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

APRIL 2014

AEROSPACE TESTING INTERNATIONAL

World military sites

Your guide to the world's top military test sites, and exclusive interviews with their commanders

RUSSIAN STEALTH

A unique insight into the development of the Russian 5th-generation PAK FA fighter

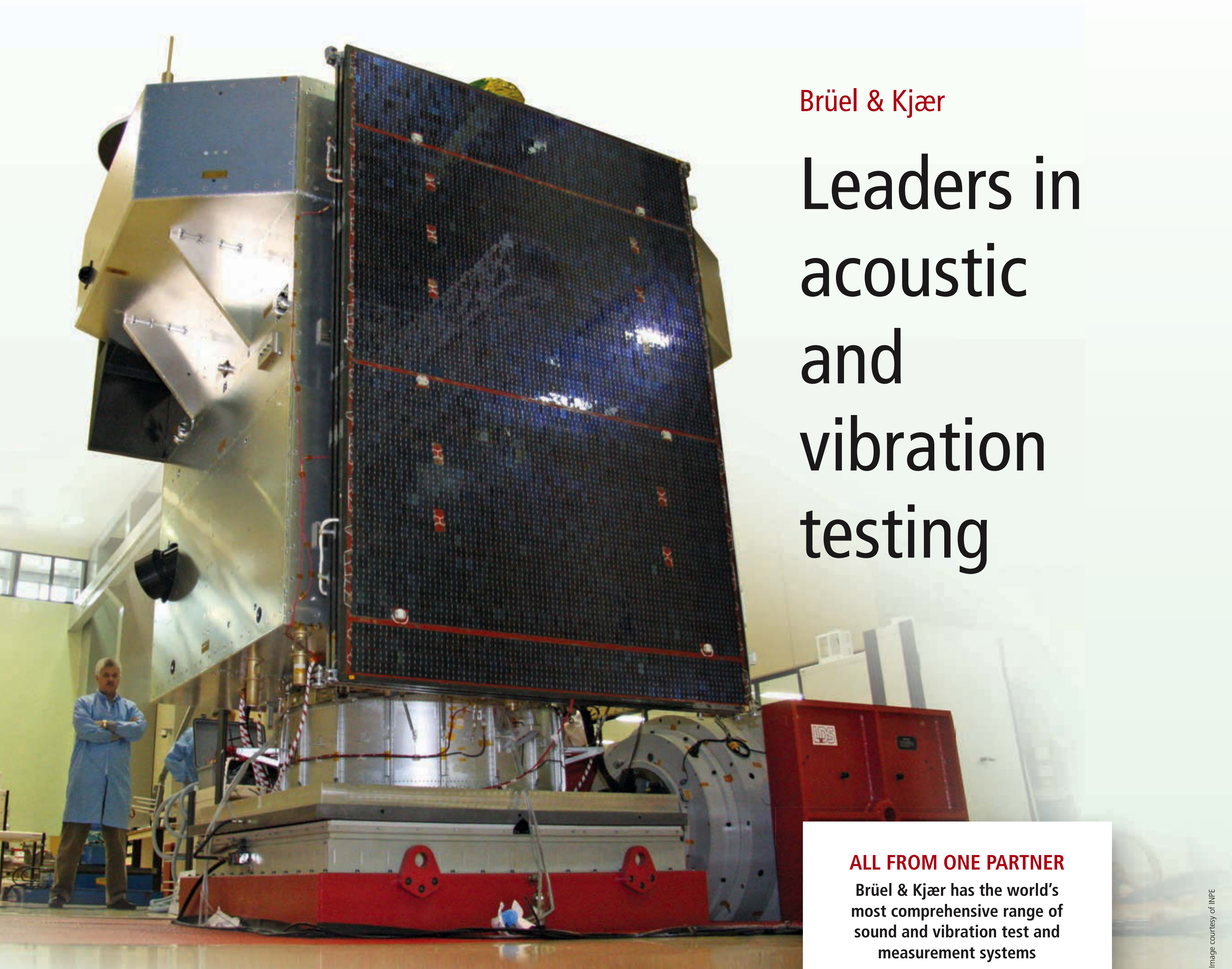
ENGINE TESTING

Flight and certification update from the Trent XWB and Trent 1000-TEN programs

LAST DITCH ENQUIRY

Eurocopter's 'war room' and the methods used to understand why two separate accidents happened

ACTIVE FLOW CONTROL • TYPHOON TEST CHIEF • MANDI (NDI ROBOT) • G-FOLD LATEST


LDS


38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62

Some time ago, I had planned to discuss aircraft accident investigation in this foreword, after receiving David Oliver's insightful article on the 'war room' investigation into the two separate ditchings in 2012 of the Eurocopter EC225. Both incidents were unrelated but involved helicopters that were transporting oil workers to and from rigs off the coast of Scotland. The combined investigation proved to be one of the most expensive ever conducted into helicopter accidents. The article is on page 38.

I intended to discuss how accidents such as these affect regulations, test procedures and MRO. The aerospace industry evolves in a reactive manner rather than being proactive. An accident happens, there is a thorough investigation, a report is published, and then a raft of new regulations are initiated, and new tests and maintenance processes enacted.

Then, on March 8, the news broke that civil airliner MH370 had gone missing over the South China Sea, and my angle of attack changed. Within a few days I had my theory penned within this column. What could have happened to the Boeing 777? People were theorizing on similarities with AF447, which went down in the mid-Atlantic in 2009. Initial speculation on that incident was that there had been electrical problems, but it turned out to be pilot error during extremely severe meteorological conditions. My position on MH370 was that a catastrophic decompression had started in the cockpit and swept backward.

My intention was that I would tune my words before going to press two weeks later. All the questions would be answered by then and I would reiterate how regulations will change as a result of cockpit decompression, unconscious pilots' oxygen being sucked out, and a locked door. How wrong.

The magazine goes to print today, and by the time it hits desks, everything will have changed again. At this point, debris has been seen by satellite far off the southwest coast of Australia, but the imagery is two days old and although the RAAF is following up the search, it is hampered by the weather and aircraft search range.

It is so easy to speculate. First it is aircraft malfunction, then terrorist attack, then missile interception, then pilot intervention. I'm dubious about it being a terrorist plot – the creed of this activity is to advertise what you have done. The point is to highlight your actions to further your cause, and this has not happened. As for pilot agenda… really? Pilots are constantly assessed and tend to be straightforward people. But there is one theory (and of course they are all only theories), that does sound credible.

Many experts have said the transponder was switched off deliberately and the aircraft was 'obviously' flown under control. But it is not obvious. Amazingly, I have read the following theory only on social websites and not in a single news item. It goes like this: A major fire in the electronics bay (underneath the cockpit area) – one of the most common forms of aircraft malfunction – occurs. All comms are disabled following a complete disruption of a major power line/bus. Transponder, radios, ACARS – it all fails. The pilots immediately turn southwest, heading for the safety of Langkawi International Airport and its coastal runway, and are tracked by radar doing so. The plan is to head to open ocean and approach the runway from there. The prime mission is to get the aircraft on the ground. No radios, no signaling ability, nothing to make anyone aware of the crisis. Below the floor, a raging fire. The turn is made to the southwest – but the pilots are overcome and die and the aircraft carries on into the southern Indian Ocean.

My father was a senior civil and experimental pilot. He nailed what happened to AF447 before they even found the debris and while news teams were reporting terrorism. I am sure he would concur with the theory above. He had a great respect for Boeing aircraft. He once told me about flying a freight 707 to Europe from East Africa with a cargo hold full of hundreds of monkeys, which escaped and tore the aircraft apart from the inside out. No avionics, no comms, no guidance system, no transponder. The monkeys even got into the wings, so fuel was flowing out. But using only a compass, the two-man crew managed an emergency landing at Malta. If they had missed the target and disappeared into the sea, what would the speculation have been?

Regulations will change but I am unsure whether they will affect anything on board. My feeling curves toward a change in how we track civil airliners, and that would be from the ground.

On a different note, look out for our brand-new feature starting on page 46, which takes an exclusive look at military test sites, with unique access to the commanders and locations.

Christopher Hounsfield, editor

PRODUCTS & SERVICES

REGULARS

EDITOR Christopher Hounsfield (chris.hounsfield@ukipme.com)
ASSISTANT EDITOR Bunny Richards (bunny.richards@ukipme.com)
PRODUCTION EDITOR Alex Bradley
CHIEF SUB EDITOR Andrew Pickering
DEPUTY CHIEF SUB EDITOR Nick Shepherd
PROOFREADERS Aubrey Jacobs-Tyson, Christine Velarde

ART DIRECTOR James Sutcliffe
ART EDITOR Louise Adams
DESIGN CONTRIBUTORS Andy Bass, Anna Davie, Craig Marshall, Nicola Turner, Julie Welby, Ben White
HEAD OF PRODUCTION & LOGISTICS Ian Donovan
DEPUTY PRODUCTION MANAGER Lewis Hopkins
PRODUCTION TEAM Carole Doran, Cassie Inns, Frank Millard, Robyn Skalsky

SALES MARKETING DIRECTOR Sally James (sally.james@ukipme.com)
PUBLICATION MANAGERS Nick Barr (nick.barr@ukipme.com);

CEO Tony Robinson
MANAGING DIRECTOR Graham Johnson
EDITORIAL DIRECTOR Anthony James

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COVER IMAGE: Military test site. Eurofighter Typhoon Warton, UK)

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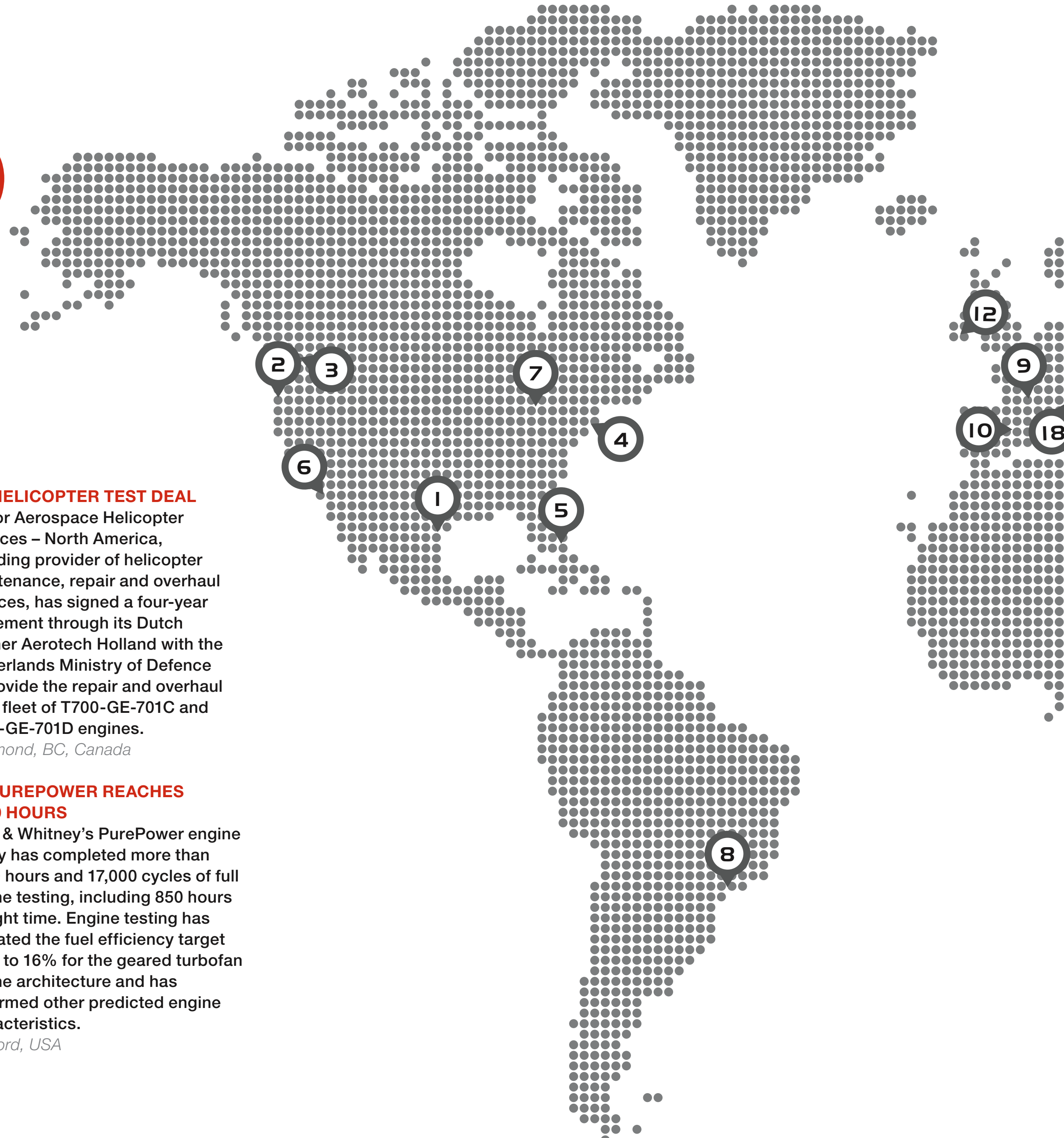
WORLD
TEST UPDATE

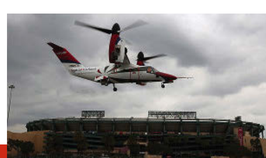


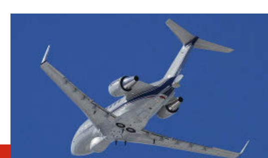
1 UNMANNED AIR SYSTEM
Texas A&M University-Corpus Christi has continued its preparations to be fully operational as one of only six federal test sites for unmanned aircraft systems with another series of test flight missions over the area. Researchers have been conducting missions twice a day with the university's RS-16 unmanned aerial vehicle (UAV), and another UAV owned by American Aerospace Advisors.
Corpus Christi, Texas

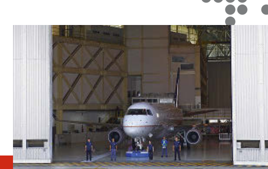
2 737 COMMERCIAL DELIVERY CENTER
Boeing has kicked-off expansion of its 737 Commercial Delivery Center (CDC) at Boeing Field in Seattle. The project more than doubles the space that will be available for customers and groups supporting increased 737 deliveries. The expanded CDC will be more than 90,000ft² and will include a new three-story building, as well as new delivery and departure areas with three covered jetways.
Seattle, USA

3 HELICOPTER TEST DEAL
Vector Aerospace Helicopter Services – North America, a leading provider of helicopter maintenance, repair and overhaul services, has signed a four-year agreement through its Dutch partner Aerotech Holland with the Netherlands Ministry of Defence to provide the repair and overhaul of its fleet of T700-GE-701C and T700-GE-701D engines.
Richmond, BC, Canada

4 PUREPOWER REACHES 7,600 HOURS
Pratt & Whitney's PurePower engine family has completed more than 7,600 hours and 17,000 cycles of full engine testing, including 850 hours of flight time. Engine testing has validated the fuel efficiency target of up to 16% for the geared turbofan engine architecture and has confirmed other predicted engine characteristics.
Hartford, USA







5 CREW PROGRAM
NASA's aerospace industry partners have met further milestones under agreements with the agency's Commercial Crew Program (CCP), as they move forward in the development of spacecraft and rockets that will transport humans to destinations in low-Earth orbit. Blue Origin, Boeing Space Exploration, Sierra Nevada Corporation and SpaceX are all developing transportation systems.
Kennedy Space Center, USA

6 DEMONSTRATION OF AW609
The first customer demonstration flight of the AW609 to Chevron took place on February 25. The round trip flight began in Angels Stadium in Anaheim and continued off the coast of Southern California. During the flight, the aircraft flew at speeds up to 220kts, demonstrating its high-speed cruise capability. The maximum cruise speed of the AW609 is 275kts.
Anaheim, California

7 MARITIME SURVEILLANCE
Boeing's Maritime Surveillance Aircraft (MSA) demonstrator has completed its first flight, an important milestone toward providing a low-risk maritime surveillance solution designed for search and rescue, anti-piracy patrols and coastal security. Field Aviation conducted the tests during a four-hour flight. Field Aviation modified the Bombardier Challenger 604's structures and systems into the MSA configuration.
Toronto, Canada

8 EMBRAER E175
Brazil-based Embraer claims its new E175 features a range of aerodynamic improvements that reduce fuel burn compared with the previous production aircraft. The modifications include the introduction of a new wingtip, systems optimization, and streamlining of aerodynamic surfaces. The first customer delivery of the E175 with the complete package of modifications is expected in the coming weeks.
São Paulo, Brazil

9 MSN2 AND MSN4 PERFORM FIRST FLIGHTS
The A350 XWB flight test aircraft, MSN2 and MSN4, have both taken to the skies for their respective first flights, bringing the number of A350 XWBs now flying from two to four. The first two A350 XWB test aircraft to fly have already performed more than 1,100 flight test hours out of the program's total of 2,500 hours. MSN2, with its carbon inspired livery, will be the first A350 XWB test aircraft to feature a full passenger cabin
Toulouse, France

15 DEMAND FOR STANDARDIZATION
Hindustan Aeronautics has stated that the CEOs forum at the India Aviation show at Hyderabad, "Largely felt that the Indian aviation industry would be better off with single certifying agency authorized to issue civil and military flying rights simultaneously for any aircraft produced in the country."
Dr R K Tyagi, chairman, HAL, said that a single certifying agency would be in the national interest as it would mean huge savings in terms of costs and time.
Hyderabad, India

16 CIVIL AIRCRAFT PROTECTION
The Israel Missile Defense Organization, in cooperation with the Civil Aviation Authority at the Ministry of Transport and the project's main contractor, Elbit Systems, has successfully completed a series of tests on the SkyShield system that protects passenger aircraft against shoulder-fired artillery.
Southern Israel

17 NEXT-GENERATION FLIGHT FOR RUSSIAN FIGHTER
The flight model of the prospective fifth-generation fighter aircraft (PAK-FA, T-50) has been taken to the 929th Chkalov State Flight Test Centre's airfield in Akhtubinsk for 'State Joint Tests'. Currently, there are four fifth-generation T-50 fighter aircraft undergoing separate flight tests in Zhukovsky.
Akhtubinsk, Russia

18 PYLON FOR GRIPEN E
Saab has awarded RUAG a contract for the production of 'pylons' for the Gripen E. RUAG has agreed to fulfill the contract in collaboration with other contractors from Switzerland. The pylons are a significant structural part of Gripen E and act as mounts for weapons, reconnaissance pods and external fuel tanks. They will feature in 22 Gripen E for Switzerland and 60 for Sweden.
Bern, Switzerland

10 A400M RUNWAY
Airbus Military has completed an important set of trials of the A400M new-generation airlifter, demonstrating the aircraft's performance on gravel runways. In tests lasting more than a week at Ablitas in northern Spain, development aircraft MSN2 performed 25 landings during six flights on the same runway. The trials confirmed that despite the harsh conditions, damage to the aircraft exterior from stones and dust was minimal.
Ablitas, Spain

11 TIGER UHT
The German Army has received the last of 12 Tiger UHT support helicopters upgraded by Airbus Helicopters for Afghanistan missions to support ground troops, protect convoys and perform reconnaissance operations. The helicopter, presented during a delivery ceremony at Airbus Helicopters' Donauwörth production facility in Germany, was provided to the military service's 36 Combat Helicopter Regiment.
Donauwörth, Germany

12 WILDCAT SEA LANDING
A Wildcat, the Royal Navy's next-generation helicopter, has landed for the first time on the flight deck of a Type 45 destroyer at sea. The Wildcat, the maritime attack variant of the Lynx helicopter, is currently undergoing extensive trials with 700W Naval Air Squadron. As part of those trials, the aircraft has been working at the MoD's aerial range in Cardigan Bay.
Cardigan Bay, UK

13 TECHNICAL COOPERATION
Airbus and China's Northwestern Polytechnical University (NPU) have signed an agreement to look at ways to apply 3D printing in the commercial aviation sector. Under the new agreement, NPU will manufacture test specimens of titanium alloy parts for Airbus using its laser solid forming technology. The specimens will be manufactured according to Airbus's specifications and will be assessed by Airbus.
Shaanxi, China

14 WEDGETAIL DEFENSE DEAL
The Australian Defence Material Organisation has signed a contract extension with Boeing Defence Australia for the support of the RAAF's E-7A Wedgetail Airborne Early Warning & Control fleet. The sustainment contract covers engineering and maintenance support, repairs, spare parts, and aircrew and maintenance training, through 2019.
Canberra, Australia

ORIGINAL CONCORDE HAS NEW HOME

One of the first Concorde jetliners built at Toulouse, France, has made its final 'voyage' with the aircraft's ground transfer to the Airbus-supported Aeroscopia museum site at Toulouse-Blagnac Airport. Designated MSN1, this Concorde made its last flight in April 1985, returning to Toulouse after a career that included a full range of test and development activity. The Aeroscopia museum, where Concorde MSN1 will be permanently displayed, has received funding from Airbus.

