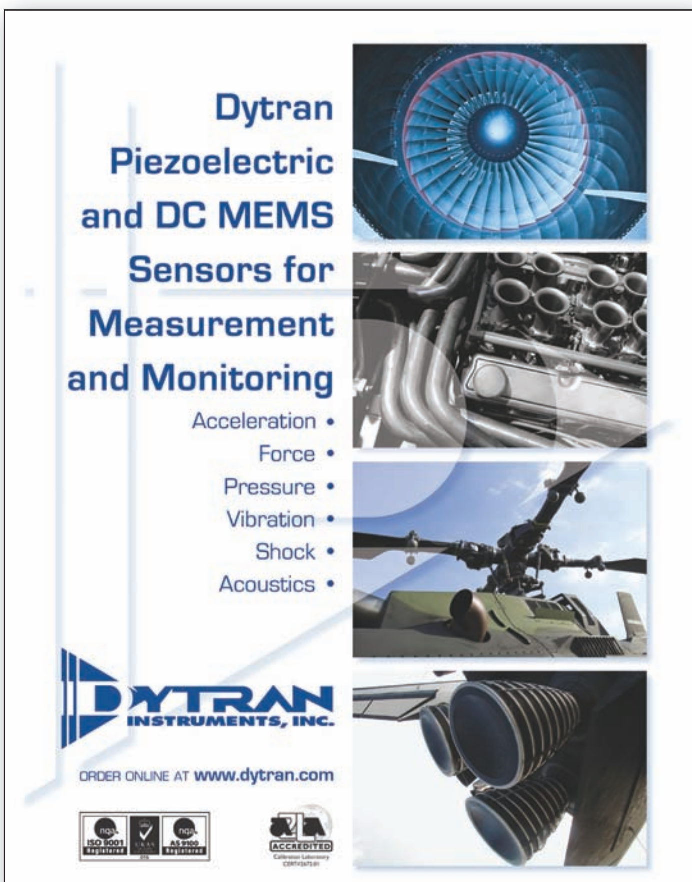
For HUMS and rotor track and balance (RTB) applications, the company offers bracket-style sensors such as models 3077A and 3232A, single-axis and biaxial sensors where the sensing element is incorporated directly into the mounting bracket. The unique design facilitates improved sensor performance while eliminating costs associated with separate mounting brackets and reducing the overall mass, compared with conventional sensors and mounting brackets. Available in a variety of sizes, sensitivities, and connector offerings, Dytran bracket-style accelerometers have become the industry's sensor of choice for RTB and HUMS applications.

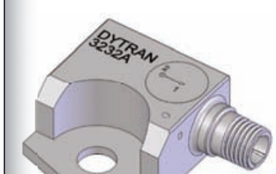
Accelerometers

Also highlighted in the catalog are a line of the company's new ring-style accelerometers, including models 3221C and 3309A. Capable of operating at temperatures up to +500°F (+260°C), these charge mode sensors offer a unique miniature through-hole mounting configuration, allowing for 360° cable orientation designed for greater ease of use.

Typical airborne applications for models 3221C and 3309A include commercial and military aircraft vibration monitoring, engine vibration monitoring, and flight testing. Units are also hermetically sealed for reliable operation in high humidity and dirty environments, and case isolated to avoid EMI/ground loop interference. Model 3309A features a radial three-pin Mighty Mouse connector, suitable for use in demanding aerospace and defense applications.

In addition to the products presented in the catalog, Dytran offers vertically integrated custom-manufacturing capabilities that include an in-house CNC machine shop running three shifts, in-house design engineering center, and dedicated R&D and engineering laboratory. At its AS9100 and ISO9001:2008 certified facility, the company offers the necessary expertise to design and manufacture custom sensors and cable assemblies to meet the requirements of unique commercial, aerospace/defense, and OEM applications, including unique packaging configurations, special connectors and calibrations with short lead times. Calibration services are also A2LA accredited to the ISO 17025 standard, ensuring the quality and uniformity of sensors and instrumentation, all tested according to rigorous in-house standards.