FAA CLEAN BILL FOR 787

The Federal Aviation Administration (FAA) and Boeing have announced the completion of a comprehensive review of the 787's critical systems. The joint review, initiated in January 2013, included an examination of the processes for the design, certification and production of the 787-8. Boeing stated that the review's findings validate the integrity of the airplane's design and confirm the strength of the processes used to identify and correct issues that emerged before and after the airplane's certification.

The review concludes that the 787 meets the intended level of safety expected by the FAA. "We welcomed the opportunity presented by this joint review of the 787 and its in-service performance," said Boeing Commercial Airplanes president and CEO Ray Conner. "The findings validate our confidence in both the design of the airplane and the disciplined process used to identify and correct in-service issues as they arise. I am grateful for the hard work of the joint review team and for its recommendations, which will allow us to further improve our processes as we move forward."

WILDCAT TEST SQUADRON

The UK's Army Air Corps has formed a dedicated squadron to bring the AgustaWestland Lynx Wildcat (AW159) helicopter into service over the next year.

From its base at Royal Naval Air Station Culdrose, 652 (Wildcat Fielding) Squadron is carrying out initial operational test and evaluation of the new variant of the veteran Lynx helicopter. The squadron will simultaneously be involved in training the initial cadre of Wildcat aircrew.

It had originally been intended that the army's Wildcat Fielding unit would be established only as a flight, but last year it was decided to expand the organization to a full squadron. More than 100 personnel are currently assigned to it.

Yeovilton is to be home to all the UK's Wildcats – both army and navy versions – and the two services are establishing joint training and engineering support facilities at the Somerset base. The Royal Navy is ahead of the game, having set up 700W Naval Air Squadron in 2009 for the Tactical Development (TACDEV) phase of the Wildcat's entry into service.

The small Army Air Corps team at Yeovilton was initially trained to fly the aircraft at AgustaWestland's nearby Yeovil plant, and was then moved to the naval air station to begin fielding trials, establish flying procedures, develop training packages and begin evaluations of the new helicopter in its future roles. These include intelligence, surveillance, target acquisition and reconnaissance (ISTAR), direction of joint fire, command and control, joint personnel recovery and battlefield evacuation.

Over the past year, 652 Squadron has been conducting a series of exercises with a variety of British Army units, including infantry regiments and Army Air Corps forward refueling teams.

The AAC presence at Yeovilton is set to grow over the coming year as the remaining elements of 1 Regiment arrive at the base from Germany to bring the strength to 600 soldiers. This unit in turn is part of the British Army's newly formed Aviation Reconnaissance Force, which is in control of all its manned ISTAR assets, including the Gazelle AH.1. Lynx AH.1 and AH.9, and the Britten-Norman Islander/Defender fleets.

652 Squadron is now moving to run the first conversion-to-type course to train the pilots to fly the new helicopter and then the first conversion-to-role course. This will see full squadrons worth of personnel trained to operate the helicopter in combat situations. The first unit to go through this process is 847 Naval Air Squadron, which will operate the army version of the Wildcat in support of the Royal Marines' 3 Commando Brigade.

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PAVEWAY IV CLEARED FOR UK TESTING

Trials and testing of the Raytheon Paveway IV dual-mode satellite/laser-guided bombs can now take place on air weapon ranges in the UK.

This follows the efforts by the UK Defence Equipment & Support (DE&S) to get the necessary safety clearances to allow the RAF's combat-proven all-weather 24-hour precision-guided bomb to be used on home turf. The Cape Wrath bombing range in the far north of Scotland is expected to be the main venue for deployment of the Paveway IV within the UK.

Previously the RAF Tornado GR4 and Typhoon combat aircraft had to deploy to overseas bases, mainly in the USA, to carry out trials or training with the Paveway IV weapon.

This situation will increase training opportunities for fast-jet crews, reducing UK reliance on overseas ranges, which will in turn reduce deployment costs, says the DE&S.

Clearance has been obtained by the Defence Ordnance Safety Group, a team of military and civilian engineers and scientists, based at the DE&S Abbey Wood headquarters near Bristol, who advise on the safety of weapons, ordnance, munitions and explosives. The Group advises project teams, agencies and contractors in the UK and overseas on munitions and air weapons range safety, as well as providing independent advice on the safe use of munitions and lasers during military training.

DE&S says the greatest challenges arise from accommodating modern long-range munitions delivered from fast-jet aircraft using greater weapon release heights and stand-off distances than during the Cold War, hence the need to use bigger overseas ranges for testing and training with those weapons.

"With the increasing accuracy and reliability of munitions, data from in-service trials, operational weapon releases and the use of the latest analytical software, we have been able to analyze historical data of Paveway IV delivery performance and reliability," said Wing Commander Jim Press of the Group's Air Delivered Weapons. "Working with scientists and NATO experts, a safety argument for the use of Paveway IV on UK ranges was produced to show that the associated risks were within UK legal tolerances and in line with Defence Land Ranges' risk threshold policy. This piece of technical work continues to demonstrate that, by exploiting current technology and embedded knowledge and skills, DE&S continues to deliver relevant solutions and cost-effective advice for front-line customers and wider defense organizations," Press stated.

PAVING THE WAY

The Paveway IV is an all-weather weapon in the 226kg (500 lb) weight class. It features INS/GPS and laser guidance, as well as a programmable fuse capable of providing a variety of impact effects. It has been used during combat operations in Afghanistan and Libya and will also be carried internally by the UK's future Lockheed Martin F-35B Joint Strike Fighters.

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MORE TESTS TO DEBUG P-8 POSEIDON

A program of additional test and evaluation is be launched by the US Navy to monitor a program of enhancements to the Boeing P-8 Poseidon maritime patrol aircraft.

The move comes after Michael Gilmore, the Pentagon's testing chief, revealed in his annual report that the aircraft is not yet effective at hunting submarines or performing reconnaissance over large areas – two of its main missions.

There are flaws in the US$35bn program, including shortcomings in the aircraft's radar performance, sensor integration and data transfer, according to Gilmore. He said in January 2014 that the new P-8A Poseidon exhibited "all of the major deficiencies" identified in earlier exercises when subjected to more stressful realistic combat testing from September 2012 to March 2013.

"Many of these deficiencies" led Gilmore to determine that the P-8A, "is not effective for intelligence, surveillance and reconnaissance missions and is not effective for wide area anti-submarine search". The US Navy now plans to conduct additional testing "to verify the correction of some deficiencies", he said.

Gilmore's conclusions suggest that the initial production aircraft are not ready for deployment, despite being despatched to Japan in December 2013. Six of the airplanes have since supported 7th Fleet maritime patrol operations at Naval Air Facility Atsugi as part of the USS's strategic pivot to the Asia-Pacific region.

In November 2013 the US Navy declared the aircraft ready for combat deployment after determining that the criteria for performing effective patrols "were fully met", Lieutenant Caroline Hutcheson, a Navy spokeswoman, said. "The P-8A was ready, was needed in theater and continues to more than meet fleet commanders' expectations," she said. Hutcheson said Gilmore's office has "consistently highlighted both effective warfare areas as well as recommendations for areas to revisit.

"Most issues cited have been collectively identified," she said, and the Navy has developed "software upgrades to correct deficiencies".

"Feedback we've received to date is that the Navy is very happy with the P-8A's performance," said a Boeing spokesman. "As always, Boeing will work hand in hand with the Navy to support any issues that come up."

A spokeswoman for Gilmore said the test office concluded the aircraft was effective in providing small-area searches, similar to the P-3C Orion it is replacing. The aircraft also is effective in conducting "unarmed anti-surface warfare missions", and its radar and supporting sensors "provide an effective, all-weather surface target search", she said.

Gilmore's office also concluded that the airframe is reliable, offering "significant improvements in hardware reliability, maintainability and availability" over the P-3C. Overall, the Boeing system "provides increased range, payload and speed".

Deficiencies with on-board electronics in detecting enemy anti-aircraft radar "limited threat detection" while "seriously degrading capabilities and aircraft survivability across all major missions", the report found.

The US Navy has plans to field two sets of aircraft upgrades to improve anti-submarine warfare capability over several years. It has developed an adequate test and evaluation masterplan to evaluate improvements.

TRITON TEST MILESTONE

A six-year-long operational trial by the US Navy's Northrop Grumman RQ-4A Broad Area Maritime Surveillance Demonstrator (BAMS-D) has surpassed 10,000 flight hours over the Middle East and the Indian Ocean, from a base in the United Arab Emirates.

According to the US Navy, the BAMS-D provides intelligence, surveillance and reconnaissance support to US and allied naval forces in the US Central Command area of responsibility. This experience is used to collect lessons learned for its successor, the MQ-4C Triton unmanned air system, which is to be the heart of the BAMS oceanic surveillance system. The operation trial is being used to refine tactics, techniques and procedures for large persistent unmanned air vehicles operating in a maritime environment.

"This was originally intended to be a six-month concept demonstration," said Captain Jim Hoke, program manager for the Persistent Maritime Unmanned Aircraft System program office (PMA-262), who oversees the BAMS-D program. "Six years later, the tempo of operations and demand for products from BAMS-D has remained steady and the deployment has been extended indefinitely."

Flown by both US Navy and contractor personnel, the RQ-4A is controlled from Naval Air Station Patuxent River in Maryland and operated by the US Navy's Task Force 57 in the Middle East.

In a typical mission the aircraft normally tracks surface shipping and images littoral targets of naval interest in the region, said Mike McDaniel, the former BAMS-D test director, who is now Triton's test director. Within minutes, crew members analyze these tracks and images and send them out to units worldwide.

"The speed of delivery, combined with the enormous quantity of information collected on each flight, has made BAMS-D invaluable to the fleet," he said.

The Navy originally acquired two RQ-4A aircraft to build US Navy experience in operating large unmanned aircraft and develop tactics and doctrine for the Triton program. RQ-4A can typically fly for 24 hours at altitudes above 50,000ft. To date, the US Navy's RQ-4A fleet has flown more than 750 sorties during test and real-world operations and has flown a total of 12,000 hours.

HIGH FLYER

The Navy's RQ-4A Global Hawk air vehicle can soar nearly 11 miles (60,000ft) above the ground. The high-flying aerial vehicle can fly persistently for more than 30 hours above most weather. Imagery and other data obtained by the aircraft feeds by satellite into the Navy ground segment, consisting of a mission control element, a launch and recovery element, and a Navy-designed Tactical Auxiliary Ground Station (TAGS). Flown by US Navy and contractor pilots, the asset is controlled from the Patuxent River airbase.

BAMS-D was used to develop methods for integrating the Automatic Identification System (AIS) into US Navy operations. Experimentation using BAMS-D also benefitted the US Naval Sea Systems Command Ocean Surveillance Initiative and Oceanographer of the Navy office with activities assessing the usefulness of long-endurance, high-altitude unmanned systems in collecting fleet-relevant meteorological data.

Five RQ-4s were originally purchased by the US Navy but one was lost in a crash in Maryland's Nanticoke River in 2012.

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AEROSPACE TESTING INTERNATIONAL NEWS EXCLUSIVE

TARANIS BREAKS COVER... AT LAST

Once upon a time, the first flight of a British military aircraft would be announced almost immediately, as proud designers, engineers, test pilots and company executives tried to trump rivals in a race to promote their products and expertise.

But not in 21st century UK, where political spin doctors from the highest reaches of government considered the first flight of BAE Systems' Taranis unmanned combat air vehicle (UCAV) demonstrator such a threat to the image of the Prime Minister that they ordered the company and the Ministry of Defence to sit on details of the event for nearly six months.

Nevertheless, media outlets in the UK, USA and Australia all reported the event only a few weeks after it occurred. Embarrassed Ministry of Defence press officers had to repeatedly bat off inquiries, citing 'security' concerns. Strangely, none of the media organizations that reported the event were visited by Metropolitan Police officers acting to enforce the Official Secrets Act. A senior ministry official revealed that the problem was "issues" over UK government departments "agreeing a narrative" between themselves over UK drone policy because of the sensitivity caused by US drone strikes in Pakistan. Similar concerns had prevented media visits to the UK Reaper unmanned aerial vehicle operations center at RAF Waddington in Lincolnshire until

TEST FACTS

Taranis, which is about the size of a Hawk trainer jet, was designed and built by a team of 250 companies, led by BAE Systems, Rolls-Royce, the Systems division of GE Aviation (formerly Smiths Aerospace) and QinetiQ, working alongside UK MOD military staff and scientists.

15 Length in minutes of the first flight in February 2014

8,000 The MTOW of the prototype in kilograms

2 Number of weapon bays the aircraft will incorporate

11.35 The length of aircraft in meters, equivalent in size to a BAE Hawk Trainer

just before Christmas 2013. Then Anglo-French negotiations over the future of cross-channel cooperation on unmanned systems reared their head with a summit between UK Prime Minister David Cameron and French President François Hollande having to be put back until the end of January. Only once the two leaders had penned a two-year £120 million deal to move forward with a new UCAV development effort were BAE Systems cleared by Downing Street to lift the lid on Taranis.

THE UNVEILING

At last a very proud Andrew Whitehead, head of BAE Systems' operation in the UK, was able to formally reveal details of the first Taranis test flight at a briefing at the Royal Academy of Engineers in London on November 5, 2013.

"The flight went entirely as expected, with the system performing as per the simulation and rehearsal, and it made a perfect landing," said Whitehead, who described Taranis as the most technologically advanced aerospace platform ever developed in the UK.

Whitehead revealed that the 15-minute first flight took place in August 2013, just over three years after the stealth aircraft had been rolled out at BAE Systems' Warton site in Lancashire. But again citing security he declined to disclose the test location, even though extensive media coverage had already identified the site as being the Woomera test range in South Australia. A brief comparison of the video of Taranis's take-off and Google Earth images of Woomera confirms the location.

The video revealed that the Taranis air vehicle, which was largely funded with UK Ministry of Defence money, sported an RAF roundel and the military registration ZZ250. The stealth aircraft and its ground control station equipment had been transferred to the test location using an RAF Boeing C-17 military airlifter, and undergone high-speed taxi trials in July 2013. Earlier test work had been carried out on the runway at the main facility at Warton, where the demonstrator was designed and built.

Data analysis from the first flight enabled the team to launch a second test flight a week later but the company was unable to divulge the total number of flights completed by Taranis, again citing security. "During the subsequent sorties – and there were many – Taranis didn't just meet our expectations, it surpassed them in every way," Whitehead said.

MORE TEST CAMPAIGNS

With the first test phase having been successfully completed, Whitehead says a further two campaigns are expected, using a closed test process. Discussions between the ministry and industry about the next set of objectives, and funding requirements, are likely to conclude "within the next weeks", said Chris Boardman, managing director of BAE's Military Air and Information unit.

RAF Air Vice-Marshal Sue Gray, director of combat air for the UK Defence Equipment & Support organization, said at the February 5, 2014 briefing that the UK is "on the right track" with planning for its future combat air system requirement. The first Taranis flight tested the UK's sovereign ability to develop advanced technology in the form of a world-class, next-generation system and to examine concepts of operation for this type of aircraft. An operational platform – likely to enter use post-2030 – would be flown in concert with manned combat aircraft. "It is not the plan for the aircraft to fly and fight on its own," said Gray, who described Taranis as being "at the edge of the technological boundary and comes with risk and [the potential for] increased costs".

Spending on the UK-only Taranis project has so far totaled £185 million since its launch in 2010, versus an originally projected £140 million, while its first flight occurred around two years later than initially scheduled. New requirements that emerged during the development program put back the first flight, said BAE Systems executives.

Without providing details of these requirements, Whitehead said, "We recognized we had opportunities to expand the nature of what we were testing."

Describing the engineering challenge of developing and flying the stealth aircraft, Whitehead claims, "Taranis has the potential to be as influential as the experimental aircraft program," referring to the EAP demonstrator of the 1980s, which helped to define the design of the Eurofighter Typhoon.

The focus of the program, Whitehead said, is on a next-generation system that incorporates low observable characteristics that would enable the aircraft to operate in contested airspace.

GARNET RIDGWAY

IS SPEED OF THE ESSENCE?

Many aerospace test programs can feel like they are overwhelmingly governed by the golden rule 'time is money' – but is this the right approach?

SOPHIE ROBINSON

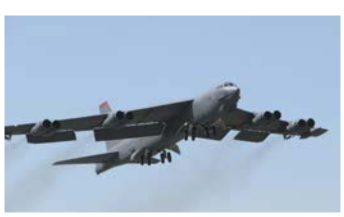
In the short term, it is undeniable that the directly proportional relationship between time and money holds true. However, accelerating a test program can be fraught with project risks. Testing is often a compromise between 'what we'd like to do' and 'what we have time to do', and prioritizing can be a delicate balance. Without sufficient time for analysis of data captured during earlier testing, it's extremely difficult to inform the choice of subsequent tests; this can lead to unnecessary repetition or omission of test points. On this basis, faster testing isn't necessarily leaner testing.

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

A slower, more measured test program also enables a closer and more productive relationship between the test and design communities. This can be achieved through an iterative test/modify/retest approach, which seeks to highlight potential problems and address them as an intended (and budgeted) part of the test and evaluation process. Note that this is distinct from the unintended emergence of design deficiencies during testing (often caused by a rushed design process) for which there is no time or budget to address.

Another benefit of a slower and well-thought-out test program is the ability to match the testing as closely as possible to the intended role of the aircraft across its whole service life. Testing programs with tighter schedules are more susceptible to seduction by the current role of similar aircraft, for example by the demands of operating in a particular theater. This can be to the detriment of the long-term life of an aircraft, which may end up being unintentionally optimized for a role that is no longer relevant by the time it enters service.

The need to work to compressed timescales is deeply ingrained in the aerospace community, quite possibly because of its close ties to the defense sector and the fiercely competitive civil aviation market. In the past, this may have been a necessity given the short service lives of aerospace products driven by the rapid advances in technology. However, aircraft are lasting longer and longer; for example, the USAF's B52 bombers are scheduled to remain in service until 2045, some 90 years after their introduction. When working to such timescales, the question must be asked – isn't it worth taking an extra year to get the test program right in the first place?



As my sparring partner on the left-hand side of the page has already stated, employing a fast-paced testing program does have financial benefits; it's hard to argue with that. The old adage that 'time is money' will always ring true in the testing community. However, a dynamic, fast-paced testing program can offer a raft of other benefits too.

Fast testing can mean lean testing. Quickly generating a broad overview of aircraft performance can enable future testing to be refined and targeted, informing 'what we'd like to do', rather than doing things 'the way they've always been done'. This approach also enables testing to be prioritized in a way that maximizes return on effort – for example, targeting particular areas of the flight envelope to allow the largest possible envelope to be provided to the operator.

The use of a fast-paced test program also endows projects, and those who work within them, with a strong focus and sense of direction. This creates a positive project culture, reducing the likelihood of delays; delays that can be costly both financially and in terms of operational efficiency. A challenging test program can also provide collective motivation in situations where those involved can often have conflicting priorities, encouraging cooperation and collaboration in order to achieve a common goal.

Tight deadlines and rigorous scheduling also lend themselves well to operation and cooperation with military stakeholders; fitting into an already existing culture of stringent planning and rapid decision making can often be both easier and more successful than trying to convert everyone to a new methodology of working.

The rapid entry into service of a new platform is often a very desirable outcome in both military and civilian sectors. New platforms are often intended to fill gaps in capability and meet urgent operational requirements (such as responding to unpredicted occurrences, such as earthquakes or flooding). Using a dynamic approach to testing can allow new platforms to enter service more quickly, even if their initial capability is reduced. This also means that future testing requirements can be rapidly identified and targeted toward the current user requirements; there's no point developing aircraft capabilities that won't be used in theater or prioritizing testing for future operations.

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

Ultimately, a fast-paced test program provides both financial benefits and targeted testing, while remaining reactive to user needs – something which is of considerable value in both the rapidly changing military and commercial sectors.

Typhoon: today and tomorrow

Andy Pegg, Typhoon flight test manager at BAE Systems, talks about the job, the jet, the test campaigns that continue to expand its capability and even sending personnel to support other programs

BY PAUL E EDEN

MAIN: The Typhoon is powered by two Eurojet EJ200 engines providing a combat thrust-to-weight ratio in excess of 1.2:1 with 30% thrust growth available

Andy Pegg,
Typhoon flight test manager

In service with six air forces and operational with the Royal Air Force since 2005, Eurofighter Typhoon remains the focus of flight test and development work, especially with the four 'partner' nations, Germany, Italy, Spain and the UK. BAE Systems has the lead on RAF testing, as well as supporting the core Eurofighter program, basing a dedicated test fleet at its Warton, Lancashire, airfield.

Andy Pegg is Typhoon flight test manager. He explains that BAE Systems has four development Typhoons at Warton, three of them – Instrumented Production Aircraft (IPA) 1, 5 and 6 – owned by the NATO Eurofighter and Tornado Management Agency (NETMA). These were built as production test aircraft, have a comprehensive internal instrumentation fit and are operated in support of the core development program.

The IPA jets have been heavily modified even beyond their original test installations. Pegg says, "In the last couple of weeks IPA5 has flown in readiness for E-Scan radar testing, although it is yet to fly with the radar. It had been on the ground for over a year, receiving the modifications necessary for the radar to be installed." In many respects the work has been about more than simply preparing the aircraft for radar trials. It has also been about productionizing the installation, as well as the ancillary equipment required to support it.

"The modification had a number of purposes. One was to get the aircraft physically ready to host the E-Scan radar, including modifications to its structure, installation of appropriate levels of ballast, modified power generation and cooling systems, and additional instrumentation for those systems. By implication it also proved

MILITARY PARTNER: 41(R) SQN, RAF

Based at RAF Coningsby, Lincolnshire, 41 (Reserve) Squadron is dedicated to the operational evaluation of the frontline Royal Air Force fast jet fleet. The unit flies a mix of Eurofighter Typhoon and Panavia Tornado aircraft, testing new equipment and software, and helping develop tactics in a service environment.

Established on July 14, 1916 and latterly a SEPECAT Jaguar unit, 41 (Fighter) Squadron stood down in 2005. It reformed on April 1, 2006 as a Reserve formation, taking over the responsibilities of the Fast Jet and Weapons Operational Evaluation Unit.

100,000	Employees from the four nation consortium
400	Tier one suppliers
+9/-3	Limitations of g-force
€126	billion project turnover by end of 2012

ABOVE: **The Typhoon can achieve 'brakes off' to 36,000ft Mach 1.6 in under 2.5 minutes**

what could be a retro modification from earlier standard aircraft to support the new radar," says Pegg.

Other than the IPA machines, Warton also operates BT17, the 17th production UK two-seater, on loan from the UK Ministry of Defence. It is flown against UK tasks and Pegg notes, "We work extremely closely with Number 41 Squadron, Royal Air Force, at Coningsby and the aircraft is in its markings. We fly it at the very latest weapons system standard, which we are allowed to do, under our control and governance. This is typically 10 months ahead of the standard in frontline service." In fact Pegg considers that 41(R) Sqn personnel are embedded into the BAE Systems team and points out that BT17 is flown from Coningsby or Warton as suits the work in hand.

BELOW: **Paul Lobley, a flight test engineer monitoring a test from the ground**

TEST TEAM

Warton's test establishment includes four Typhoon test pilots, as well as 25 flight test engineers, busy on what Pegg calls a "myriad of ongoing trials". The work is intense and extensive: "We take trials from the early planning stages, write the trials documentation required for test flying and the trial safety case, then support the flying in terms of briefing aircrew, monitor the aircraft by telemetry and debriefing, and then write the technical reports. It's not just a case of getting the jet airborne!" Some engineering work is trialed on simulators and by modeling before it makes its way into the air and Warton's systems integration rigs and active cockpit rigs are used as appropriate.

As well as RAF Coningsby, small teams might be dispatched, often with a jet, for work that cannot be completed from Warton. "Usually it's because of a trials range requirement or a particular constraint. A few years ago, for example, we sent an aircraft to Germany for a range trial and 18 months or so ago we hosted a Spanish Typhoon here – it joined us for a couple of weeks.

"In terms of personnel, we regularly send people around Europe to support the core program. In the past 12 months members of my team have been to Germany, Italy, Spain and Saudi Arabia, all for trials supporting the core effort."

TEST CAMPAIGNS

The most recent large test campaign on which work has finished and the team are reporting is associated with P1EB (Phase 1 Enhancement Part B), the latest software development for Tranche 2 Typhoons. It delivers expanded multirole, precision weapon capability, particularly through compatibility with the Raytheon Paveway IV GPS/INS and laser-guided bomb. "We've done the development work for the P1EB package and completed our reporting. Now it has a four-nation release to service route to go through, but to save time we have BT17 at that standard and we're supporting the RAF's OpEval [operational evaluation] of it. They need to decide how they'll deploy the capability and, crucially, how they'll train for it."

Taking P1EB as an example, Pegg described how a trials campaign is managed. "At the top level we sit down with 41 Squadron and break the campaign into manageable chunks, usually around particular sensors or capabilities. We allocate a lead engineer to each, work out the objectives for the task, write a plan, build a safety case, and then the individual trials are integrated into a calendar-based program plan for the

> **"FOR ALL FLIGHT TRIALS WE HAVE A LEVEL OF BACK-UP OR CONTINGENCY AND WITH SOMETHING LIKE A MISSILE FIRING, NEEDING A LOT OF DEPENDENCIES TO COME TOGETHER"**

aeroplane. For P1EB OpEval this was sketched out in the latter part of last year and extends into this summer. Of course things change as the work progresses and we review on a weekly basis to get the best out of the program."

E-Scan will be among the next major test objectives when IPA5 flies it for the first time later in 2014, but in early March the other aircraft were heavily engaged in other trials. "IPA1 is a Tranche 1 aircraft and we're in the middle of a drop program with it, currently flying it at Drop 3 standard, the latest evolution for the Tranche 1 product. After that our main focus for the second half of this year will be the continuation of the Meteor campaign.

"We had a firing late in 2012. It was a pre-contract risk reduction exercise and we're now on contract to the partner nations for integration of the weapon. A series of firings is planned over the next two years, with two scheduled for this year. The aircraft will be based at Warton, but we'll be using another range in the UK to conduct the trials. I'll make use of our mobile telemetry capability and send a team to a position adjacent to the range. Another team will launch the aircraft from Warton, while a smaller group will pick it up during transit, assisting in the execution of the firing thereafter.

"We're unlikely to be able to pick up the telemetry from Warton because the system is line-of-sight and the aircraft will essentially be over the horizon at the time of launch. My people are also very much involved in the range safety task, in combination with the missile supplier and range personnel."

Although a safety aircraft is not required for the Meteor beyond-visual-range air-to-air missile firings, a chase plane is likely to be used to provide photography of the launch. "For all flight trials we have a level of back-up or contingency and with something like a missile firing, needing a lot of dependencies to come together, you have to know what you can and can't launch with." As well as the serviceability of aircraft and systems, missile test firings are at the mercy of external influences, typically the weather, or shipping entering the range area.

Clearly BAE Systems is deeply involved at all levels of the Typhoon test program. And even though it is not directly responsible at this stage for the Storm Shadow missile integration work that began on Typhoon in recent months, for example, Pegg says that it has been supporting the efforts of the partner nations. "In February I had a couple of guys over in Germany working with Airbus Defence & Space and we've also been doing some prep work for the Spanish involvement. A lot of our work is part of the four-nations program." ∎

BEING ANDY PEGG

Aerospace Testing International **asked Andy Pegg what his role as Typhoon flight test manager looks like on a day-to-day basis. "I'm in at around 07:30 and generally have a week that combines meetings for planning short-term work, then a week of planning meetings for the longer term. Formal safety reviews are dotted around the diary, because one of my personal responsibilities is to sign off trials as good to go – I sit in on and chair the reviews for each case.**

"Then it's a combination of admin, the regular work that comes through managing a team of 25, and focusing my time on the 'over-the-horizon' stuff. The men and women in my team are more than capable of discharging the job on a daily basis and I let them get on with it." He explains that a flying test was scheduled for later in the day of our interview, but that he would have no involvement in it since the team knew what to do, leaving him to focus on meetings for the next series of trials.

"Two of the team are fully trained flight test observers and they fly in the back seat reasonably regularly; both have more than 100 trips. They receive all the regular fast jet survival training and must be able to add something to the sortie, usually as flight test engineers specializing in a particular area."

So what's the best kind of day for Andy Pegg? "When we've achieved what was on the plan, we've delivered a couple of flights and everything's gone well. I get a particular kick out of my team doing well. If they've made people happy, I'm happy."

Paul E Eden is a UK-based writer working for Aerospace Testing International *and editor specializing in the aviation industry*


N898WC

A tale of two helicopters

A clean sheet and an old timer refreshed along with the various requirements of current helicopter testing: the EC175 and Sikorsky S-61T

BY PAUL E EDEN

Certification delays darkened Eurocopter's ultimately successful EC175 test program, but perhaps should have come as no surprise. Meanwhile, Sikorsky has embarked on a very different test program as it works toward certification of the thoroughly upgraded S-61T version of the venerable Sea King.

Well-deserved smiles of satisfaction no doubt brightened many faces at newly rebranded Airbus Helicopters when the EC175 medium twin was granted European Aviation Safety Agency (EASA) certification on January 27 this year. The 7.5 metric ton class helicopter was designed as a game-changer, but continued delays in certification have left customers cautious about placing orders, a situation that Airbus Helicopters CEO Guillaume Faury is certain will change.

Any attempt to bring such an innovative product to market is always open to setback and delay. However, Airbus Helicopters' experimental test pilot, Alain Di Bianca, was pragmatic in his response when *Aerospace Testing International* asked him about the EC175's protracted certification period. "The EC175 is a new, clean-sheet development. All its systems are brand new and the development effort and risk in terms of delay are much more prominent than in a product that is derived from a helicopter already in service.

"With regard to its engines, avionics and autopilot, the EC175 is a fully integrated helicopter and to achieve great simplification in the pilot interface, as well as ease of flying and maintenance, it was necessary to undertake a huge development effort, accepting the associated risk of delay. The result is an innovative suite of avionics with many new features that have never been seen on a helicopter before. These include developments for the pilot interface, autopilot, navigation and maintenance. It made for a challenging development program, but the results provide our customers with huge improvements in operation and safety."

GAUGING EXPECTATION

Of course the EC175 was, until very recently, a Eurocopter product and the company worked hard with its customers to precisely establish their needs for the new aircraft. As well as asking what they'd like it to do, Eurocopter also requested feedback on their current operations and how their in-service helicopters performed. "After this campaign, all the helicopter behaviors and customer remarks were collected and integrated in a product improvement effort," Di Bianca explains.

Confident that it was working to deliver a product that customers really needed, Eurocopter embarked on a massive development and test campaign. Alain Di Bianca was unable to reveal full details of its extent, but confirmed: "Paper engineering, computer simulation, component bench simulation and cockpit simulators were used extensively before the aircraft's first flight." As well

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as using cockpit and flight simulators, the flight test crew worked with similar aircraft to gain flight experience before taking the EC175 aloft. These techniques were subsequently further exploited in advance of flight envelope expansion flying.

In previous programs Eurocopter has typically telemetered first flights, then used the technique more sparingly as the flight test campaign continues. The EC175 prototype was extensively equipped for telemetry and extensive use of the capability was made throughout the development phase. Di Bianca reports: "Almost all of the prototypes' primary systems are equipped for telemetry monitoring, including the engines, rotor hub, flight controls, rotor blades and so on.

"We used telemetry a lot for flight expansion and during the work any weakness or performance varying from the norm was detected either on board the prototype or on the ground in the telemetry room. Any of the engineers following the flight in real time could stop the flight maneuvers immediately should the data suggest a problem." He adds that the process of expanding the EC175's flight envelope was incremental and that on its maiden flight the aircraft was airborne for around an hour, reaching an airspeed of 120kts.

A pioneering development program might reasonably be expected to incorporate pioneering test techniques and technologies. Di Bianca is happy to confirm that this was indeed the case, but says that details of the new tools and development methods employed remain confidential. He is also tight-lipped over the program's full extent, declining to comment on how many aircraft or flight test crews were involved, but reveals that 1,000 hours, in around 800 test flights, had been flown by the time EASA certification had been granted. Airbus Helicopters' website suggests that two prototypes and the first serial aircraft were involved in the program.

He also confirms that EASA was involved in the test process from the early stages of development in mid-February 2007, working to verify that the EC175 would fulfil its Certification Specifications for Large Rotorcraft (CS-29). "An EASA operational panel has also been involved to assess the aircraft's operational suitability," he says, "while EASA certification and operations pilots and engineers flew the EC175 from the beginning of the flight test program through to certification."

TESTING A NEW OLD TIMER

Early in 2010 the US State Department confirmed its intention to procure up to 110 Sikorsky S-61T utility transport helicopters for non-combatant flights in support of US diplomatic missions. The program is based on legacy S-61 airframes, and while many will be from stored ex-US Navy SH-3H Sea King stocks, the commercial S-61N is also suitable for conversion. Reworked helicopters build on upgrade work developed by Carson Helicopters.

Announcing the S-61T's successful first flight in January 2014, Steven Rogers, Sikorsky's director of S-61 programs, noted that the modernized aircraft benefits from "full structural refurbishment, overhaul of all major dynamic components and installation of key upgrades, including new composite main rotor blades, a survivability suite and state-of-the-art glass cockpit, as well as all new electrical wiring throughout".

John Johnson, director of modernization programs, reveals that while the S-61T clearly doesn't have the trials complexities of a clean-sheet design, it requires a test and evaluation program that begins by assessing the suitability of individual airframes for conversion:

"The legacy H-3H aircraft are individually evaluated to qualify for

BELOW: The EC175 includes a glass cockpit and four-axis digital automatic flight control system

BOTTOM: The EC175 holds the record for time-to-climb to an altitude of 6,000m, performed in 6 minutes, 54 seconds

AIRBUS HELICOPTERS EC175

Powerplant: Two Pratt & Whitney Canada PT6C-67E turboshafts with dual channel FADEC, delivering 1,645shp maximum continuous power

Passenger/range capability: 16 pax over 140 nautical miles, 12 pax over 195 nautical miles or 18 pax over 105 nautical miles

Maximum take-off weight: 7500kg (16,535 lb)

Avionics: Airbus Helicopters Helionix, including self-monitoring, vehicle monitoring display system, dual-duplex four-axis automatic flight control system, synthetic vision system, automatic collision avoidance through TCAS II autopilot coupling, six 8in displays and electronic flight bag

Orders as of February 18, 2014: 48

Initial deliveries: Scheduled for 2014

S-61T conversion. Every airframe is assessed based on its logbook information, maintenance records, verification of the correct inducted configuration and current, overall condition. A team highly experienced in S-61 helicopter refurbishment uses a specialized checklist to review every section of the aircraft in detail. The selected airframe undergoes a major inspection process, part of the qualification and evaluation plan for induction into the program."

Carson's experience in maintaining and upgrading S-61s is recognized in the joint Sikorsky/Carson approach to the S-61T program. Carson is deeply involved in the test program and will assemble the production conversions at its Perkasie, Pennsylvania, facility.

Explaining more on Carson's involvement, Johnson says: "The Sikorsky/Carson partnership brings together the best of both companies' experience to execute the program. Sikorsky Aircraft is responsible for defining the test scope, plans, overall test execution and reporting results in support of qualification by the Sikorsky Qualification Assurance Board. Close collaboration is required with Carson Helicopters since it is maintaining the test aircraft for the S-61T program. In addition, as aircraft undergo modifications, the Sikorsky and Carson teams are aligned in addressing these changes and performing the required updates."

SUBSYSTEM TRIALS

Sikorsky has a fully established test program in place at the subcomponent, subsystem and aircraft level. Legacy subcomponents are subject to existing overhaul and test requirements, while new components may be subject to qualification requirements depending on part type and prior qualifications.

Full systems testing depends on the maturity of the aircraft and Johnson notes that all production aircraft have acceptance test procedures to evaluate the various systems, including avionics, electrical, fuel and flight control/hydraulic.

Relating these procedures directly to the S-61T, he says: "The first S-61T test asset, configured with a newly developed glass cockpit and electrical system, required an extensive ground test program. This comprehensive testing included the electrical system and various avionics system aspects prior to ground running. It led to a successful first flight on November 22, 2013 and full qualification of S-61T is planned for the second quarter of 2014."

The H-3H was derived from the original S-61A/SH-3A introduced into military service in 1961. Developed for the US Navy, but also spawning civilian variants, the S-61 line has been subject to considerable certification and airworthiness testing, but just how much of this remains relevant to the S-61T?

Johnson answers: "The specifics of the test program are defined by the level of modification, the modification standards being used and the aircraft mission. The S-61T changes are extensive and include the addition of a glass cockpit, new electrical system and composite main rotor blades.

"A cockpit modification alone drives testing associated with comm/nav performance, handling qualities and temperature and vibration. The standards and requirements also need to be considered, and the original certification requirements may not be applicable based on the type of modification – for example, the addition of a redundant pitot-static system for the glass cockpit, which would be aligned with current FAA and industry standards for a new development.

"As a result of the S-61T configuration, some of the aircraft-level testing performed by Sikorsky is related to flight load survey, comm/nav performance testing, airspeed performance, handling qualities, hover and level flight performance, temperature and vibration. Wherever applicable, historical test data and results are used to produce an efficient test program and Sikorsky executes all aircraft-level testing to ensure the proper integration, safety and reliability of the product." ∎

ABOVE: The latest order from the US DoS is for 13 S-61T models, with the first delivery scheduled in the first quarter of 2014

BELOW: The successful maiden test flight of the modernized S-61T helicopter includes an integrated glass cockpit and enhanced performance capabilities

SIKORSKY S-61T

Powerplant: Two General Electric T58-GE-16 turboshafts delivering 1,870shp maximum

Avionics: Cobham Commercial Systems five-screen (6 x 8in) cockpit with radar video, three-dimensional terrain awareness warning and other systems

Orders as of February 18, 2014: 13 (with five-year indefinite delivery, indefinite quantity agreement for up to 110 for US State Department. Sixteen refurbished aircraft to less ambitious standard already delivered)

Initial deliveries: Scheduled for first quarter 2014

AW189 CERTIFICATION

UK-based AgustaWestland has announced that its latest helicopter has cleared all safety requirements. The new generation AW189 medium twin-engine helicopter has been issued with type certification by the European Aviation Safety Agency.

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Multi-channel dynamic testing solutions

Photo courtesy of Airbus Defence and Space, Germany

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United Kingdom
m+p international (UK) Ltd
Phone: (+44) (0)1420 521222
sales.uk@mpihome.com

Germany
m+p international
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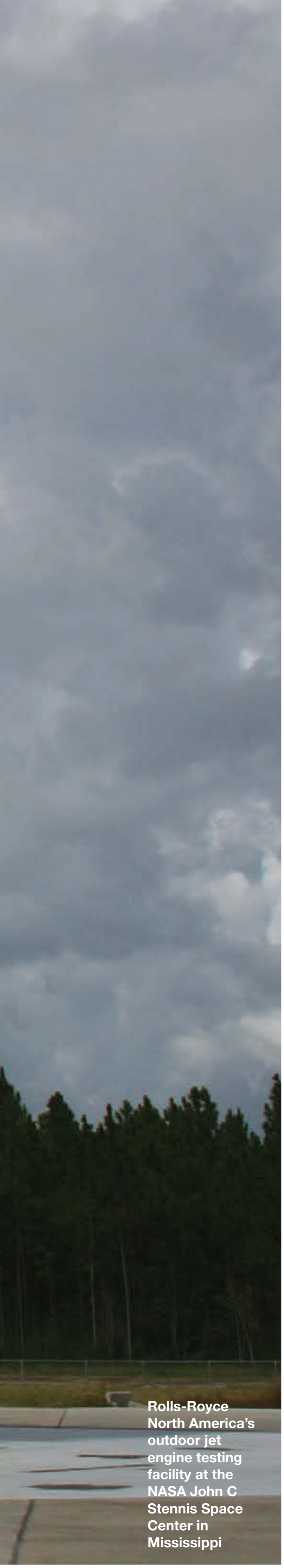

Rolls-Royce North America's outdoor jet engine testing facility at the NASA John C Stennis Space Center in Mississippi

Trent trends

Rolls-Royce is working with Airbus to achieve flight and certification testing on the Airbus A350 XWB with the Trent XWB-variant. It is also developing the Trent 1000-TEN sub-variant for Boeing's 787-10, while continuously providing enhanced technologies for other members of the engine family

BY IAN GOOLD

Alongside development of new Trent high-bypass turbofan engine variants or sub-variants, Rolls-Royce's strategy of feeding new technologies back into current products as retrofit upgrades has resulted in enhanced performance (EP) packages being introduced.

Since the original Trent 700 (T700) entered service on an Airbus A330 twinjet in 1985 (the 1,000th A330 was delivered in mid-2013), a 'tailored family' of engines with common architecture has emerged with each variant dedicated to specific twin-aisle (wide-body) jetliners.

Rolls-Royce (RR) has developed an EP suite that raises engine-build standards or provides modifications for earlier Trent designs. EP packages are available for the T500 (which powers the A340-500), T700 (A330), T800 (Boeing 777), and T900 (A380), in some cases as further improved EP2 upgrades.

The UK manufacturer reports increasing efficiency with successive family variants and upgrades, with the new Trent 1000-TEN (standing for 'thrust, efficiency and new technology') – for the Boeing 787-10 – said to provide 2% better specific fuel consumption (SFC) than the basic current-build standard unit with performance improvement package C (Pack C), which had offered a 1% gain over T1000 Pack B engines.

SUB-VARIANTS

The company has revealed a T700 Regional sub-variant planned to be "perfectly matched" to the proposed reduced-weight A330 Regional (A330R) variant and which will be optimised at less than the standard unit's 72,000 lb thrust.

Assembly of the 97,000 lb thrust Trent XWB-97 engine, designed to power the heavier, 308 metric ton (680,000 lb) stretched Airbus A350-1000 began in early 2014 and the variant should run for the first time before July, according to program director Chris Young.