Dytran *Piezoelectric and DC MEMS Sensors for Measurement and Monitoring*, a new 172-page commercial catalog

The Dytran model 7600B was designed as a drop-in replacement for piezoresistive units in new or existing zero- to medium-frequency applications

The 3232A, a unique bracket-style accelerometers are available in a variety of sizes, sensitivities, and connector offerings

CONTACT

The Dytran Instruments Piezoelectric and DC MEMS Sensors for Measurement and Monitoring catalog is available to download at www.dytran.com, or may be ordered in printed form by emailing marketing@dytran.com.

Go to online reader enquiry number 101

Inspecting composites

Ultrasonic NDT is an attractive method for inspection of composite materials, which are unsuitable for eddy current technology and can be difficult to inspect with x-ray. Thermography and shearography methods offer quick visualization of some problems with composites, but detailed interpretation and defect classification can be difficult.

Ultrasonic NDT is widely used within the aerospace sector for NDT of CFRP materials, and has many other applications in industries such as the automotive, marine, and wind energy sectors. The design and properties of composite materials vary widely, from high-quality well-consolidated CFRP to large structures comprised of GRP and sandwich core materials. This places many tough demands on ultrasonic instruments and probes, both in terms of obtaining optimum signal quality from the materials, and also providing all the software tools to both analyze and evaluate inspection data.

Phased array

The Sonatest Veo 16:64 phased array flaw detector offers wide bandwidth with low frequency capability for attenuating composites, together with dedicated low noise channels for conventional ultrasonic testing.

High speed and uncompressed waveform storage enable fast inspection speeds, with the ability to inspect very large areas. With the latest release of software launched just in September 2011 the Sonatest Veo now has enhanced composite inspection capabilities, together with a system of powerful corrosion mapping functionality.

Whether inspecting aircraft structure during production or in-service, the Veo 16:64 has the storage and processing power to cope with large volumes of inspection data; providing a very capable platform for obtaining the best signals from a large range of the latest composite materials.

Often composite materials are ultrasonically noisy, requiring flexible gating and fast C-Scan processing to accurately classify and report on defects. Multiple views of the inspection data provide insights into the structure of the material, enable defect ply depth to be determined, visualize the effects of fibre-wrinkling, and facilitate volumetric analysis for impact damage and porosity assessment.

Swift mover

Analysis of inspection data and reporting is designed so that fast decisions can be made, shortening overall inspection time, and minimizing impact on aircraft availability.

Sonatest will be exhibiting the Veo, along with other NDT Inspection technologies at the up and coming Composites and Aerospace Engineering Exhibition at the Birmingham NEC, UK, November 9-10, 2011, Stand 539.. Alongside this as a leading example of NDT instrumentation in aerospace and composites inspection sectors, Sonatest will also be demonstrating the Rapidscan Series of equipment together with a range of the WheelProbes, ideal for fast large area scanning and testing advanced materials.

Above: MRO Inspection using the Veo (Courtesy of Torngats Technical Service Inc)
Left: New software release for composite inspection using the Sonatest Veo 16:64

CONTACT

To find out more about the Sonatest Veo please visit www.sonatestveo.com.
For further information about NDT and composite inspection please visit the new Sonatest Ltd website, www.sonatest.com.

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Engine vibration monitoring

Turboprop and jet engine vibration test data can offer real-time warning signs of the critical mechanical engine design issues that often lead to premature equipment failure. While pressure, flow, temperature, and acoustic parameters are also important, they tend to offer later-stage clues of an ongoing mechanical issue, long after damage may have already occurred. As such, the use of high-accuracy sensors and instrumentation for engine vibration monitoring is essential for new aircraft engine R&D and the establishment of longer-term predictive maintenance strategies.

Sensors used in onboard and test cell aircraft engine vibration monitoring are typically mounted over engine bearings, as well as in and around suspected high-vibration and stress areas, such as fan casings, compressor stages, and combustion chamber 'hot zones'. While each manufacturer's choices of sensing technology type and mounting locations are unique, certain performance attributes are universal. The accelerometers must be field-proven as highly rugged, with precision amplitude, frequency, and phase response, as well as stable performance over extreme inflight speeds and temperatures, with precise data matching from multiple sensors. Many feature low base strain sensitivity, a rugged hermetic connector, integral cable, and through-bolt design for easy installation within cramped areas.

Due to their stability, high-temperature survivability, high-frequency measurement capabilities to 30kHz, and availability in different sensitivities, weights, sizes, and shapes, charge output piezoelectric accelerometers are popular choices. Meggitt's Endevco® charge output models feature high-sensitivity, high-output, rugged connectors, and standard three-point ARINC mounting, with a long mean time between failures (MTBF). As self-generating devices, the accelerometers require no external power source for operation, presenting a major onboard testing advantage.

For routine post-overhaul engine testing, a case-isolated balanced differential output accelerometer, such as the model 6233C, operating to +482°C with standard sensitivities of 10, 50, and 100 pC/g, is specified. With such high temperatures, use of a charge amplifier or remote charge converter accepting a 100kΩ source resistance, such as model 2777A, is additionally required. Differential output units feature a wide operational bandwidth and direct compatibility with any industry charge amplifier. They also offer high immunity to electromagnetic interference (EMI).

For onboard aircraft engine monitoring, the low-profile model 6222S series, available in high sensitivities of 20, 50, and 100 pC/g and operating to +260°C, is specified. This product offers the field-proven pedigree of nearly 14,000 successful field installations to date. Models feature Isoshear® construction, significantly reducing transient temperature and base strain outputs, with high mounted resonance frequency. The series also includes a choice of three ruggedized connector types.

Measurement requirements for new aircraft engine R&D can prove to be even more extreme. Specified accelerometers typically require rugged Inconel housings, the use of high-temperature connectors, and both case and ground isolation.

Operating to +650°C, low-profile models 6237M70 and 6237M71, with 10 pC/g output, are specified. Their design facilitates installation into cramped locations with minimal structural support. Both offer a resonance frequency of 11kHz, with frequency response to 3kHz (±5%). Units are supplied with integral hardline cable and single-bolt mounting. The compact model 2721B is a directly compatible charge amplifier for these transducers, offering ±15 VDC operation and resistance down to 1kΩ, with output voltage directly proportional to input charge level. This amplifier features a flat frequency response from 3Hz to 10kHz, output signal decoupling, front panel switchable filter, and range switching in mV/g. The output is then normalized in mV/g.

To verify instrumentation settings and cable integrity, the use of a portable, handheld, battery-powered simulator, such as the model 4830A, is common. Model 4830A is able to accurately simulate single-ended and differential charge (pC), single-ended voltage (mV), current-sinking Isotron® (IEPE) and tachometer (TTL) outputs over a frequency range of 1-10,000Hz and with adjustable output amplitude to 10,000 pC or mV pk.

Above left: the Endevco model 6222S, a low-profile high-sensitivity charge output accelerometer for on-board aircraft engine monitoring

Above right: Models 6237M70 and 6237M71 are used to support demanding aircraft engine R&D requirements

Left: Sensors used in on-board and test cell aircraft engine vibration monitoring are typically mounted around suspected high-vibration and stress areas