RR began technology feedback with the T700, which generated improvements for the RB211-535 and -524G/H engines powering Boeing 757s and 747s, respectively (see *Trent Portfolio,* overleaf). The T700 itself now uses technology from both the T800 and the T1000 models, while the T900 has contributed to the T500 and the new A350 XWB's Trent XWB is enhancing T1000 development.

Currently, RR is preparing to start two years of development of the T1000-TEN while supporting Airbus in flight testing and certification of the A350 and maintaining momentum with performance-enhancement activity. By the end of March 2014, the first development engine was planned to have begun testing, with formal airworthiness approval scheduled for the second half of 2015 and service entry – initially on 787-8s and -9s – in 2016, according to T1000 chief project engineer Jeremy Hughes. Service on the heavier 787-10 'double-stretch' model is planned to follow about two years later.

Two technology demonstrator engines (TDEs) have been running for the up to 78,000 lb thrust T1000-TEN, one of two engine options available to power all Boeing 787 variants and which RR regards as an innovative milestone in such developments as large-diameter leaf seals and high-pressure turbine (HPT) disk architecture. The second TDE is testing turbine blade and segment coatings, a modulated HP internal air system, HP compressor (HPC) banded stator blades, and fan-case 'externals'. RR has scheduled a 500-cycle test of a full development engine for 'early 2014'.

Including the latter unit, the manufacturer has built four full T1000-TEN demonstrators, assembly of which benefitted from 'donor' hardware from earlier Trent models. In addition to the 500-cycle test unit, each development engine features new technologies being developed for the new model.

Hughes hopes that this will ensure that the -TEN accommodates "all the lessons learned" from Trent service to date. As well as an upgraded compressor, the -TEN benefits from Trent XWB technology claimed to have contributed a "significant [performance] improvement".

CYCLIC TRIALS

Cyclic trials will test enhanced cooling available with a new HP turbine (HPT) disk and, like those of other models, the T1000-TEN's hardware characteristics are enhanced by technological feedback. This includes:

- A new 'rising line' intermediate pressure compressor (IPC), using Trent XWB technology;
- A new HPT, with a full-face cover plate, expected to extend life and to


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TRENT PORTFOLIO

The Rolls-Royce (RR) Trent engine family powers 50% of next-generation wide-bodies, says civil large engines strategy and future programs executive vice president Simon Carlisle. The six variants comprise: Trent 500 (powering Airbus A340-500s), T700 (A330), T800 (Boeing 777), T900 (A380), T1000 (787) and Trent XWB (A350XWB). The design evolved from the early 1970s RB211 three-shaft engine developed for Lockheed's L-1011 TriStar.

An apparent 'missing' family member is the RB211-524L-based Trent 600 selected for the stillborn longer range Boeing 767-400ERX, which competed against Pratt & Whitney PW4000 and General Electric CF6 engines on the McDonnell Douglas MD-11.

A350 TESTING

Rolls-Royce Trent XWB performance on the first two Airbus A350-900s has gone extremely well, with "good operability and reliability" supported by only routine inspection and maintenance, according to program director Chris Young. By February 2014, the engines had logged around 2,000 flight hours during 200+ A350 flights (including a 12 hour 48 minute transatlantic flight to Bolivia for 'hot and high' testing).

Altitude- and temperature-related performance trials involved operating in temperatures up to ISA +21°C (ISA +38°F) at Cochabamba (about 8,300ft above sea level), says Young. Engine starts, take-offs, simulated engine failures, automatic landings and touch-and-goes at La Paz's 13,300ft-altitude airport were performed "immaculately with no flaws, no nothing". Subsequent high temperature/sea-level tests in Martinique were followed by cold-weather trials in Canada that included starts at temperatures as low as -40°C/F.

enable through-life improvements;
• A modulated HP air system reducing parasitical flow to improve fuel burn efficiency and performance retention (through better seal margins);
• A new, more efficient HPC (from the New Aero-engine Core (NEWAC) concepts program and Trent XWB);
• Lighter, more efficient bladed disks or 'blisks' (Trent XWB).

The engine maker believes that the T1000 variants offer the best lifetime fuel consumption for 787 operators on average range flights, being "well ahead" on typical 500-1,000 nautical mile sectors flown by launch customer All Nippon Airways, says Hughes.

RR plans to fly a T1000-TEN on its Boeing 747 flying testbed, while Boeing testing is scheduled for the second half of 2015, about a year after ground tests should start. By January 2014, T1000 engines had logged 175,000 flying hours and around 70,000 flight cycles, one unit having recorded 5,268 hours in 2,023 cycles according to Hughes, who puts overall dispatch reliability at 99.96%.

Before February's Singapore airshow, RR said the Trent XWB program had seen only minor tuning of scheduled plans, with performance "on track, exactly where we expect to be", according to Young.

ASSEMBLY PROCESS

Trent XWB-97 assembly follows a critical design review and prototype demonstration runs. Early activity since late last year has included early-component fabrication, stator-vane assembly welding, and IPC intermediate pressure compressor Stage 1 blisk completion.

To avoid production hiccups, initial Trent XWB flight test engines will be built in a preproduction 'factory' before the variant is integrated into the assembly flow line. Because the XWB-84 and 97 are very similar with common tooling, Young says the models can be mixed in final assembly. Can RR advance the engine should Airbus accelerate A350-1000 development? The manufacturer has an "agreed program" with Airbus, says Young.

Active preproduction testing should start in the first half of 2015. It will involve at least eight (possibly more) flight test Trent XWB-97s, the focus being to meet 'exit criteria' – understanding each workstation's requirements – before assembly really begins to flow. There will be seven ground-test units, plus additional modules and cores (see next page).

To release future capacity at the UK factory in Derby for the larger XWB-97 engine, the predominant proportion of Trent XWB-84 production will be at

2,000	Number of scientists and engineers used to bring the engine together
18,000	The number of components making up a Trent XWB engine
1.3	The amount of air in tons that the engine sucks up every second at take-off
1,200	The mph the blade tip reaches at take-off speed creating the same hp as a Formula 1 car. The blade clears it's casing by a fraction of a millimeter
200	The temperature in degrees centigrade in the hottest part in the engine 'above' material melting point

RIGHT: 11,250 real and simulated flight cycles have been completed on the Trent XWB-84

BELOW: The Trent XWB on the A380 flying testbed

T XWB AND T900 GROUND TEST ENGINES

Rolls-Royce Trent XWB-84 testing carried out in early 2014 involved four units. Two were running cyclic tests at RR North America's outdoor jet engine facility at NASA's Stennis Space Center in Mississippi: one had completed 1,610 simulated flight cycles, including 3,000 thrust-reverser deployments, and the other is for 350-minute extended twin-engine operations approval. An 'endurance' engine was being used to expand temperature margins, and the fourth unit was one of two devoted to proving robustness.

Of nine other development engines, three were to fly on Airbus's A380 testbed and two are for mechanical tests. Others will be (or have been) used for integration, low-pressure system and performance trials. Low-temperature testing has been conducted to demonstrate a required 10 starts at -40°C/F to represent winter operations.

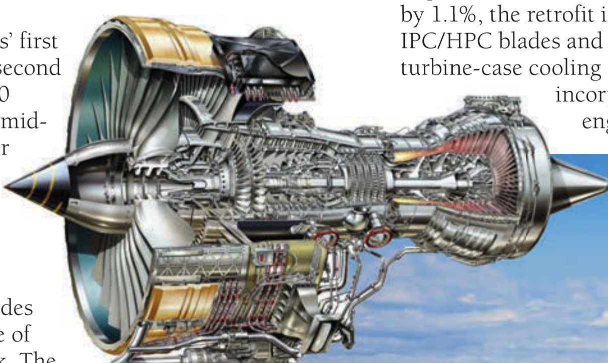
the manufacturer's Singapore manufacturing center at Seletar.

The A350 XWB flight test aircraft, MSN2 and MSN4, have both now taken to the skies above Toulouse, France for their respective first flights, bringing the total number of A350 XWBs now flying from two to four, the first with an airline cabin interior and intended to carry the first (non-flight test) passengers on early long flights. With A350-900 MSNs 001 and 003 having flown in 2013.

By early February 2014, RR expected to have shipped engines for final flight test machine MSN 005, the second to sport an airline cabin and scheduled to fly in May. Despatch of these units to Airbus effects transition to the formal Trent-XWB production phase.

Also in February, RR planned to begin assembly of Trent XWB engine serial number (ESN) 20019, which is earmarked for launch customer Qatar Airways' first A350 (MSN 006). The second Qatar engine ESN20020 should reach Airbus in mid-year, along with another unit identified as a spare for the A350's entry into service.

The Trent 1000's elliptical leading-edge (ELE) HPC and IPC blades provide a good example of RR technology feedback. The blades reduce fuel consumption and are available for all Trent variants, including T800EP and T500EP+ upgrade kits. Sophisticated blade aerodynamics reduces airflow separation behind the leading edge to reduce fuel burn by 0.5-0.7%, valued by RR at up to US$200,000 per aircraft per year. The initial T800EP entered service last October, operators of the older and relatively less efficient design enjoying the best performance enhancement, according to fleet programs customer marketing head Peter Johnston.



BELOW: The first flights of A350 test aircraft MSN 2 and MSN 4 took place in February 2014

INSET: The inner workings of the Rolls-Royce T700

TRENT 700 UPGRADE

A second improved performance package for the Trent 700, the most popular RR wide-body aircraft engine and powering 70% of A330 operations with 99.9% reliability, is expected to enter service in mid-2015. This T700 EP2 will appear about two years after the initial EP upgrade, which offered modified compressor rotor blades.

Modified EP2 engines will have three-dimensional stators and other minor IPC and HPC changes said to provide a further 0.5% fuel saving over the first EP package. The simultaneous adoption of improved nozzle guide-vane sealing and better aero standard anti-flutter bridge in the LPT should push improved efficiency to a full 1%.

Again, the upgrade is worth US$200,000 per year per aircraft.

The initial T700 EP package had improved in-service engine fuel burn by 1.1%, the retrofit including ELE IPC/HPC blades and optimised turbine-case cooling that were incorporated in new engines, which also benefitted from optimised blade-tip clearance, 'pocketless' fan-spinner fairings, super-polished turbine hardware, and HPC improvements that increased fuel efficiency by 1.3%.

The planned T700 Regional (T700R) will take advantage of these EP and EP2 packages. Operating at lower engine speeds and temperatures, they are expected to offer lower maintenance costs. T700Rs will be interchangeable with basic T700s, which can be converted to the later specification, and will be available to A330 operators not employing the A330 Regional.

The engine manufacturer is "competing hard" to get the Trent 900 onto the latest 50 Airbus A380s ordered by Emirates, which has previously always selected General Electric/Pratt & Whitney GP7200 engines for its first 90 aircraft. Emirates wants the OEMs to compete for the business, which is thought to be in line with Airbus preferences for balance among suppliers. "We're not going after cheaper engines, we're after technological crossover that manifests itself in lower weight and lower fuel consumption," says Emirates president Tim Clark.

By April 2014, RR's new T900 EP2 upgrade should have become the production build standard, with the company suggesting it could offer increased A380 payloads on transpacific Qantas flights and improved range at current maximum take-off weights. ∎

Ian Goold is a UK-based freelance aviation writer and editor who has covered the aerospace industry for more than 40 years

Stealthy discussion

A unique insight into the development of the PAK FA, the Su-35; and next-generation Russian fighter design. This report even gets a glimpse at the Russian take on the West's fighter technology

BY CHRISTOPHER HOUNSFIELD

MAIN: First flight of PAK FA, which translates as 'future air complex'. Up to 35% has been developed with the Indian aerospace industry

Russia is undergoing an aircraft renaissance. It has to. With the US development of the F-22 Raptor fully in service, the US-led collaboration of the F-35 very advanced, and the European Typhoon all in production and established, the Russians have had to move fast to catch up. Now the experimental T-50 is not far from becoming PAK FA, its 5th-generation fighter aircraft.

Nikita Dorofeev is head of one of the Sukhoi departments dealing with the latest Su-35 simulator and is willing to discuss the new systems. Design work on the Su-35 was completed by 2007, paving the way for Komsomolsk-on-Amur Aircraft Plant to construct the first prototype in the summer of 2007. Upon completion, Su-35-1 was ferried to the Gromov Flight Research Institute at Zhukovsky Airfield.

The new Su-35S is labelled a '4++ generation' derivative of the baseline Su-27S Flanker B. It is a comprehensive redesign of the aircraft's systems, and employs a supercruise-capable 117S variant engine. The Su-35S is expected to be the last Flanker variant to be mass-produced before the PAK-FA enters full production.

"The simulator is designed to provide information through testing, including indication, control consoles, layout, and navigation and aircraft logic when in combat mode," says Dorofeev. "The simulator serves two main goals: highlighting new testing concepts and aircrew correction implementation. For example, it was difficult to reach some panels on the left console, so we reconfigured them. Now we are ready to introduce the new configuration into the aircraft. We have a joke here: 'Two pilots – three opinions.' So it is necessary to try all the variants very carefully to choose the easiest to use."

WORKING WITH PILOTS

Dorofeev is keen to convey that each test pilot's opinion is highly subjective, saying how different each can be with their own physiological make-up and individual parameters. He says it is important to merge results generated on the basis of collective opinion.

Aerospace Testing International wanted to know how much influence the test pilots have on the design of the aircraft cockpit, and to what extent the engineers and designers have their say. "There was an interesting example recently, from my point of view, for PAK FA," says Dorofeev. "At the request of the pilot we moved the location of the handgrip to the exact position he had specified in his comments. He then asked us to move it further, which we did. He still found it uncomfortable, so we ended up putting it back in the original position after all!"

A Russian journalist reporting for *Aerospace Testing International* flew the simulator for a little over 10 minutes. He describes it as: "Awesome. The control knob is so sensitive that it seems the airplane is controlled by thought. We can only guess how much adrenalin the pilot must have to accurately control such a finely tuned machine. After a 10-minute workout

2,135	The top speed in km/h of the PAK FA
5,500	The range in kilometers of the PAK FA
250	The number of PAK FA aircraft India intends to purchase
4++	The designation of Su-35S

I became a skilled pilot, and at the end of the flight I performed three barrel rolls in a row, which made the nearby staff feel nauseated," he explains.

ELECTRONIC CO-PILOT

Next the reporter went to the Scientific and Technical Center (STC), i.e. the department of information management systems (IMS) which was created in 2002. IMS holds a powerful computer, which can be used as an electronic co-pilot. Deputy chief Alexander Baranov says that the human pilot should not be distracted from battle in order to operate the aircraft. He should only have to deal with operational issues in an emergency. If there is any sudden failure, a message pops up with instructions on handling the situation, and all he has to do is say "yes" or "no". 'Hint' is a system that issues warnings electronically in accordance with the integrated analysis of all systems.

As an example, take-off failure is very critical, but it is not necessary to give a 'hint' while on the take-off route; the electronic pilot understands this. Or if the airplane is under attack, the electronic pilot engages the defense systems. The electronic pilot issues 'hint' depending on the current state. It flies the optimal route to dodge missiles. But the human pilot always has priority manual control and can always take over.

IMS

This is the first time that Sukhoi has developed a system where the central computing machine multiprocessor works with different software developers.

So how was it before? Baranov explains: "Each system had its own computer. And now there is just the central computer, which comes from various software companies. The engineers have developed a real-time operating system that provides memory protection and independent processes software that ensures the independence of applications from each other. That means that an error occurring in one application does not affect others.

"Su-35 IMS are now being commercially manufactured and more than a dozen sets have already been supplied. We are currently working for T-50 as well. Moreover, at the development center the software is being developed, its integration with the avionics tested and detailed testing of all functions conducted. Next we will face the military representatives and then we should get the work accepted," he states.

POGOSYAN'S CORPS OF ENGINEERS

It was necessary to create a special database in order to turn the system into electronic form. "There are hundreds of thousands of 3D elements in a standard database of units, and millions of records for the procurement of materials," says Baranov. "Nothing works without this database. Nothing works without standardization. We have made the subcontractors do the same. We make them give us electronic layouts together with the design specifications and the usual documentation. The whole industry complies with our requirements now – it's not only about us. We put in those standards. Two aircraft – the civilian Superjet and T-50 – are entirely digital."

THE THREE ELEMENTS

Sukhoi says it has developed technologies "very actively" over the past 10 years and with "even greater

SCIENTIFIC RENAISSANCE

Not only has the latest scientific technology helped the aircraft industry, but it also gets back substantial investment from industry itself, says United Aircraft Corporation. This year the Institute of Theoretical and Applied Electrodynamics (ITAE) completed the certification of a new experimental complex. Construction of the facility took 10 years and cost more than US$15 million. Funding was allocated by Sukhoi, the Ministry of Industry and Trade, and the Russian Academy of Sciences. The complex is equipped with the largest anechoic chambers in Europe, where new aircraft are tested for their radar signature.

Sukhoi scientists and ITAE conducted fundamental research on the nature of the scattering of electromagnetic waves, the creation of new materials and testing facilities to ensure electromagnetic compatibility. They developed a number of technologies that are now successfully working on MiG and Su-35, and in summer 2013 their partners completed the next stage of laboratory and bench tests.

"Thanks to Sukhoi we have not only managed to build a powerful testing facility, where new technologies are developed, but were able to gather top scientists from all over the country," says Andrei Lagarkov, head of ITAE. "We employ graduates from leading Moscow universities and therefore create a good basis for further development of science."

ABOVE: Each thrust-vectoring engine of the Su-35 is rated at 86.3kN thrust, or 142.2kN with afterburn

FUNDAMENTAL TAKE-OFF

Over the past few years Russia has begun to create not only new aircraft, but also new technology. Five branches of the Russian Academy of Sciences are working with aircraft manufacturers on more than 20 projects. Scientific breakthroughs from Russian and foreign scientists are used at the theoretical and experimental stages, and some have already been implemented or are being implemented to create new aircraft. For example, as far as the introduction of composite materials to civil aviation is concerned, Russia will be the first country to manufacture a 'black' aircraft wing entirely through infusion.

intensity" in just the past three or four years. The company says this is because it coincided with the year the Presidential Commission decided to launch the project to create a wide range of supercomputing technology in 2009.

There are three main elements: the first is machines and communication channels. The second is a set of software tools that provides a wide range of physical processes, including modeling that describes the behavior of a real flying object. And the third is training to use the technologies.

RUSSIAN STEALTH

One of the 5th-generation fighter's peculiarities is its invisibility to enemy radar. Whether Russian stealth technology is able to compete with American is a big question, according to academician Andrei Lagarkov, head of the Institute of Theoretical and Applied Electrodynamics: "I am often asked whether we utilize stealth technology for our military aircraft, and I just say 'yes'. Its parameters are not inferior to the best international standards. In general, our research in this area is not worse than in the West, because Russian stealth technologies have existed for a long time, even long before the foundation of our institute was created to meet the challenges of stealth. But the range of interests expanded further, and today we as an institute are engaged in solving problems of electrodynamics, superconductivity, ferromagnetism and many others. Stealth technology covers many scientific fields, including nanotechnology, optics, materials and of course the theory of how electromagnetic waves are scattered by objects with complex shapes."

A major question is whether it is in fact possible to make an airplane invisible. "Generally speaking, it is impossible to make an object completely invisible," Lagarkov

observes. "You can only greatly reduce the effective dissipation for some areas; it is impossible to reduce it completely. It is difficult and there are several ways to solve the problem. First, you can change the shape of the aircraft so that the radar waves are reflected from the object and not returned back to the locator. This does not mean that the object is invisible, and if you look at the airplane from another point it will be more noticeable. For example, on the US bomber B-2, the 'flying wing' has a low signature at a certain angle of observation in a wide range of radio frequencies, but it is perfectly visible from space, because it has a huge top surface reflection."

A second technique is the application of special coverings that translate the radio signal into thermal energy. This method greatly reduces the visibility of an aircraft without losing its flight characteristics. Naturally these two techniques are being productively combined.

Finally, the third and the most effective technique is to create a shield of plasma cloud around the airplane. "I must say," comments Lagarkov, "that this technology is applicable only at high altitudes in the stratosphere. If you try to do something like that at low altitudes, the aircraft will need a very powerful generator – and unfortunately they don't carry hydro-electric power stations. In addition the pilot would need to be protected from the powerful x-rays. But if you climb high into the stratosphere, this stealth technology becomes real and very effective, and the necessary power is reasonable."

ABOVE: **The Su-35 has an improved airframe, which will increase its service life to 6,000 hours, or 30 years of operation**

WHAT ARE THE LIMITATIONS FOR STEALTH TECHNOLOGY?

Lagarkov openly discusses stealth limitations, "First of all is the speed. Reducing the effective scattering surface of the airplane degrades its performance. All US aircraft named 'invisible' – the F-117 and the B-2 – fly at subsonic speed because of their shapes. The second problem is connected with the bistatic location when the radiation source and the receiver are separately located. In this case, the task of reducing the radar visibility is considerably more complicated."

There are also problems with the use of radar-absorbing coatings and materials. Aviation needs not only the world's best radar-absorbing material, but also one that is not too heavy or too fragile. And yet it must be resistant to extreme temperatures. In short, there are many problems. But in fact, in today's world no one tries to make an airplane completely invisible. "The most urgent task is to make military aircraft invulnerable to missiles," Lagarkov says. "Suppose you see an airplane on the long-range radar coming at you. You need to fire at it with a rocket. But for more precise targeting of missiles a shorter wavelength is used. And when viewed by shortwave radar the stealth airplane is lost.

"I have listed only some of the problems of the stealth technology. Actually it is necessary to solve a complex multiparametered task," Lagarkov says.

FLY THE AIRCRAFT

But it is not enough just to create a system using integrated modular avionics that consists solely of hardware, as it will be useless without the necessary software.

The Russian program is becoming more complex year by year. Effectively the 'brain' of the machine has brought in more functions and complexities, which include navigation in the airspace and work with the electronic map, radar control, optics, weapons and life-support systems. Today, an aircraft's IMS is engaged in processing more than 100 data streams.

MOVING ON

Interestingly, the UAC (United Aircraft Corporation) has created a special team for the development of the software for the information management system of the Su-35 4++ and the 5th-generation T-50. This is a young team – the average age of employees in R&D Center Sukhoi is only about 30.

"The foundation of the center began in 2001, at which time there were very few enthusiasts who believed in the feasibility of our ideas," says Dmitry Gribov, chief of Science and Technology Center (STC), Sukhoi. "More established engineers do not particularly like to work on a new, challenging project, preferring to engage in export contracts or work in areas where proven solutions are being used safely. Several professionals with experience came from specialized institutes, such as the National Institute of Aviation Systems. But the main experts had to be taken right from the Moscow Aviation Institute."

Another youthful team is engaged in software testing. The final stage of avionics integration is a joint bench-systems testing. Gribov says, "Before you put in the new software, you must test it at Sukhoi laboratory." ∎

Manning the war room

Over the past couple of years, a number of accidents have occurred involving helicopters manufactured by Eurocopter. As a company it established an unrivaled investigation team to piece together what might have been going wrong

BY DAVID OLIVER

MAIN: North Sea operations were badly affected by the EC225 grounding (Airbus Helicopters)

In May 2013, Guillaume Faury was appointed president and CEO of Europe's largest helicopter manufacturer, Eurocopter, (now Airbus Helicopters right in the middle of the most exhaustive and expensive accident investigation in the company's history.

On May 10, 2012, a Bond Offshore Helicopters EC225LP Super Puma en route from Aberdeen Airport to Maersk Resilient drilling rig with 14 passengers and crew carried out a controlled ditching in the North Sea 20 nautical miles east of Aberdeen. All passengers and crew evacuated the helicopter into a life raft and were subsequently rescued.

On October 22, 2012, a CHC Scotia Ltd EC225LP Super Puma en route from Aberdeen Airport to Phoenix drilling rig with 19 passengers and crew ditched in the North Sea, southwest of Sumburgh, Shetland Islands, UK. All passengers and crew evacuated the helicopter and were subsequently rescued without injury.

The Bond crew ditched the helicopter following indications of a failure of the main gearbox (MGB) lubrication system and, subsequently, a warning indicating failure of the emergency lubrication system (EMLUB). A UK Air Accidents Investigation Branch (AAIB) investigation identified a 360° circumferential crack in the bevel gear vertical shaft in the MGB, in the vicinity of a manufacturing weld, causing disengagement of the drive to both mechanical oil pumps.

The AAIB investigation into the CHC ditching found the same signs of a failure of the MGB lubrication system and, subsequently, a similar warning indicating failure of the EMLUB system to that of the Bond incident.

The investigation of these two incidents became a number one priority for Eurocopter and a major crisis for the company and its management. As a result, the company's recently appointed chief technical officer, Jean-Brice Dumont, was placed in charge of a crisis management team in what became known as the 'war room'. An aerospace engineer and helicopter pilot, Dumont began his career on the French Army's Tiger program, joining Eurocopter in 2004 to work on the NH90, Super Puma and EC225/725 programs, before being appointed CTO in January 2013.

Responsibility of the management of the war room was taken over by Pierre Maret, whose background included 15 years in gearbox design, production engineering and as chief engineer of light helicopters.

with more than 1,500 flight hours, industry co-chair of the European Helicopter Safety Team, and was appointed to his present position in 2011.

He was responsible for appointing a team to advise the UK AAIB in its investigations of the EC225 incidents. "I am responsible to the CEO for any accident-related updates. The design department is my first call and, as part of the war room, I was involved in all the classified investigations and the corrective measures taken. I work closely with the operators, and am responsible for flight manual updates and the flight simulator syllabus updates."

Responsibility for establishing what caused the contributing factors that led to the initiation of a fatigue crack, and ultimately the rupture of the shaft, fell to the Material Quality Laboratory, where 30 engineers analyzed the properties of all the materials involved in the manufacture of the EC225's MGB. This coincided with testing

INVESTIGATION OBJECTIVES

The war room objectives were to determine the root cause of the two ditchings as quickly as possible, to develop the appropriate solutions to solve the problems, and to gather all the information relative to the investigations, reports, analysis and tests performed appertaining to the two incidents, for all the main stakeholders in one dedicated place, to improve communication and the exchange of key results.

Pierre Maret told *Aerospace Testing International* that it was quickly established that the second event was similar to the first, but crucially, not exactly the same, and this completely challenged the initial conclusions.

A root cause analyst tree was established to list all potential causes of each incident: firstly to avoid becoming fixated too quickly on only one subject and to focus on the potential combination of several contributing factors; and then to start investigations in parallel on a number of potential factors that challenged the original speculations.

Around 150 potential root causes were eventually assessed and validated. These were divided into eight groups that were classified as Without Significance, Moderately Significant and Significant, and all the findings were to be confirmed or discarded. The only significant group came under the heading of 'Welded Joint Area – Lower Fatigue Strength'. Having identified exactly where the failures occurred, the crisis management team had to find out how they occurred.

THE TEAM

No one was more aware of the challenges facing the company than its new president, Guillaume Faury, who graduated in aeronautics and engineering before becoming a flight test engineer with the French defense procurement agency (DGA) flight test center. He joined Eurocopter in 1998, working as chief engineer on the EC225/725 program, as head of the flight test department, and eventually executive vice president of research and development. He left in 2008 to work for the automotive industry before returning to Eurocopter in May 2013.

"I rejoined in challenging times," he explains. "I had to catch up with developments. I was really focused on the investigation team and had daily updates from the war room. By their very nature, oil and gas support helicopters are operating in difficult environments, where safety has to be the priority."

With this in view, Gilles Bruniaux, vice president fleet safety, was heavily involved in the accident investigation. He began his professional career as a flight test engineer in the French military flight test center alongside Guillaume Faury, is a helicopter pilot

"ALL AFFECTED SHAFTS IN THE 170+ FLEET WILL BE REPLACED BY NEW ONES, STARTING FROM THIRD QUARTER OF 2014"

ABOVE: A Bond Helicopters EC225LP Super Puma similar to the one that ditched in the North Sea on May 10, 2012 (Airbus Helicopters)

undertaken by QinetiQ to confirm the material properties and the material's susceptibility to cracking.

It was here that an exceptional corrosion phenomenon, or active corrosion, resulting from a combination of gear corrosion pitting and specific environment such as trapped moisture, was identified. The presence of a paste, produced from the splines usual wear, MGB oil and water inside the shaft in the welded area, trapped moisture. Corrosion pits on the rough surfaces of welds alone did not explain the cracks, but the pits plus humidity trapped by the paste in the shaft the CHC helicopter and in the bevel of the Bond helicopter produced the exceptional corrosion phenomenon.

It was then time to define the behavior of the crack. This complicated and time-consuming phase of the test program was undertaken at the company's vehicle test center under the head of the project team, Bérengère Vignal. The center has a staff of 83, whose main function is to test all

SCOTTISH POLICE EC135T2I ACCIDENT

On November 29, 2013, a Bond Offshore Helicopters Eurocopter EC135 T2i operated by the Scottish police force crashed through the roof of a public house in Glasgow's city center at 22:22. A crew of three on board, consisting of two police officers and one pilot, were killed in the accident, as well as six people in the building, while 32 other people suffered injuries. Initial investigations were carried out at the site of the accident by the AAIB and BFU (the UK and German accident investigation boards) assisted by a Eurocopter accident investigation team.

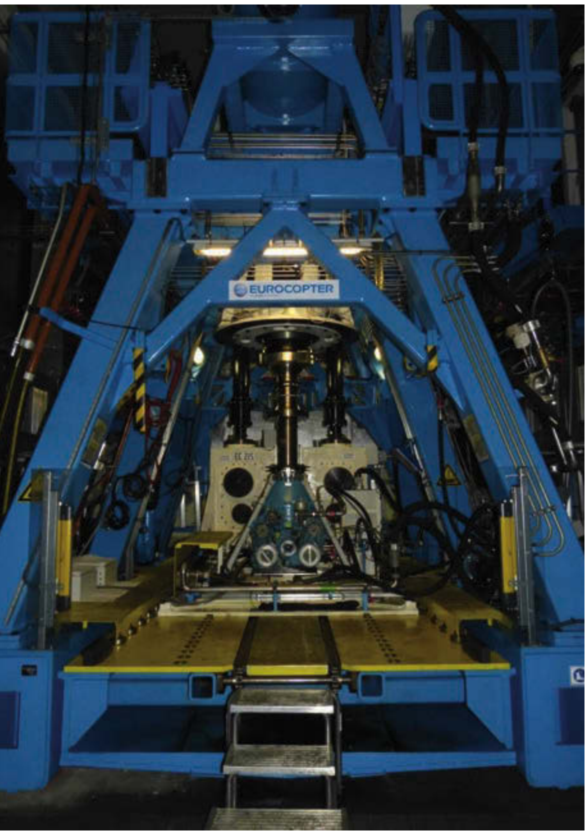
Once removed from the building, approximately 95 liters of fuel were drained from the helicopter's fuel tank. The examination continued at the AAIB's Farnborough headquarters, where it was confirmed that all significant components were present at the time of impact. Initial assessment provided no evidence of mechanical disruption of either engine and indicated that the main rotor gearbox was capable of providing drive from the No 2 engine power turbine to the main rotor and to the fenestron drive shaft. Clear impact distortion of the structure had caused a splined shaft on the drivetrain from No 1 engine to disengage, preventing a similar continuity check.

The AAIB investigation is continuing to examine all the operational aspects of this accident and to conduct a detailed engineering investigation of the helicopter – and will report any significant developments. At the same time, Eurocopter, now rebranded Airbus Helicopters, established a war room at its Donauworth plant in Germany, where the EC135 is manufactured.

Although the European Aviation Safety Agency (EASA) has never issued an Airworthiness Directive to ground the EC135 fleet ever since its entry into service in 1996, Eurocopter was informed by Bond on December 12 that it decided to temporarily suspend flights with its EC135 fleet for precautionary reasons. Bond and four other UK EC135 operators subsequently performed checks on their own initiative after a fuel tank system sensor issue was identified by Bond. Following a Safety Information Notice (SIN) issued on December 16, Eurocopter issued two Alert Service Bulletins (ASB) on December 19 concerning the fuel tank system of its global EC135 fleet. The first ASB introduced a mandatory one-time system check of the supply tanks, the results of which must be reported to Eurocopter. This collective reporting will provide Eurocopter with an overall worldwide EC135 fleet status regarding the fuel tank sensors.

The second ASB introduced a revision of the flight manual with regard to the low fuel warning and the fuel pump caution indications. The corresponding airworthiness directive to be issued by EASA will be an Emergency Airworthiness Directive (EAD), meaning the revision to the manual must be made immediately. This is not because there is a safety concern, but the EAD ensures the revision is made immediately instead of at the next scheduled update of the manual.

By mid-January 2014, 934 sensors had been tested on 467 aircraft, 45% of the global EC135 fleet, which contains 2,100 sensors on 1,050 helicopters. Of the checked sensors, 19 on a total of 16 aircraft needed to be cleaned, but were fully functional afterward. Separate to those, three sensors failed and needed to be replaced. The remaining 866 sensors passed the test with the red 'low fuel' warning working on every single aircraft tested.



LEFT: **An EC225 main gearbox under stress testing on a test rig in the Vehicle Test Laboratory at Marignane (David Oliver)**

prototype and production components. In order to ensure that the dynamic flight loads acting on the shaft were consistent with the design parameters, the laboratory ran an EC225 MGB equipped with 32 strain gauges through a series of dynamic tests. After almost 400 hours of testing, the failure was reproduced.

REASONS BEHIND THE CRACK

During the crack propagation campaign, nine bench tests and one flight test that all went up to the rupture, confirmed the previously observed raising trend of the bevel shaft indicator before the rupture incident from the Health and Usage Monitoring System (HUMS) data retrieved from both EC225 ditchings.

Having identified the cause the fatigue crack and ultimate rupture of the shaft, the war room set about devising preventative measures by reducing the factors of active corrosion. A new modified oil jet was installed to improve the cleaning of the welding area in order to prevent paste accumulation and improve the splines lubrication to reduce the wear at the origin of the paste.

Eurocopter also defined two precautionary measures. Regular ultrasonic non-destructive inspection (NDI) of the shaft, using a specific probe provided by Eurocopter, allows detection of a potential crack at a very early stage. In addition to the usual ground analysis performed after each flight on daily basis, and the ultrasonic inspections, a new EC 225 HUMS version proposed by Eurocopter will monitor shaft vibration levels in real time and inform the pilot on the condition of the shaft. If an abnormal situation is detected in flight, a dedicated HUMS alarm will be displayed, which will enable the helicopter to continue to operate safely for a sufficient time to allow the crew to return to base or perform a normal landing in a safe area.

During the two EC 225 ditchings, the EMLUB system was activated by the pilots and operated properly. However, a warning light, indicating a system malfunction, came on and resulted in the crew making the decision to perform a controlled sea landing, as required in the flight manual. This is not linked to the shaft issue, but Eurocopter conducted another intensive test campaign, in which an EC 225 MGB with its complete EMLUB system was run for 24 hours. These tests identified the cause of the false alarm as a wiring discrepancy, and confirmed that the systems on the ditched helicopters were operating successfully. The solution to the problem included changing the pressure switches to optimized thresholds and an improved maintenance procedure with specific tools.

In addition to the mandatory validation by the airworthiness and investigation authorities, an independent specialist, Shainin Engineering, validated Eurocopter's investigation methodology exemplified by its war room, while the crack propagation investigation and HUMS methodology were independently verified by the Georgia Technology Research Institute.

NEW SHAFT AVOIDS MOISTURE

However, Eurocopter's long-term solution is to introduce a new shaft design that will avoid any collection of moisture, improved lubrication of the bevel shaft splines, a different type of surface finish designed to prevent corrosion, and improved strength and thickness to eliminate stress points and hot spots.

The redesigned shaft is expected to be certified later this year and will be fitted to all new aircraft on the production lines, and all affected shafts in the 170+ fleet will be replaced by new ones, starting from the third quarter of 2014.

In the frontline of customer relations during the past year has been senior vice president program support global business and support, Michel Macia. He says, "I was in constant communication with EC 225/725 customers for the first three months of the investigations. For the in-service fleet, safety is the number one priority. When the cause was identified and the precautionary and preventive measures defined in April 2013, we had to design and manufacture 470 modification kits and the probes for inspecting the shafts. These were certified in June and we then had to train between 50 and 100 qualified staff belonging to the operators or MROs. The first modified aircraft was ready to fly, non-passenger flights, in July." Since then, more than 85% of the EC225/725 fleet is now back in service, some 144 aircraft, including those used for oil and gas missions as well as other operations.

NEXT STAGE

Guillaume Faury was now able to issue a positive message saying that, "The EC225 has been the industry's most examined aircraft, and we are proud to have it back as a key player in the oil and gas sector, continuing to safely accompany our customers in their challenging missions."

According to Dumont, there were many positives resulting from the investigation process. "I learned a lot about dynamic testing, but more importantly, I learned a lot from the oil and gas industry. It is also involved with cutting-edge technology in challenging environmental conditions and has an ongoing quest to improve safety standards. It learned how to deal with a major crisis such as the environmental disaster that occurred when the tanker Amoco Cadiz sank off the coast of Brittany, resulting in the largest oil spill of its kind in history."

Jean-Brice Dumont said that the effort that went into solving the EC225 incidents must be maintained when facing other day-to-day issues within the company.

CHANGE OF DIRECTION

However, as the war room was being wound down, Dumont was leaving London on August 23, 2013, on his way back to France after a series of positive meetings with oil industry representatives in Scotland, when he was given the news that a CHC Scotia Eurocopter AS332L2 Super Puma, with 18 crew and passengers aboard, had crashed into the sea on approach to Sumburgh Airport, Shetland Islands. Four of the passengers did not survive the accident. He immediately returned to Scotland.

After an anxious few weeks for all the Eurocopter staff involved in the war room, the AAIB issued a special bulletin on October 18, 2013, the summary of which stated that the wreckage examination and analysis of the recorded data had not found any evidence of a technical fault that could have been casual to the accident, and that the investigation will focus on operational aspects of the flight, specifically on the effectiveness of pilot monitoring of instruments on approach, operational procedures, and the training of flight crews. ∎

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

1,000 EC135 five- and seven-seat twin-turbine light helicopters are in service worldwide, with approximately 296 customers in 58 countries.

57 The total number of EC135 aircraft in service in the UK: 20 on police operations; 20 used for emergency medical services; 10 for private and business aviation; and 7 utility aircraft.

15,000 The number of missions flown by UK EMS fleet in a year, and the UK police fleet flies some 19,000 hours per year.

BELOW: A UK-registered EC135T2i, similar to the police-operated helicopter that crashed in Glasgow city center on November 29, 2013 (David Oliver)

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INVESTIGATION: TEST SITE

In a new series, *Aerospace Testing International* gains exclusive access to global test sites. In this issue, reporters look at some of the leading military test locations around the world, and talk to those who run them, including: Istres, France; Warton, UK; Edwards AFB, USA; and Vistel, Sweden.

- At any given time, Edwards AFB has more than 100 test programs underway
- DGA Essais en vol runs two test sites, one for aircraft, and one for weaponry and radar systems
- Woomera, Australia, is the largest land range in the world, the size of England
- WTD 61 has a specific area just to test for air cargo drops
- 5,300 personnel are employed at the fast jet test site in Warton, UK

AEROSPACE TESTING INTERNATIONAL EXCLUSIVE

NEXT ISSUE: SPACE VEHICLE DEVELOPMENT TEST SITES

Image: Google Maps

Wehrtechnische Dienststelle 61 (WTD 61)
Location: Manching, Bavaria, Germany

Coordinates
Latitude: 48.7109
Longitude: 11.5353
Elevation: 364m

Situated in Manching in Bavaria, WTD 61 (Wehrtechnische Dienststelle 61) is Germany's military flight test center. With a remit of evaluation and testing, research and development, and provision of technical expertise, WTD 61 reports to the BAAINBw – the Federal Office of Bundeswehr Equipment, Information Technology and In-service Support – the body charged with project management and administration for the armed forces.

The daily work, for the approximately 550 personnel, of WTD 61 comprises test and evaluation of aircraft and related airborne equipment, up to and including type certification and approval. Experts from the center are on hand to provide engineering support to project management throughout the procurement process for new aircraft and equipment, and for the management and support of R&D projects.

The local facilities at Manching include north and south runways of 8,000ft and 9,646ft, respectively, a hover lane for rotary-wing operations, and a drop zone for testing cargo drops. Four hangars (jets, transports, helicopters and unmanned) serve a fleet of instrumented test aircraft, including subsystems, weapons and armament control systems. Data is gathered using aids that include stationary and mobile telemetry systems, tracking measurement equipment and engine test stands. For armament tests, an indoor range is proved for gunnery.

CURRENT PROJECTS

In terms of scale, the most important current projects relate to the Eurofighter, A400M, NH90, Tiger and various weapons projects, as well as the study of a number of forthcoming capabilities. The latter includes the Light Support Helicopter (LUH), Future UAV and Future Large Helicopter (FLH). Other recent test campaigns have included arrestor gear testing; Eurofighter flutter testing and data gathering with the MBDA Taurus stand-off precision missile; CH-53 deck-landing trials; helicopter sensor testing with the UH-1D testbed; and development of the EC135 variable stability helicopter. The latter is a joint project with DLR, the German Aerospace Center.

WTD 61's combat aircraft test fleet will eventually include three Eurofighters, the first of which is the two-seat Instrumented Production Aircraft 3 (IPA3) from the Tranche 1 production batch. IPA7 from Tranche 2 has been used by the unit since 2013, and in early 2014 it began flight tests of the Taurus missile. Currently it is operated under a lend-lease agreement with industry. It will be joined in future by IPA8, which entered final assembly in 2013. The combat aircraft fleet is rounded out by examples of the Tornado IDS and ECR, including aircraft engaged in the ongoing ASSTA 3 upgrade program.