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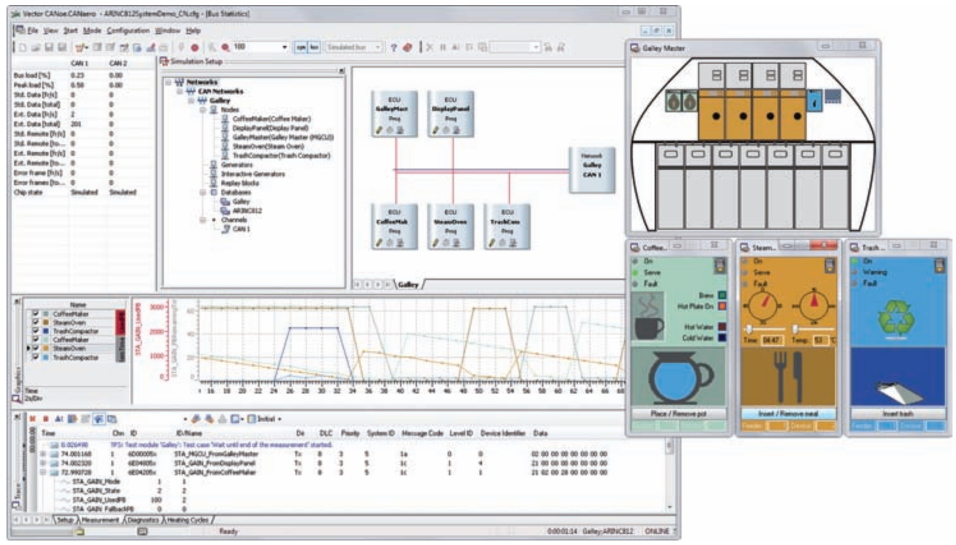
Simulation and analysis of CAN-based avionic bus systems



Along with the CAN protocol, CANoe.CANaero 7.6 from Vector also supports ARINC protocols 810, 812, 825, and 826. The development and test tool covers many task areas in developing CAN-based networks for the aerospace industry. These tasks range from network design to comprehensive network analysis and systematic testing of electronic units. Network designers, development and test engineers at aircraft manufacturers, system suppliers and component manufacturers can use the software tool CANoe over the entire development process, especially in the testing area. Versions 7.6 of CANoe.CANaero, and CANalyzer.CANaero contain extensive functions for networking with ARINC protocols and the CANaerospace protocol.

The columns of the Trace Window are now user-configurable. CAN identifiers can be subdivided into segments and displayed in separate columns of the Trace Window. In addition, users can define a value table for each identifier segment, which enables text interpretation of different segments during measurement. This greatly simplifies the interpretation of proprietary protocols.

One of the primary applications of CANoe. CANaerospace is testing electronic units and networks – from simple interactive tests performed in design or implementation to systematic automated tests. Detailed test results are documented in an automatically generated test report.

The user assigns attributes in a project database to the messages and their data segments, such as project-specific names, conversion formulas and units. ARINC 825 profile files can be read-in and exported. Building upon this, it is possible to display messages and their data contents on the system level, service level, and message level. Examples include cabin pressure control, water waste, body pitch angle, boiler water temperature and many more. Sending of messages and their data contents is also parameterized in this way.

The ARINC organization manages and administers a number of specifications in the aerospace field. ARINC 810/812 is used to standardize communication between on-board galley inserts, for example. The focus here is on power management. The latest challenges in the development of onboard galleys involve the issues of increasing modularization, interchangeability, and the disposal of aircraft electronics. ARINC 810 defines the physical interfaces for this and ARINC 812 the CAN-based galley databus. Among other things, it provides services and protocols for coordination of onboard galley inserts by the galley master control unit. ARINC 825 specifies both the fundamental communication within CAN-based subsystems and between CAN subsystems, which might be interconnected by AFDX. It offers addressing mechanisms, communication mechanisms, a service structure, profile descriptions, and much more.

ARINC 826 specifies software data load over CAN. The mechanisms of ARINC 615A were adapted and optimized for CAN here. AFDX (Avionics Full DupleX Switched Ethernet) will serve as the next-generation aircraft data network. CANaerospace was developed by Stock Flight Systems. Key protocol applications are in engineering simulators, simulation cockpits, and especially drones (UAVs).

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Spacecraft Technology Expo 2012 set for Los Angeles

Smarter Shows, a globally renowned developer and organizer of next-generation B2B conferences and exhibitions, has announced official show dates for Spacecraft Technology Expo. Set for May 8, 9 and 10, 2012, at the Los Angeles Convention Center in Los Angeles, California, USA, the show will bring together global decision makers, supply chain experts, suppliers and customers to identify present and future market growth opportunities for the design, manufacture, and pre-launch testing of spacecraft and space-related technologies. Invited technical experts and guests shall include representatives from NASA, ESA, CSA, JAXA, and other key players from government, military, and private sectors.

Confirmed exhibitors include SpaceX, United Space Alliance, ACRA Control, Siemens, Axon Cable, Martinez & Turek, Microflown Technologies, RAL Space at

the Rutherford Appleton Laboratory (UK), AlphaStar, Flotron, Cryoconnect, Wyle Laboratories, Collier Research and DNB Engineering, among dozens of others. With its technical programming, comprehensive hall offerings and targeted networking opportunities, Spacecraft Technology Expo is anticipated to offer exhibitors and attendees the opportunity to share in a one-of-a-kind marketplace of ideas via one of the most targeted return-on-investment channels ever offered by an exhibition of this type.

For further information contact

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Safety first

Over almost 30 years, VOGT Ultrasonics GmbH, based in Hanover, Germany, has gained a major reputation as a competent, strong and reliable partner for the most intricate and demanding non-destructive material testing and quality-assurance tasks. Today, companies from all fields of industry, above all from the aviation, aerospace, and automotive sectors, put their trust in know-how and reliability of VOGT's services. VOGT's performance and high expertise has been recognized by the repeated renewal of its accreditation to EN ISO/IEC 17025 and EN 9100. All VOGT's service personnel is highly trained and experienced with EN 473 and EN 4179 qualifications and certifications.

One of VOGT's main competencies is ultrasonic material testing which has proven to be a highly efficient means of ensuring quality in production processes – reliably controlling the thickness and the integrity of surfaces, welding seams etc. However, ultrasonic testing requires valuable systems and experienced personnel, making for intensive investment which gives good return in large-scale series production but can be too expensive for small and medium-batch production runs. Fully automated scanning enables VOGT to perform reliable inspections on very demanding and highly complex parts, such as rotationally symmetrical or flat components. With a sophisticated range of stationary and portable ultrasonic scanners, VOGT is able to inspect parts in their own laboratory or on-site at customer facilities.

In 2008 VOGT gained approval to provide ultrasonic testing (UT) for Rolls-Royce related parts for various manufacturers. The approval specifically applies to UT inspection in accordance with RPS 705. The first applications of the Rolls-Royce approval have been to perform turntable-related immersion testing of gas turbine engine-disc forgings.

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Dynamic ICP pressure sensors for rocket motor research

Rocket motor combustion instability is a problem that reduces engine performance, induces structural vibration and can possibly lead to failure of the exhaust, motor or its components. The design goal for a rocket motor is to eliminate combustion instability, because it leads to unsteady thrust resulting in structural vibrations, an uncomfortable ride for astronauts or payload, difficulty with guidance systems, and in extreme cases, catastrophic failure. Amplitudes of damaging combustion instability can range from just a few hundred psi for small motors up to the low thousands of psi for very large motors. Most damaging frequencies tend to occur in the low Hz to low kHz band.

Combustion instability, due to chamber acoustics or fuel supply, is a common design problem not easily modeled. Water-cooling and Helium-bleed allows ICP pressure sensors to operate at extremely high temperatures in rocket motor combustion environments for detection of rapid pressure transients and pulsations.

They monitor dynamic pressure while subjected to high static background pressure. ICP output features onboard electronics to provide conditioned output signals and ease of use. All of these tools assist in measuring very small dynamic pressure instabilities, allowing test engineers to find the source and correct design problems.

For the complete PCB paper titled, Dynamic ICP Pressure Sensors for Detection of Combustion Instability and High Intensity Acoustics in Rocket Motor Research.

The company PCB manufactures the largest selection of sensors and sensor accessory products worldwide. Our product lines include sensors for the measurement of acceleration, acoustics, force, load, pressure, shock, strain, torque, and vibration.

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The MIL-STD-1553 PCI express has arrived

AIM's all new and powerful design PCIe module for MIL-STD-1553 is packed with features to enhance the experience when analyzing, testing, simulating, and monitoring MIL-STD-1553A/B databuses. It offers up to four dual redundant MIL-STD-1553A/B streams on one PCIe card.