In terms of Eurofighter testing, WTD 61 is a strong proponent of European cooperation to reduce time in fielding systems and modifications, and cutting costs. This is aided by a close working relationship with the flight test centers in the other Eurofighter partner nations: Qinetiq at Boscombe Down; INTA in Madrid; and the RSV in Pratica di Mare. The Manching site is also home to the German Eurofighter production effort, undertaken by Airbus Defence and Space (formerly Cassidian).

TEST SYSTEMS

Helicopter test activity encompasses air transport, combat support, training, medical evacuation and research and technology, and the fleet includes examples of most types in Bundeswehr service, comprising the CH-53G, Bo105, UH-1D and the Unterstützungshubschrauber Tiger (UHT) attack helicopter. WTD 61 operates an example of the specially equipped UH-1D Mission Avionics Test Helicopter (MAT), a testbed that allows systems and data to be evaluated during the development phase and under operational conditions. Typical assignments for the rotary-wing section include testing and research of handling qualities. Innovative and highly productive research is also undertaken in the field of sensor integration and pilot displays.

Within the field of transport aircraft, WTD 61's work encompasses air transport, cargo airdrop, aerial refueling, medical evacuation, research and technology, and the governmental VIP fleet. In the absence of the A400M from the Manching test fleet, WTD 61 has been

Eurofighter Typhoon began flight tests with the Taurus KEPD 350 in 2014

Phantom flight test aircraft WTD 61 (Image: Alexander Golz)

Tornado aircraft upgraded to the new ASSTA 3.0 (Image: Avionics System Software Tornado Ada)

UNIQUE ASSET

WTD 61 can claim a number of unique capabilities: "Like every national test center, we have special capabilities that are tailored to our very own national requirements," explains Oberstleutnant Hierl. "For instance, we did a lot of test work on Russian-made fighters and their equipment, including weapons, after German reunification. Besides that, we used to have in our inventory the only fully calibrated supersonic-capable 'Pacer' aircraft in Europe (the F-4F, now retired). I believe we are unique in being co-located with our industry (Airbus Defence and Space) with whom we share many facilities and resources."

Key future challenges for the German flight test community will include the introduction of larger UAVs, expanded A400M testing, and the continued support required by the varied governmental fleet, comprising the A310 MRTT, A340, A319 and Global 5000. "It is essential to have modern measurement systems and recording devices (telemetry, optical and GPS sensors, etc), and to possess a group of very well trained, motivated and experienced test pilots, flight test engineers and data measurement specialists," concludes Hierl.

employing the Transall to conduct certain tests for the new airlifter, including airdrops over the adjacent dropping area. Ballistic parameters of different loads and parachutes are measured for future integration into the A400M's onboard computer. Other A400M tests have been conducted at Toulouse, and will soon begin in Seville.

Unmanned aerial systems under test at the center extend from mini and micro UAVs, up to high-altitude long-endurance (HALE) platforms, and include the tactical Heron 1 and KZO and, prior to its May 2013 cancellation, the EuroHawk UAV. Meanwhile, the military remain hopeful that the SIGINT payload developed by Cassidian for the EuroHawk may find a future application in an alternative manned platform.

LOOKING TO THE FUTURE

In terms of military flight test technology, WTD 61 recognizes the importance of providing highly trained personnel and appropriate test facilities in order to cope with the ever-increasing complexity of modern systems. Oberstleutnant Robert Hierl is the chief test pilot at the unit. "The technology must be provided by both industry and the government," he says, "and test efforts must be more integrated and further optimized.

"From an experienced test point's of view ????, both the appropriate technologies – smaller, more capable (digital), providing instant feedback – and adequate methods are required for successful flight testing, e.g. handling qualities stress testing, boundary avoidance tracking, and special facilities enabling meaningful testing of digital flight control systems."

Such a future-proof system has already once been put to use by WTD 61, in the form of the Ground Attack Test Equipment (GRATE II). Comprising a specialized array of computer-controlled lights on the ground, this required the test pilots to make quick and aggressive corrections during aiming, thus investigating flight control system characteristics and developing special filtering methods, in order to perform state-of-the-art exploratory testing on the Eurofighter. Judged as being highly successful, these trials were also supported by research engineers from the DLR and are set to aid the Eurofighter's continued expansion into the air-to-ground realm. ▮

Military Test Site: Naval Air Warfare Center Aircraft Division
Location: Patuxent River, Maryland, USA

Coordinates
Latitude: 38.28319
Longitude: -76.41
Elevation: 5m

Sixty-five miles south of Washington DC, the Naval Air Warfare Center Aircraft Division (NAWCAD) at Patuxent River, Maryland, concentrates Research, Development, Test and Evaluation (RDT&E) facilities and unique intellectual capital to develop US Naval aircraft. "We've got everything," says US Marine Corps Colonel Roger Cordell, commander, Naval Test Wing Atlantic. "We have a first-class airfield facility. We have the Naval Test Pilot School [NTPS], which enables us to train test pilots in the manner they will actively test. We have ranges and airspace supported by the Atlantic Test Ranges that time and again have proved very agile to accommodate relatively immature systems."

Systems under test include the mature F-18 strike fighter to pioneering experiments such as the X-47B Unmanned Combat Air System Demonstration (UCAS-D). The F-35 Joint Strike Fighter program flies 5-10 sorties a day backed by an Integrated Test Team (ITT) of 800-900 people. Pax River test squadrons also continue to fly the legacy Hornet and Super Hornet. "There are always things going on, whether it's discovery of a problem or a new weapon being integrated into the aircraft," says Cordell.

Follow-on test and evaluation continues on the latest E-2D version of the veteran Hawkeye carrier-based airborne warning and control system. The combat-proven MV-22 tilt rotor likewise continues with testing. "They just recently released a new flight control software program that is in operational testing right now and will make the MV-22 safer and more effective."

Unmanned aircraft systems (UAS) remain in comparative infancy, and an ITT including Air Test and Evaluation Squadron VX-23 and contractor Northrop Grumman orchestrated the first X-47B carrier recovery and launch last July. "I am the higher headquarters to VX-23 – what used to be called the Strike Aircraft Test Directorate," notes Colonel Cordell. "They were responsible for the whole thing. We did cats and traps [catapult launches and arrested recoveries] on both air vehicles in preparation to going to the USS Bush. X-47 certainly overcame a bunch of technical maturity issues and was able to get to the carrier very well."

OVER LAND AND SEA

Established in 1942, Naval Air Station Patuxent River today hosts the Naval Air Systems Command (NAVAIR), which manages US Navy and Marine Corps aircraft programs. It affords the Naval Air Test Wing access to 5,000 square miles of controlled airspace and an air-sea environment situated and equipped for naval aircraft development. NAWCAD has five runways up to 11,800ft long. The associated Atlantic Test Ranges, with their air and surface target facilities, are covered by radar and optical tracking systems and a telemetry data center. "The temptation now is to gather reams and reams of data," acknowledges Cordell. "You've got to be a little bit careful in what you go after. Our ability to mine it and go through it all has really increased."

The Air Combat Environment Test and Evaluation Facility (ACETEF) at Pax River includes a large anechoic chamber, shielded hangar, and electronic warfare test and simulation facilities. "Our ability to isolate the electromagnetic environment and test aircraft around the ship environment is unique," notes Cordell. "It allows us to get a lot of test points in order in a very controlled environment." The ACETEF also provides threat air defense and avionics labs. "We have an integrated battlespace simulation and test facility. We're trying to exploit the live, virtual-construct side of testing."

CURRENT PROJECTS

NAWCAD Pax River continues real-world tests of the P-8 Poseidon patrol aircraft. "P-8 just recently got some bad press from the OT [operational testing] side," acknowledges Cordell. "The reality of the press coverage was that nothing was brought up that had not been discovered in developmental test. We made very clear what deficiencies existed. The capability was designed to be incremental, which is why it is in the fleet now. In its incremental process, it is doing things better than the P-3."

The unmanned adjunct to the P-8 is meanwhile scheduled to start testing in the third or fourth quarter of this year. The big MQ-4C Triton UAS has so far flown from the Northrop Grumman facility at Palmdale, California, monitored by Pax River engineers.

Development testing of the Marine Corps CH-53K Heavy Lift Replacement helicopter is expected to begin this October. "With all the budget pressures, a lot of lines in the programs are being decreased," notes Cordell. "But as long as no vertical cuts are made – as long as you don't eliminate a program – my pace doesn't change. As long as you buy any of them, we still have to do all the testing." ∎

Image: Google Maps

An F-35C Joint Strike Fighter from the Naval Air Warfare Center Aircraft Division at Patuxent River releases a 500 lb inert laser-guided bomb over the Atlantic Test Range. (Image: US Navy)

Image: Google Maps

Military Test Site: Vidsel Test Range and air base
Location: Vidsel, Sweden

Coordinates
Latitude: 65.881424
Longitude: 20.116739
Elevation: 178m

Vidsel is Europe's largest overland test area. Founded in 1958, when the Swedish Air Force was one among the largest air forces in the world, its strength lies in the expanse within which it is located; the remotest part of northern Sweden, where only two people reside per square kilometer. This translates into a one-way flight test distance of 350km, a missile range of 1,650km² and restricted ground space of 3,300km².

"Our air force is still important, but over the years we have opened up the range for others to do their testing," says Lt-Colonel Mats Hakkarainen, Vidsel Test Range commander. "Today we have two types of customers: organizations who do everything from practice to pilot certification; and the military who use our test range during development or adaptation of their product."

All major European countries, including Germany, the UK, France and Spain, have carried out military flight testing at Vidsel, as have many large European and US defense manufacturers, although Hakkarainen is unable to name names. "Vidsel started as a test range for air-to-air missile firing, then developed air-to-ground and ground-to-air," he says. "In the past couple of years, we have been doing more surface-to-surface missile testing. Currently we have a couple of large surface missile testing developments, as well as high-profile missile integration projects for European helicopters."

RANGE CAPABILITIES

In addition to an impressive array of instrumentation, including optical and radar tracking systems, high-speed cameras and telemetry systems, the range boasts electronic warfare capabilities, and air- and ground-based targets, both static and mobile. This year a new target drone system from Composite Engineering Inc – the BQM167i – will be implemented. Meanwhile, Vidsel is developing a multi-tracking radar system that will enable it to perform more advanced test scenarios with more airborne crafts.

"To provide a completely realistic test environment is impossible," says Hakkarainen. "All the frictions that will occur in reality are extremely difficult to simulate. What we try to do is to verify and validate the specifications set by the armed forces and other customers. Due to Vidsel's size, we are able to stage comprehensive test scenarios comprising full combat loop with surprise factors to train evasive maneuvering."

Hakkarainen has observed that, as time passes, weapons are being designed to go lower and lower. Having the largest test range over land in Europe is undoubtedly an attractive option. This was enhanced in recent years by NEAT, the North European Aerospace Test range. NEAT consists of two individual air restriction areas over Esrange Space Center and Vidsel joined together to create a space the size of Denmark, which is what gives Vidsel its unique expanse. Add this to Vidsel's test range in the Baltic Sea and it creates a formidable array of options.

"I think what we see is that for certain types of test we are the only place in Europe," says Hakkarainen. "Otherwise you have to go to the USA, which may mean greater expense and a loss of flexibility."

PLACE IN THE NORTH

According to Hakkarainen, what sets Vidsel apart from its competitors is its history, its geography and its flexibility, all of which lead to a high level of repeat business, something Hakkarainen regards as Vidsel's greatest achievement.

"Normally you take large development projects, then at some unknown point you need to test," he says. "We offer great flexibility in this area. We can always discuss when and how, and normally manage to satisfy the customer, both for planned testing and Urgent Operational Requirement. It is rare that we don't solve the problem before the customer goes home. And despite excellent access by land, air and sea, the area is superbly undisturbed."

THE G-FACTOR

The site also operates the Flight Physiological Center (FFC) located in Malmslätt, Sweden, just outside Linköping. Here, there is expertise and equipment for testing and training in the aerospace medical field.

Within the facility, there is a dynamic simulator that combines the centrifuge ability to produce g-forces with a flight simulator. This means that the pilot will be as close to the actual flight situation as is possible, while still remaining on the ground. This so-called fourth-generation g-simulator is a combination of a traditional g-spin and a flight simulator.

The simulator exposes the pilot to high forces with a fast g-increase combined with a realistic flight experience, including business intelligence presentations. The maximum g-force is 15g and maximum g-increase is 1g per second.

DFS is used for basic and advanced g-training, research in the HCI (human computer interface) area, aerospace medical research and testing/development of aero-operator equipment.

There is also an under-and over-pressure chamber, and a pool with the ability to create different weather conditions for survival training. ■

Fighters and helicopters at Sweden's VTR

Image: Google Maps

Military Test Site: BAE Systems Warton: Military Air and Information HQ and Air Test Centre
Location: Warton, UK

Coordinates
Latitude: 53.749949
Longitude: -2.892395
Elevation: 14m

British industry has been developing and testing fast jets at Warton since the late 1940s. Today the airfield is a cornerstone of BAE Systems' UK operation, building and testing Hawks and Typhoons, and driving UCAV technology. As Paul E Eden explains, this world-class facility boasts a range of test facilities unique in the UK.

Situated between the Lancashire city of Preston and the seaside resort of Lytham St Annes, regular host of golfing's Open Championship, BAE Systems' Warton airfield sits on the northern bank of the River Ribble, just a moment's Typhoon flight from the Irish Sea. The site dominates the village of Warton, but at the same time manages to remain all but invisible to drivers approaching from the north until they emerge suddenly from its suburban streets and find themselves at its main gate.

Warton is the headquarters of BAE Systems' Military Air and Information (MAI) business. Spanning 27 sites in the UK and overseas, MAI employs around 13,000 people, some 5,300 of them at the Lancashire facility. Warton's principal activities include Typhoon and Hawk production and flight test, while its UAV business also has a major and very security conscious presence. A range of engineering teams and facilities is also available, including wind tunnels, an electronic warfare test facility and aircraft support teams.

TEST PROGRAMS

Warton's post-war history is intertwined with the machinations of the UK aerospace industry and it has hosted development and test programs for several of the era's iconic designs, among them the English Electric Canberra and Lightning, BAC TSR.2 and SEPECAT Jaguar. More recently, its primary association has been with the Panavia Tornado and Eurofighter Typhoon, the first production Tornado for the RAF having rolled out of what is now the Typhoon production hangar on June 5, 1979. Tornado test work continues in support of its operators and the type finds occasional use as a chase plane.

Andy Pegg, flight test manager, Typhoon, explains more: "Warton is home to BAE System's Flight Test Centre for Typhoon production and development flying. Tornado and Hawk flying is also conducted from the Warton site, which is ideally located for fast jet flight testing in the UK, with direct access to the Irish Sea airspace for supersonic flying and proximity to air ranges for weapons trials.

"The current Warton-based test fleet of four Typhoon aircraft makes extensive use of real-time analysis technology (telemetry) in all its programs. BAE Systems also builds and test flies all UK-built Typhoons from Warton, as part of production flight acceptance testing (PFAT), before delivery to customers."

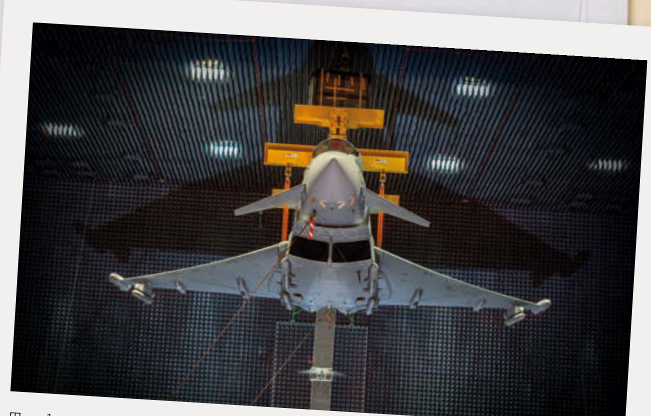
BAE Systems' Tornado and Typhoon test activities fall under the Warton umbrella regardless of their actual location, but the company is reluctant to reveal operational details on its UAV test work, especially Taranis. A spokesperson noted: "Taranis flew for the first time in 2013, and was designed to provide the Ministry of Defence with critical knowledge on the technical and manufacturing challenges, and the potential capabilities of unmanned combat air systems. We will continue to gather data and complete additional test points as per the requirements of the test program."

Asked about other current projects, the spokesperson revealed that manufacturing, as well as ongoing support, are key elements of the MAI business at Warton: "We are pursuing a range of export opportunities for Hawk and Typhoon, along with developing our capabilities in key areas such as manufacturing – 3D printing technology is a prime example – and providing technical support to our customers' fleets of Tornado, Typhoon and Hawk."

GLOBAL IMPORTANCE

Warton boasts a number of capabilities unique in the UK and, according to Damian Austin, Core Engineering Team, among just a few available globally. He notes that the one-of-a-kind UK capabilities include an electronic warfare test facility, acoustic fatigue facility, Typhoon widescreen simulator, high-speed wind tunnel, guided-weapons wind tunnel and blower, far-field stealth range, hot-gas laboratory and F-35 motion dome.

Other on-site test facilities include a lightning strike generator, electromagnetic compatibility (EMC) test sites, EMC shielded chamber, infra-red tracking system, low-speed wind tunnel, flight test and ground station, active cockpit rig, ambient lightning dome, environmental test laboratory and stealth materials laboratory. ∎



Typhoon can fly from Land's End to John O' Groats (603 miles) in under 30 mins

Military Test Site: DGA Essais en vol
Location: Istres, France

Coordinates
Latitude: 43.513006
Longitude: 4.987968
Elevation: 48m

Image: Google Maps

Dassault nEUROn UCAV undergoing testing

The DGA Essais en vol (DGA Flight Testing) operates from two facilities: Istres, on the Mediterranean; and Cazaux, on the Atlantic. With its 5km runway, the longest in Western Europe, Istres can receive all aircraft types and is equipped for the testing of fixed-wing aircraft and helicopters (both as individual vehicles and as integrated systems), system integration, flight test simulations and provision of expertise to EASA, the European Aviation Safety Agency.

Co-located at the Istres site are the head office of DGA Essais en vol and EPNER, the French test pilot school. Cazaux, meanwhile, is specially equipped for the testing of weapons (aided by an instrumented firing range), electronic warfare and radar systems, navigation systems and crew rescue equipment.

DGA Essais en vol provides air traffic controllers who ensure safety for each test and acceptance flight. These are distributed at various air control centers across France. The flight-test fleet makes use of Falcon 20, two-seat Mirage 2000B, N and D, CASA C-212, plus Dauphin and Puma helicopters. Training and chase planes are available in the form of the Alpha Jet, PC-7 and Fennec helicopter. Finally, a variety of ground assets are on hand to test aircraft and their systems, as well as to follow trials and collect data.

KEY PROJECTS

In terms of the center's most important current projects, Claude Chenuil, the head of DGA Essais en vol, mentions the flight tests of the Neuron, the first UCAV to fly in Europe, and acceptance of the A400M, of which the French Air Force is the initial operator. "DGA Essais en vol has also contributed to the French Air Force Reaper acceptance trials," he notes, "and is working on other high-visibility projects such as the NH90 and Tigre helicopters, the continued development of the Rafale (next to come is the F3R standard, whose development contract has been recently awarded) and upgrades to the Mirage 2000 fleet." He also highlights the separation tests of the Meteor missile from the Rafale conducted at the end of 2013. The center is currently working on the RBE2 radar with an active antenna, and on a new missile launch detector, both of which will be fitted on the Rafale as standard equipment. Finally, the ASTAC is an ELINT system that can be carried under a jet fighter.

When pushed to choose one project indicative of the center's greatest recent successes, Chenuil opts for the acceptance of the first A400M transport last year: "France was the first country to receive this aircraft in its armed forces, so the DGA had to determine the process to verify whether the aircraft was good for service." Other countries will now use the process as they undertake their own A400M acceptance. "On another level, I would also mention the direction of the flight demonstrations at the Paris Air Show, where DGA Essais en vol is in charge of flight safety," he adds.

Looking to the future of flight-testing, Chenuil expects to see increased importance placed on simulation and complex systems. 'DGA Essais en vol facilities have the necessary assets to simulate situations that may be encountered in operational reality. When a new situation is identified, we study how to develop the assets to provide an answer at the optimum cost. We make extensive use of computer simulation, which allows us to associate cost savings and safety, but it is clear that real flight tests will always be necessary to validate concepts."

NEW-GENERATION TESTBED

Set to become a vital flight-test asset at the center is the Avion Banc d'Essais – Nouvelle Generation (ABE-NG, new-generation flying testbed), which is now under development on the basis of a Fokker 100 airframe. Larger than the Falcon 20 currently used, the ABE-NG will use modular test systems and will conduct tests more easily and at reduced cost. Prepared outside of the aircraft, the test systems will be plugged into the aircraft, rather than requiring long periods of immobilization during which the aircraft is modified for a test. "The Fokker 100 offers a very high payload capacity and some unique capabilities," Chenuil continues. "The modified nose allows it to carry a fighter radar, reinforced wings offer the capability to carry two missiles, and a modular central stores station under the fuselage is available for heavy and cumbersome payloads, such as reconnaissance or EW pods."

Chenuil explains that DGA Essais en vol assets will also evolve in order to be able to test new airborne technologies. "For example, stealth is one of these technologies, and the center has been working on Cyclops, which is a helicopter-mounted system for measuring the infrared signature in flight."

As a military flight-test center, the DGA Essais en vol is set apart by its operations from twin facilities at the Istres and Cazaux facilities. Chenuil highlights some of the center's other unique assets. First, the test and acceptance air controllers, who ensure a volume of safe airspace around aircraft engaged in flight tests. Second, the center's expansion into the non-military domain: DGA Essais en vol is also a major player in civil aircraft certification, providing expertise to the EASA. Finally, the center runs EPNER, France's test and acceptance crew school. A highly selective flight-test academy, EPNER is one of only four such schools in the Western world with full international recognition by major regulatory authorities. ∎

Test and Evaluation Centre, Boscombe Down
Location: Boscombe Down, Wiltshire, UK

Coordinates
Latitude: 51.152
Longitude: -1.7475
Elevation: 119m

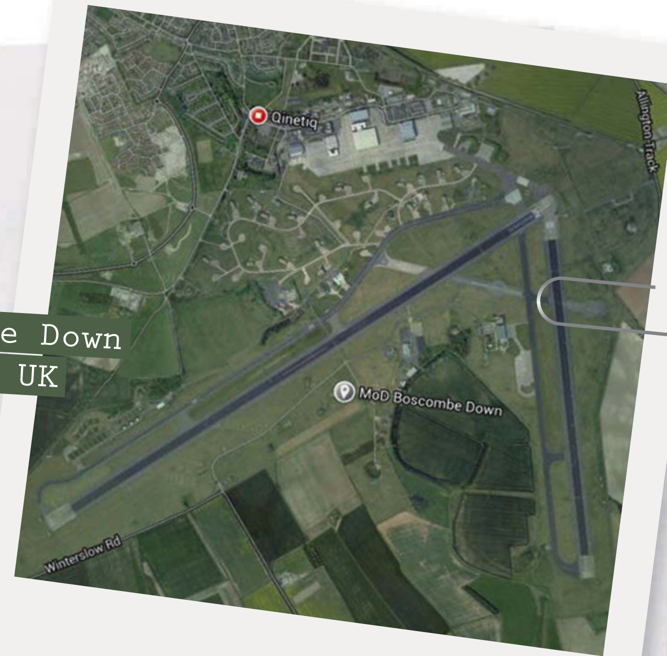


Image: Google Maps

In the heart of the lush Wiltshire countryside lies the Ministry of Defence (MoD) UK Boscombe Down test centre. It is currently run and managed by QinetiQ, the technology company created in the dismemberment of the former Defence Evaluation and Research Agency in 2001.

The site was originally known as RAF Boscombe Down, and since 1939 it has played a significant part in the testing of many of the iconic aircraft operated by the British armed forces, including the first flights of the English Electric P.1, forerunner of the English Electric Lightning, the Folland Gnat and Midge, Hawker P.1067 (the prototype Hunter), Westland Wyvern and the BAC TSR.2.

Following the creation of QinetiQ in 2001, a 25-year Long Term Partnering Agreement (LTPA) between the new company and the MoD was agreed, covering the management of all the UK's air, land and sea test and evaluation ranges and facilities. The most recent five-year 'block' of funding was agreed in 2013, worth some £998m (US$1.65bn).

The Boscombe Down site remains a government airfield but is operated by QinetiQ on behalf of the MoD. It boasts the longest military runway in the UK. During the Cold War it was a US reinforcement airbase and there are still 18 hardened aircraft shelters positioned along the flight line.

Boscombe Down's primary role is to support the MoD by performing impartial flight trials of new aircraft, airborne equipment and weapons to assess safety and suitability. Trials can be carried out during research, development and production phases as well as during operational service. The site houses a fleet of test aircraft as well as being home to the Empire Test Pilots' School (ETPS) and a variety of ground-based test facilities for aircraft and other military vehicles.

CHANGE OF DIRECTION

The past decade has seen a major shift in the UK's test and evaluation procedures, with greater emphasis being given to 'live' testing taking place at original equipment manufacturers' own sites. As a result, Boscombe Down has became a focus for the analysis of these tests.

A key element of this is the UK's Release to Service (RTS) process. Through the LTPA, QinetiQ's personnel at Boscombe Down support the MoD by providing RTS recommendations. By specifying the limitations within which the aircrew and aircraft can operate, QinetiQ says clients can have "confidence in the safety of their equipment, knowledge of where the risks lie, and information on how to extract the best functionality in a safe way".

The RTS process of new or modified aircraft is carried out in partnership with elements of the RAF's Air Warfare Centre based at Boscombe Down. These include the RAF's 206 (Reserve) Squadron, which looks after issues related to large military aircraft, the Fast Jet Test Squadron, which supports combat aircraft, and Rotary Wing Test and Evaluation Squadron, which is responsible for helicopter issues.

Over the past decade, Boscombe Down has been heavily involved in clearing modifications for aircraft and air systems destined for use in Iraq and Afghanistan, under the MoD's urgent operational requirement (UOR) program. Steve Attrill, the MoD's LTPA operations manager, comments, "The LTPA is set out to manage the sites at which tests and trials can take place, supporting the MoD's long-term equipment program. A UOR needs very similar tests to those needed in standard procurement, so by using LTPA facilities we're using what we've already paid for. We are just making maximum use of the resources that we have. The more UORs we can put through the LTPA, the greater value we get from it."

Royal Air Force Centre of Aviation Medicine has a detachment at Boscombe Down to provide the MoD's inflight aviation medicine research and assessment capability.

EMPIRE TEST SCHOOL

The famous Empire Test Pilots' School (ETPS) is also based at Boscombe Down. It provides the MoD and overseas governments with tri-service pilots and engineers for acceptance testing, aerodynamics and systems research flying duties.

Since 2013, Boscombe Down has been home to the MoD's new center of excellence. The Unmanned Air Systems Capability Development Centre (UASCDC) is intended to "support the rapid development of UAS programs from concept to deployment", according to QinetiQ. The airfield is also to be home to the flying elements of the British Army's two Watchkeeper unmanned aerial vehicle regiments from 2014, to enable them to fly routine training missions over the nearby Salisbury Plain training area.

QinetiQ's chief executive, Leo Quinn, recognizes the importance of Boscombe Down and the company's other aircraft test facilities: "Our air business de-risks complex aviation programs by testing military aircraft and equipment, evaluating the risks and ensuring safety. Our long-standing relationships with key customers have been enhanced by integrated working and new contracts for test and evaluation that are delivering efficiencies and value."

Military Test Site: RAAF Woomera Test Range (WTR)
Location: Woomera, Australia

Coordinates
Latitude: -31.2
Longitude: 136.826
Elevation: 167m

RAAF F/A-18 test aircraft

Image: Google Maps

Situated in a remote part of South Australia, with less than one permanent resident per 1,000km², the Woomera Test Range (WTR) has a land area comparable to that of England and is the largest land range in the world. Its unique location and vast size makes it ideal for testing long-range weapons, and its remoteness and quiet electromagnetic background supports electronic warfare and electronic countermeasures development work.

However, despite recent upgrades to some sensors and equipment, much of the range infrastructure is aging and in need of replacement.

RANGE FACILITIES

The Woomera Prohibited Area (WPA) covers almost 124,000km² of land 448km NNW of Adelaide and boasts a range centerline of over 600km. The facility currently provides 13 weeks of instrumented and 48 weeks of non-instrumented range services each year. Woomera airfield has two runways, 7,782ft and 5,295ft long, large hangars and hardstanding for aircraft up to C-5 Galaxy size.

In 2005, BAE Systems was contracted to install an MPS-36 tracking radar, previously owned by the German Aerospace Center (DLR) and installed at Esrange Space Center in northern Sweden. Between 2009 and 2012, QinetiQ delivered an upgrade to the range control and safety system (RCSS), using similar equipment to that in use at the Aberporth Range in the UK.

WOOMERA HISTORY

Woomera, aboriginal for 'spear launcher', was established on April 1, 1947, as a joint project between the UK and Australia, primarily to facilitate the testing of long-range weapons, and initially known as the Long Range Weapons Establishment (LRWE).

In addition to supporting British atomic weapons testing at Maralinga in the 1950s and early 1960s, a range of cold-war weapons owe their development to Woomera, including the Bristol Bloodhound surface-to-air missile, Firestreak and Red Top air-to-air weapons, and the Blue Steel stand-off munition.

It has also supported the US, European and Japanese space programs, from the Deep Space 41 tracking station in 1960, which supported the Mercury and Gemini projects, to Japan's Hayabusa program in 2010.

Access to the WPA is highly restricted and controlled by the test range director on behalf of the Australian government. However with iron ore, gold and uranium deposits within its boundaries, a 'timeshare' arrangement, giving pastoralists and miners greater access, was introduced by parliament last year.

RECENT PROJECTS

The WTR is administered by the Royal Australian Air Force's Aerospace Operational Support Group (AOSG), which also oversees the Aircraft Research and Development Unit, the Australian Defence Force's flight test organization. ARDU uses Woomera on a regular basis, carrying out flight test of platforms and weapons on behalf of all three services.

Recent trials have included live firing of the AGM-114 Hellfire missile, 30mm cannon and 70mm rockets from the army's Tiger Armed Reconnaissance Helicopter, as well as integration of the AGM-158A JASSM missile with the RAAF's F/A-18A/B Hornet and testing of the AGM-154C JSOW on the Super Hornet, both of which also culminated in live testing.

The empty airspace is also ideal for the test of UAVs and the RAAF maintains a detachment at Woomera to conduct training on its Heron unmanned system.

BAE Systems has used Woomera for several years for UAV testing, including HERTI in 2004 and Mantis in 2009, and the company announced the first flight of the Taranis supersonic system in August 2013. "There will be an increased focus on testing unmanned air and ground vehicles, as well as longer range smart weapons and increasingly non-kinetic weapon systems," Reg Carruthers CSC, director, Woomera Test Range, said when asked about future testing.

RANGE UPGRADE

Joint Project 3024 Phase One (JP3024/1) will deliver an upgrade to testing equipment at WTR in the latter part of this decade, with a particular focus on electronic warfare, to coincide with the introduction of the EA-18G Growler electronic attack platform.

Known as the WTR Remediation Plan, JP3024/1 will update existing radar and optical systems (tracking and surveillance); behavioral systems (including imagery); telemetry systems; range communications; RCSS, including integration of a mobile RCSS system; test and training enabling architecture; enhanced fibre-optic network; and meteorological and trials room systems. "The primary objective is the remediation of the existing system, providing assurance that future tasking can be safely and reliably completed," says Air Commodore Steve Roberton, director general, aerospace development for Australia's Defence Materiel Organisation.

412th Test Wing, Edwards Air Force Base, California, USA

Location: Edwards AFB, California, USA

Coordinates
Latitude: 34.924031
Longitude: -117.89
Elevation: 701m

The F-35 Integrated Test Force tests all versions of the JSF

Image: Google Maps

The 412th Test Wing at Edwards Air Force Base (AFB), California, has about 7,100 people focused on US Air Force aircraft and weapons systems. Wing commander Brigadier General Michael Brewer explains, "The 412th Test Wing is the Center of Excellence for the Air Force Materiel Command. Its mission is to conduct and support engineering research, development, testing and evaluation of aerospace systems, performing all the steps and challenges from initial concept to final combat readiness." Within the 412th Test Wing, dedicated squadrons and combined test teams conduct ongoing fighter, bomber, tanker, cargo and UAS test programs. General Brewer says, "The 412th Test Wing serves as the proving ground for the bulk of the emerging combat, combat support and training capabilities for the US Air Force."

At any given time, Edwards AFB has more than 100 test programs underway. The F-35 Joint Strike Fighter (JSF) is currently the busiest with nine aircraft in three versions and more than 1,000 people assigned, including airmen from the UK, Norway, the Netherlands, Australia and Canada. The JSF Integrated Test Force (ITF) at Edwards conducts all flight sciences testing for the Air Force F-35A and complete mission systems testing for all three (US Air Force, Marine Corps and US Navy) JSF models. F-35 developmental testing (DT) continues in tandem with operational testing (OT). The OT effort is expected to grow to 656 personnel and 21 aircraft for Block 3F software initial operational test and evaluation (IOT&E) in 2017, with all F-35 variants and personnel from other US services and international partners.

OTHER PROJECTS

Squadrons of the 412th Test Wing meanwhile continue work on the F-22 Raptor, the C-17 Globemaster III and RQ-4 Global Hawk, as well as the F-16 Fighting Falcon. The Wing, for example, continues the European Participating Air Forces (EPAF) test program for the F-16 to deliver improved combat capabilities to warfighters overseas.

SPACE TO FLY

The Edwards Test Wing is also responsible for the historic Edwards infrastructure, hosting the Air Force Test Pilots School, Detachment 7 of the Air Force Research Laboratory (AFRL) and other organizations. Edwards testers are now grouped with those at Eglin and Arnold Air Force Bases under the Air Force Test Center to enhance flight test efficiency. Edwards AFB also partners with the NASA Neil A Armstrong Flight Research Facility (formerly Dryden Flight Research Center) to advance aerodynamic knowledge.

As a test location, Edwards AFB is distinguished by Mojave Desert weather, affording visual flight rules conditions approximately 350 days a year, and by 18 natural runways spread over 44 square miles of Rogers Dry Lake. Runway 04R/22L, the longest in the world, stretches 24,612ft, including paved and groomed lake bed portions. Edwards AFB is near the heart of the renamed Hugh L Dryden Test Range, which pools the airspace and instrumentation resources of Edwards, NASA Armstrong, Navy Weapons Centers China Lake and Point Mugu, and the Army White Sands Missile Range, Yuma Proving Ground and Utah Test Range.

Edwards also has the largest anechoic chamber in the western hemisphere to test avionics and aircraft systems. The base offers world-class competencies in directed energy, modeling and simulation, electronic warfare, hypersonics and general aerodynamics. UAS systems testing at Edwards dates back to flying bombs during the World War II, and more recent efforts included the MQ-4 Global Hawk and the X-47 Unmanned Combat Aircraft System.

The US Air Force Test Pilot School at Edwards was the first to institute a formal curriculum for UAS pilots and flight test engineers. The TPS is recognized worldwide for academic excellence in applied aerodynamics and was the first test pilot school to award graduates masters-level degrees. The TPS remains the only test pilot school to have students work on actual test programs within its curriculum.

Edwards' flight test capabilities continue to evolve. The Integrated Network Enhanced Telemetry (INET) system will reduce spectrum use to enhance flight test operations. It will also allow the flight test engineers in a control room to designate what telemetry data they want to see. Engine inlet temperatures, for example, could be isolated for a time and full engine telemetry or other data restored when needed. ∎

HYPERSONICS

Edwards AFB maintains an active hypersonics test capability and the AFRL detachment can test rocket engines and fuels for the largest missile boosters or nano-engines in satellites. It remains the job of Edwards testers to help the Air Force maintain the edge it needs in any environment from conventional combat to high-intensity cyber warfare.

ADAPT and overcome

The safe descent onto a distant planet still thwarts space exploration programs. NASA's Joint Propulsion Laboratory has been testing new concepts to overcome the enormous problems of just 'dropping in'

BY GEORGE COUPE

Far out in the Californian desert, a group of engineers from NASA's Jet Propulsion Laboratory (JPL) watched as a strange apparatus, resembling a large clothes horse, fired its rocket and lifted slowly into the sky.

Up it went, 1,200ft into the blue. Then the clothes horse did something that had never been done before, 'unprecedented… in autonomous rocket technology'. Instead of descending gently to its intended landing spot nearby, engineers on the ground sent a command to abort the plan and land at a new site, half a mile away across the desert floor. The onboard flight control computer automatically calculated a new trajectory in mid-air, in one second, optimizing the vehicle's path through the sky to burn the least amount of fuel possible, stay upright, and touch down gently and accurately without so much as bending a pin. It landed just 9in from its target.

The perfectly executed divert was performed in late 2013, the details of which were released at the end of January 2014. The test flight was intended to demonstrate the potential for future space missions of JPL's revolutionary landing control algorithm – known as the Guidance for Fuel Optimal Large Diverts (G-FOLD).

The software was developed as part of NASA's Autonomous Descent and Ascent Powered-flight Testbed, known as ADAPT. It was tested on board the Xombie XA-0.1B vertical launch/vertical landing experimental rocket built by Masten Space Systems, as part of a NASA initiative to use commercial suborbital vehicles to test concepts that could further exploration of space, and build up the industrial base to support future space endeavors.

THE NEXT STEP

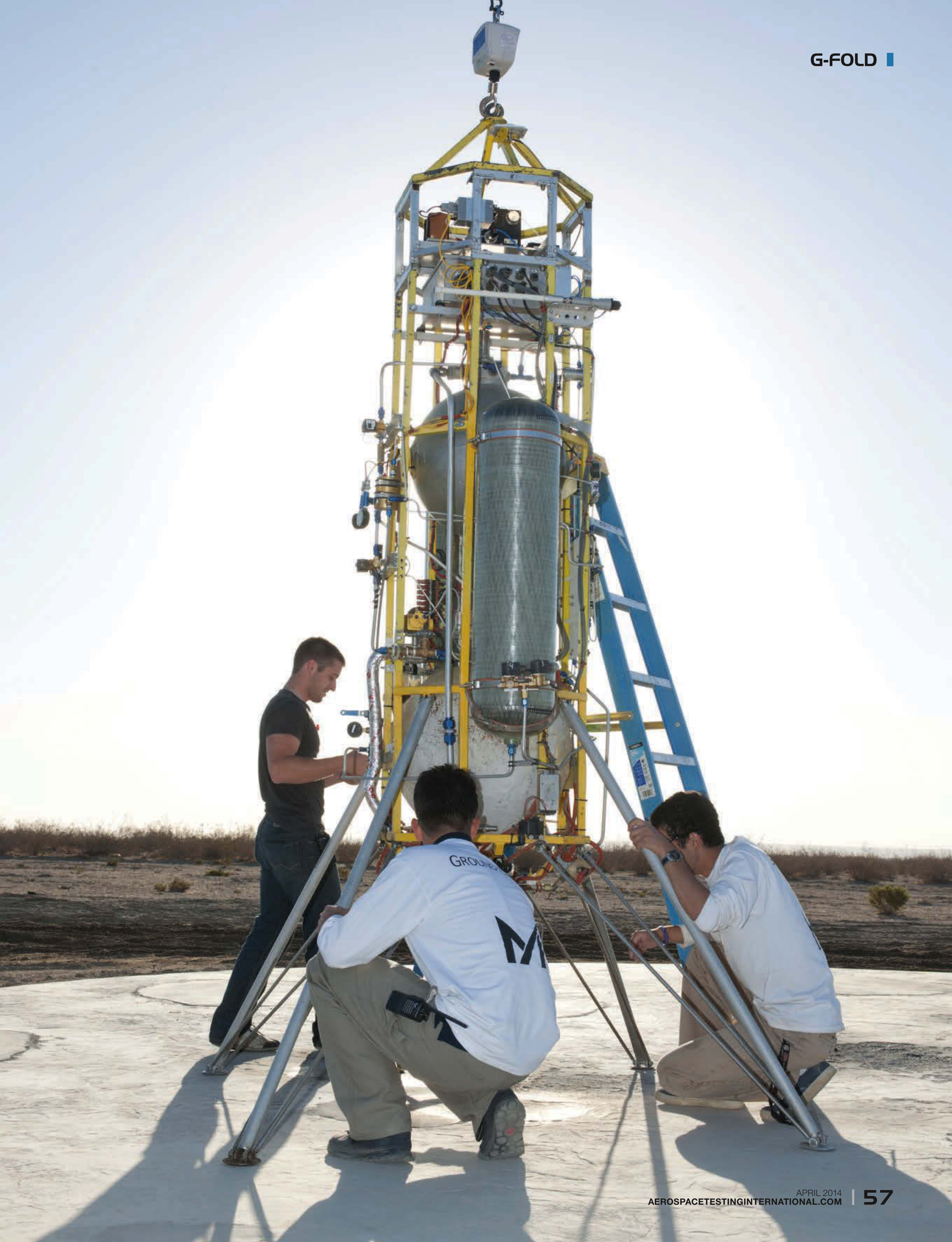
The G-FOLD technology represents a giant leap forward in powered descent guidance: in 2012 NASA's Curiosity rover landed on Mars using systems based on those inherited from the Apollo moon landings era. Compared to that software, G-FOLD can provide six times more divert range for a lander of that class. Such a capability would be needed for landing on Europa (one of Jupiter's moons) or for human missions to Mars, said NASA.

The possibility of pinpoint landings may also improve the efficiency and reduce the difficulty of future robotic missions to Mars, allowing rovers to land closer to features of interest instead of driving long distances to reach them. A future rover similar to Curiosity might be able to land right next to a target of scientific interest like Mount Sharp instead of driving for a year to get there.