The highly integrated new design uses a high-speed FPGA with integrated PCI-Express bus (2.5Gb/sec rates) and IRIG-B Time Encoder/Decoder. The autonomous boot up system means the APE1553-x is an ideal solution for any MIL-STD-1760 weapons test control application.

Full function versions concurrently act as bus controller, multiple remote terminals (31), chronological bus monitor/mailbox bus monitor. Single function or simulator only versions are also available as are extended temperature range versions. Powerful features include full MIL-STD-1553A/B protocol error injection/detection (as4112/4111 compliant), multi level triggering and filtering, real time recording (100% bus loads – all dual redundant channels concurrently) and physical bus replay. The physical bus interface (PBI) provides programmable bus-coupling modes and variable output amplitude to the MIL-STD-1553A/B bus.

The APE1553-x also integrates eight (Avionic Level) general purpose discrete I/O (GPIO) signals that can be used to generate strobe outputs or to sample external digital inputs, as well as hardware in- and outputs.

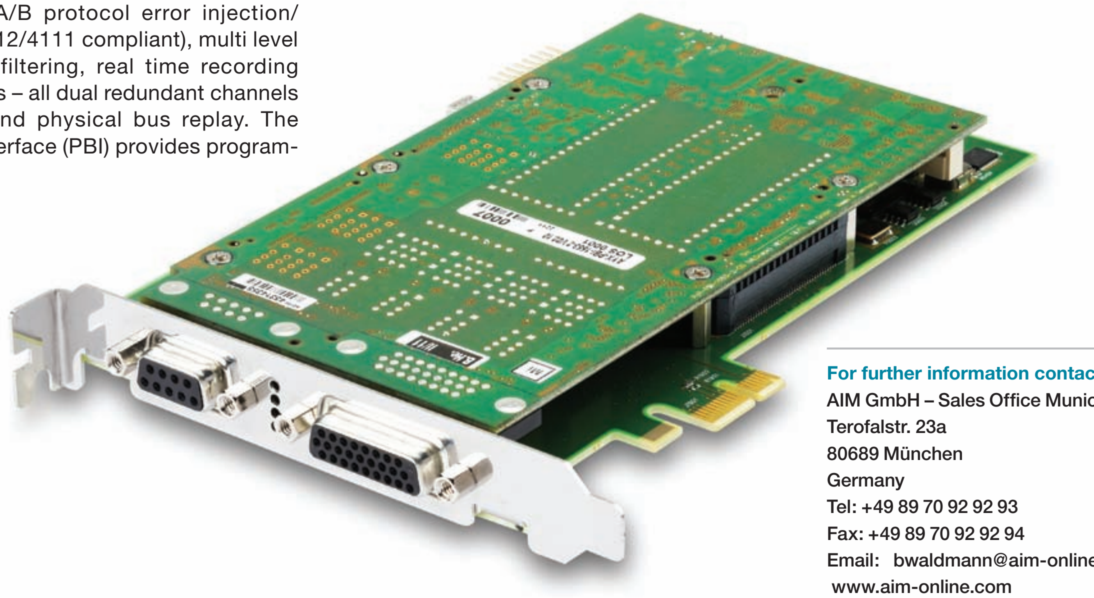
To maximize performance and reliability, a highly integrated design incorporates multiple RISC processors with 128MB of Global RAM and 128MB of ASP RAM. An application support processor (runs a real time Linux OS on board) runs the driver software on the card, minimizing the host PC interaction and latency for real time requirements.

An onboard IRIG-B time encoder/decoder provides a sinusoidal output and 'free-wheeling' mode for time-tag synchronisation on the system level, when using one or more AIM cards.

The application programming interface (API) is bundled into the module price. The driver is compatible with 32bit/64bit versions of WindowsXP/Vista/7, and Linux. LabVIEW VIs and LabVIEW RT drivers are included with the package. Host applications can be written in C/C++ or C#. The APE1553-x is software compatible with AIM's family of PCI/PCI-X, PC/104-Plus, USB, PC-Card/Express-Card, PMC, cPCI/PXI, VME, and VXI MIL-STD-1553 cards.

The powerful and industry standard PBA.pro databus test & analysis tool (for Windows & Linux) can also be used in combination with APE1553-x cards.

AIM will roll out several exciting new PCIe cards for ARINC429 and AFDX/ARINC664P7 based on the third generation common-core design in the coming months.



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Flying fish

BY FRANK MILLARD

The MiG 21 short-range fighter-interceptor was designed and built by the Mikoyan-and-Gurevich (MiG) Design Bureau in Russia, which was founded by Artem Mikoyan and Mikhail Gurevich. MiG aircraft must not be thought of as the product of a single genius but of a very special partnership between two remarkable aircraft designers and their team.

Mikhail Iosifovich Gurevich (1893-1976) briefly attended the University of Kharkiv in Ukraine and then relocated to Montpellier University in France, where he specialized in aeronautics, before returning to the Soviet Union, and graduated in aeronautical engineering. In 1937 he led a design team at the Polikarpov Design Bureau in Moscow before joining with Artem Mikoyan as Mikoyan-and-Gurevich and becoming their company's chief designer.

Gurevich's partner, Armenian Artem Ivanovich Mikoyan (1905-1970), entered the Zhukovsky Air Force Academy after fulfilling military service. He then joined the Polikarpov Design Bureau on graduation in 1937 and in 1939 headed the new Mikoyan-and-Gurevich bureau.

After a slow start, the design team learned a great deal from captured German aircraft and obtained British jet-engine technology after World War II, basing their early post-war jet designs on this. As a sign of goodwill and an attempt to improve relations between the two countries, in 1946, before the cold war got too frosty, UK Prime Minister Clement Atlee had given permission for 40 Rolls-Royce Nene turbojet engines to be sent to the Soviet Union.

Stalin was amazed, and the MiG 15, derived from British technology and German aerodynamics, was fitted with Russian-built and adapted Nene engines.

Aerial warfare came into the modern jet age in the early 1950s when MiG 15s engaged in the first full-scale dogfights between jet aircraft over North Korea, in what the Americans called MiG Alley. It easily outclassed the UK's Meteor and the US F-84. No allied aircraft could match the MiG 15 until the USA deployed the F-86 Sabre in combat. Even so, MiG Alley was never a safe place for allied jets to fly. The MiG 15 provided the blueprint for subsequent Russian fighters, such as the MiG 21: robust, agile, easy to produce, and easy to fly.

Iconic jet

The iconic MiG 21 (known by NATO as the Fishbed, and popularly called the Balalaika) was a highly maneuverable and reliable supersonic Soviet fighter aircraft of the Cold War era. It was distributed widely to the allies of the Soviet Union and more than 10,000 were built in three factories in the USSR, with others built under license in India and Czechoslovakia.

The MiG 21 was simple to fly, and therefore eminently marketable around the world. It had the longest production run of any jet combat aircraft in history and holds the record for the number produced. Like all good aircraft it was regarded as a pilots' airplane – agile and highly responsive to good handling.

Considerably modified over the years, its durable airframe accounted for its suitability for upgrade. The aircraft featured square-tipped 57° swept delta wings, mounted in the middle of a long tubular fuselage, with a swept-back square-tipped tail fin, a round air intake in the nose, and a single exhaust.

Originally armed with a cannon, the MiG 21 was later fitted with air-to-air missiles and bombs; later versions featured missiles exclusively. Although it had a very fast climbing rate, afforded by its delta-wing configuration, this also meant a dramatic loss of speed on the turn.

MiG 21s flew with more than 50 air forces around the world and saw action in 30 theaters of combat. In the skies over North Vietnam, during the Vietnam war, the MiG 21 distinguished itself against the US Phantoms – until the superior training of the US pilots turned the tide. It also saw action in the India-Pakistan conflict of 1971 and in the Middle East it was flown by the Egyptian and Syrian air forces. During the Six-Day War, in 1967, it was put to the test against the Dassault Mirage, flown by the Israelis. ∎

MAGNIFICENT MEN

and their flying machines