So what exactly are the mission problems that G-FOLD is trying to address? Any spacecraft that needs to touch down gently on a planet's surface has to use powered descent. This is when rockets are fired to slow the spacecraft through the last few kilometers of flight. For example, Curiosity let go of its parachute about a mile above the surface of Mars, when it was moving at about 200mph; then it used its rockets to slow to 0mph at the surface. The vehicle also had to perform a 1,000ft side-step to get out from under the falling parachute.

The first problem, says Daniel Scharf, the G-FOLD lead engineer and experiment/payload systems engineer at JPL, is that due to the uncertainties of the conditions and location, you don't know when powered descent should begin; working that out is a task for the onboard autonomous powered descent guidance system. "Powered descent guidance is the

RIGHT: Members of Masten Space Systems' ground crew make final adjustments to the company's technology demonstrator rocket before liftoff on the final test flight of JPL's G-FOLD spacecraft landing flight control software (Photo: NASA/Tom Tschida)



> **"WITH POLYNOMIAL GUIDANCE, YOU'RE STUCK CARRYING A LOT OF FUEL TO GO EVEN A SHORT DISTANCE, AND YOU MIGHT STILL CRASH BY TIPPING OVER"**

algorithm that figures out the path the lander will take from one mile up, going however fast it is, to a safe and sound place on the surface. Due to uncertainties about where a lander starts its plunge toward a planet, even if an atmosphere exists, *and* using the sensors a lander needs to propagate its knowledge of where it is, we still don't know exactly where powered descent will begin!

So with the ground rapidly approaching, a lander has to get a positive measurement of the ground (with radar or a lidar); figure out its altitude, altitude rate, and horizontal velocity; and do powered descent guidance from where it is to the ground. It has to happen quickly, accurately, and reliably."

The onboard computer has to do all this running at about 100MHz. Due to the levels of radiation, the computer spends most of its power on double-checking itself. "This is about as fast as a computer in 1990," adds Scharf.

FUEL TESTS

To plan the path of a spacecraft within the limitations of its fuel, rocket thrust, maximum tip-over angle beyond which the radar loses sight of the ground, and maximum speed, is a very hard mathematical problem, certainly beyond the power of conventional flight control systems. "The fancy term is 'non-convex optimization,' which is a way of saying there's no good way for a computer to solve it," says Scharf.

As a result, Curiosity in 2012 used a refined version of the powered descent guidance that was used for the Apollo missions in 1969, a standard referred to as polynomial guidance.

A 100MHz computer can easily run polynomial guidance, but there are compromises to be made. First, the lander has to carry a lot of extra fuel because, while polynomial guidance gives a smooth path to the landing target, it doesn't 'optimize'; that is, it doesn't follow the most efficient path. The second major trade-off is that a large amount of testing is required before the mission to make sure that the lander has been designed not to use too much fuel, too much or too little rocket thrust, doesn't tip over, and doesn't go too fast.

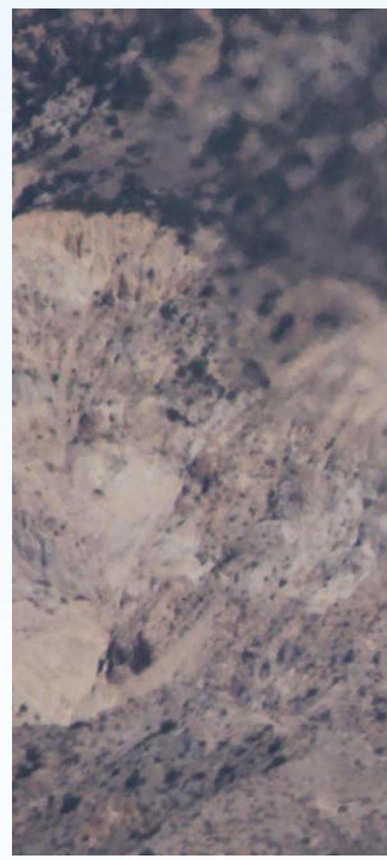
"You have to test, test, test… and then test some more. So with polynomial guidance, you're stuck carrying a lot of fuel to go even a short distance and you might still crash by tipping over, or trying to use more rocket thrust than you have if the situation on landing day is really different than that you tested for."

G-FOLD finds the path to the landing target using the absolute least amount of fuel, which makes the lander lighter and therefore cheaper, while respecting all the other limitations of the vehicle in real time.

So how does G-FOLD work? While polynomial guidance requires only algebra, G-FOLD requires onboard optimization running in real time, says Scharf.

"Onboard optimization is a lot more complicated than algebra. It requires doing a little math, seeing where you get, then doing a little more math, seeing where you get, and repeating this until the algorithm decides that it has a good path to the ground."

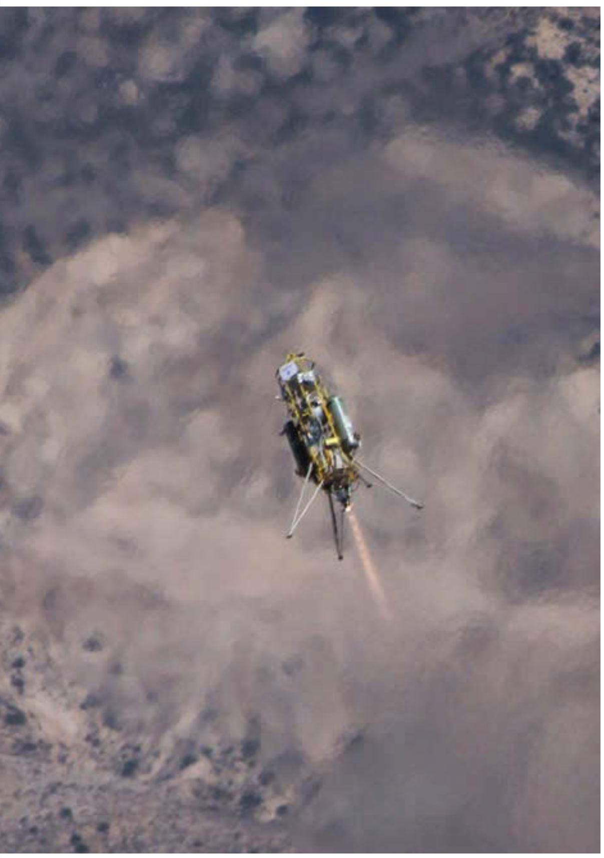
Scharf likens the process to trying to cross a dark room full of furniture: you take a small step, feel around a little to see if there is anything in your way, turn if so, take another small step, and repeat until you feel the far wall. He said that even 15 years ago,



real-time, onboard optimization would not have been possible, but starting in the mid-1980s, researchers started making breakthroughs in what are called interior point methods (IPMs). These are fast and guaranteed-to-work optimization algorithms for 'convex problems', which have a particularly useful mathematical structure, says Scharf.

"That is, IPMs take the 'small steps in a dark room' quickly and effectively. So G-FOLD has a theoretical component that first shows the full, non-convex, constrained problem is actually a convex problem in disguise and a computational component that further tailors an IPM to the specific structure of the 'undisguised' convex powered descent guidance problem."

LEFT: JPL payload in Xombie payload cage. Photo: NASA/ Thomas Tschida, NASA Flight Opportunities Program



LDSD – LATEST ROUNDUP

The Jet Propulsion Laboratory is also leading tests of a new balloon-like device that uses aerodynamic drag to dramatically slow a lander vehicle as it penetrates the atmosphere of future target planets.

The Low-Density Supersonic Decelerator project (LDSD) has completed three rocket sled tests of a device known as the Supersonic Inflatable Aerodynamic Decelerator (SIAD-R), the first of three new systems now in development.

The SAID-R, built for NASA by ILC Dover of Frederica, Delaware, is a balloon-like pressure vessel with a diameter of nearly 20ft, designed to inflate around a vehicle to slow its entry. The rocket sled tests were conducted at the Naval Air Warfare Center Weapons Division, at China Lake, California, in November last year.

"The tests demonstrate the ability of the SIAD-R to survive the aerodynamic loads experienced during inflation and operation [while entering the Martian atmosphere]," says Mark Alder, the JPL engineer who manages the supersonic decelerator project.

As the rocket-powered sled accelerated down the 4-mile-long track at speeds of several hundred miles an hour, the inflatable device experienced aerodynamic loads 25% greater than it will face during atmospheric entry at Mars. The team said the inflatable device survived the tests, with no rips or damage to the vessel.

Adler said his team was looking forward to testing the project's next piece of hardware, a massive parachute 110ft in diameter, intended to further slow the entry vehicle once the SIAD-R (or its larger counterpart, the SIAD-E, which has a diameter slightly larger than 26ft) has cut the vehicle's speed from Mach 3.5 to Mach 2.

NASA said the first SIAD-R and parachute supersonic flight test is scheduled for summer 2014. The devices could be used in Mars missions launching as early as 2018.

The theoretical breakthrough that underpins G-FOLD was made in 2004 by Scharf's colleague Behcet Acikmese, a former senior technologist at JPL, and now assistant professor at the University of Texas, Austin. The initial version of G-FOLD was coded in MATLAB in 2005 using a stock IPM, that took about 10 seconds to run on a 1.5GHz processor.

There were more theoretical refinements over the next few years, then in 2012, G-FOLD was migrated from MATLAB to C code. For the test flights in 2012, G-FOLD in C took 100ms to run on a 1.5GHz processor, said Scharf.

"And we have a path to get that down to 20ms, which with some hand-waving, is about a one-second runtime when using 25% of a 100MHz computer: fast enough to run while falling through the sky over Mars or Europa.

"The flights showed that the paths generated by G-FOLD respected the rocket's limits: the rocket then flew the diverts with meter-level precision, consistent with our pre-flight predicts."

The final test was with the rocket initially moving diagonally away from the target, in the wrong direction and across the line connecting the launch pad to the target pad. "As a result, G-FOLD had to plan a fully three-dimensional and direction reversing path: it really exercised the characteristics of a worst-case divert scenario."

687	The number of days in a Martian year
0.8	The distance in kilometers achieved in a 3D diversion by G-FOLD during tests
90	The vertical descent in feet at which JPL initiated a radical diversion
142,000,000	Distance in miles from Mars to Sun (Earth is 93,000,000)

"ONE REASON FOR LANDING IS TO GET THROUGH THE SURFACE ICE TO WATER BELOW. TO DO SO, WE WOULD LAND WHERE THE WATER IS CLOSE TO THE SURFACE"

ABOVE: **Zombie lander, running the G-FOLD algorithm in test flight over the Mojave desert, and in landing mode**

In addition, the starting altitude of the divert was 290m and the divert distance was 800m, so the divert was 275% of the starting altitude: much greater than the roughly 15% practical limit of polynomial guidance for Curiosity-like landing scenarios.

NOT JUST MARS

Looking ahead to future missions to Mars and Europa, Scharf said his current understanding was that they would fly the existing polynomial guidance system, in part to keep costs under control. Even so, he said his team had done some 'quick' studies to see what G-FOLD could offer a similar class of lander to Curiosity. "Very roughly speaking, there are lots of technical caveats; G-FOLD could buy up to a six-fold increase in divert distance. We have not yet looked at a Europa landing scenario, but the farther out in the solar system you go, the greater the benefit, exponentially so, in saving, say, 5% of the mass of the lander in fuel."

This new generation of powered descent guidance also relies on terrain relative navigation (TRN). This enables the lander to know where it is in relation to the plateaus and craters of Mars and then G-FOLD plans a safe divert. The ADAPT program is developing a new TRN called the Landing Vision System, which will be demonstrated with G-FOLD for the first time later this year.

While the technology has yet to be included on any forthcoming missions, Scharf believes that it will be needed not just for pinpoint landing, but also for so-called Multi-X landing scenarios in hazardous terrain. In these cases, multiple safe landing targets would be preloaded onto the lander. At the start of powered descent, one of these Xs is autonomously chosen by the lander, and the powered descent guidance plans the divert.

"Personally, I also believe it will be needed for landing on Europa," says Scharf. "One reason for landing is to get through the surface ice to water below. To do so, we would land where the water is close to the surface, that is, in chaos terrains or lineae (long lines or marking on the surface). In either case, I suspect we'd be aiming for a flat area a few hundred meters across. Hitting such a football-field sized 'landing pad' from Europa's orbit will probably require the lander first seeing where it is and then diverting in the order of at least a kilometer to the pad." ∎

George Coupe is a technology and engineering writer based in the UK

Aerodynamic duo

The unique features of the world's biggest aerodynamics complex made it the ideal choice for wind tunnel testing of a Boeing 757 vertical tail equipped with active flow control technology. The testing, concluded at the end of 2013, showed how active flow control can enhance the performance of the tail

BY JIM BANKE

The largest wind tunnel in the world. No narrative of the National Full-Scale Aerodynamics Complex (NFAC) at NASA's Ames Research Center, located about an hour's drive south of San Francisco, could possibly describe the key feature of this iconic technological installation in the USA, more succinctly.

Yet there is much more to explore, because within its artificial hollows, scientists, engineers and technicians go about their business of testing anything influenced by aerodynamic forces that can be replicated at low speed, sea-level conditions here on Earth.

Parachutes and inflatable heat shields for landing on Mars have seen the inside of the NFAC, as have semi-trailer trucks, or artics – all in the name of improved aerodynamics. But the complex's principal use has been, and always will be, for advancing aviation technology.

Originally opened in 1944 as a single, closed-circuit wind tunnel with a 40 x 80ft test section, and later expanded in 1987 to include an open-circuit tunnel with an 80 x 120ft test section, the facility has hosted an impressive array of historic aircraft.

An extremely short list includes scale or full-sized models of Northrop's original flying wing, North American's F-86 Sabre, Bell's HU-1 helicopter, the Grumman F-14 Tomcat, the McDonnell Douglas F-18 Hornet and De Havilland's DASH 8 – not to mention a replica of the Wright Brothers' 1903 Flyer.

"It's really a fun place to work," says Joe Sacco, a NASA manager assigned as the NFAC's deputy director. Although the complex sits on NASA's Ames Research Center and is owned by NASA, it is the US Air Force's Arnold Engineering Development Complex (AEDC) in Tennessee that actually operates the facility, maintains it, and is responsible for any investments and upgrades. It's an arrangement that has been in place since 2006, three years after NASA was forced to close the NFAC due to budget concerns.

"The US Department of Defense decided it was too critical to future operations and so they made the decision to reopen the facility. It now operates as a geographically separated branch of AEDC," says Scott Waltermire, an Air Force manager who serves as the NFAC's director.

THE TUNNELS AT WORK

The two tunnels that make up the NFAC share similarities and are characterized by just as many differences. The 40 x 80ft is a closed-loop system, with possible wind speeds of up to about 300kts depending on the desired dynamic pressure. The open circuit 80 x 120ft tunnel is officially the world's largest and is so big that it can host a full-scale Boeing 737 inside, and can go up to about 100kts. But because of the way the two tunnels share much of the same space, only one section can be operated at a time.

A system of moveable vanes can be positioned so that air is either drawn through the 80 x 120ft test section and exhausted into the atmosphere, or driven around the closed circuit through the 40 x 80ft test section. A passive air exchange system is used in the 40 x 80ft circuit to keep air temperatures below 125°F.

The current fan drive system is composed of six variable pitch fans, each 40ft in diameter, and arranged in two rows of three. Each fan has 15 laminated wood blades and is powered by a 22,500hp electric motor. The six fans rotate together at 180rpm drawing 106MW of electricity at full power, while moving more than 60 tons of air per second.

Utility support systems that have been used for testing powered vehicles and components include variable frequency electrical power, hydraulic power units, cooling water, and jet fuel systems. Rotor testbeds incorporating electric motors and rotor balance systems are available for testing complete rotor and hub systems independent of the flight vehicle.

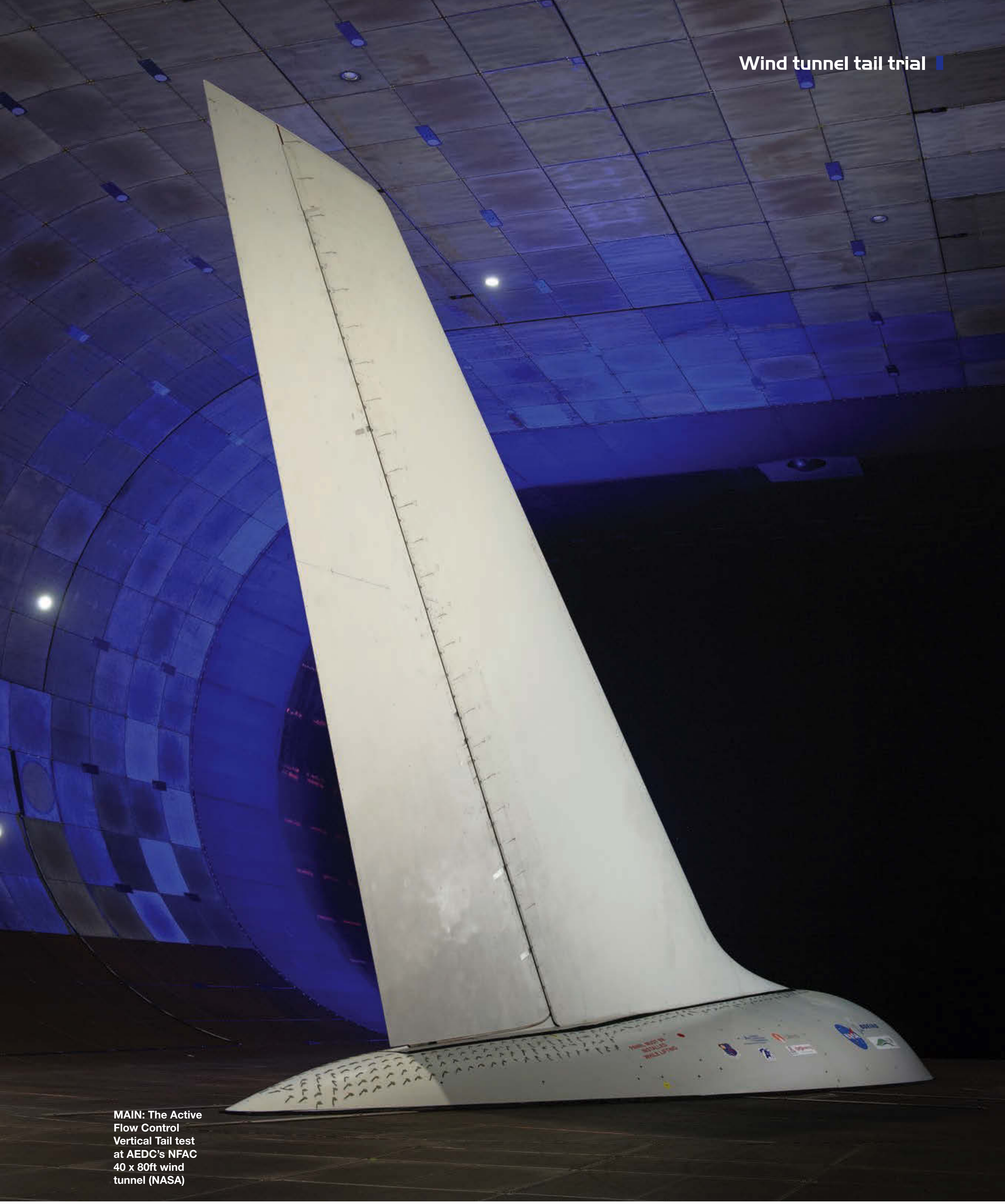
"They largely have the same basic capabilities. You take the same basic flow measurements – pressure, temperature, velocity, humidity – in either test section. They are both acoustically treated. The 40 x 80ft has deeper acoustical liners than the 80 x 120ft, so in general it's a bit better at attenuating sound reflections," says Charlie Rogers, a US Air Force contractor who serves as a test director.

Both tunnels have video surveillance available during tests and the ability to support optical measurements depending on test requirements. Often a customer will bring in their own non-intrusive optical equipment, which the tunnels can accommodate.

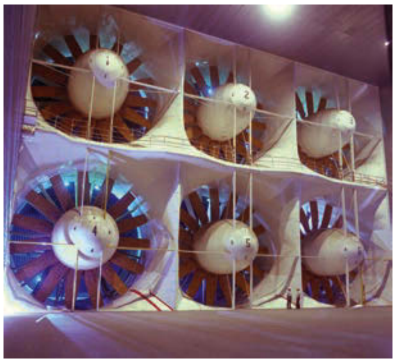
A wide variety of options are available for mounting test subjects in either wind tunnel, with a three-pillar system commonly used in which two of the pillars are fixed in height and the third can be raised, lowered, or yawed to adjust an aircraft's angle of attack and sideslip to the relative wind.

A TYPICALLY UNTYPICAL TEST

"Every test is unique," Waltermire says. So to call any test in the NFAC wind tunnels typical, or the preparations that went into it as following a standard timeline, is pure folly. Still, there are certain rules of thumb that NFAC managers attempt to abide by; the first being that planning for any given test is best started about a year in advance. A test director must be assigned to facilitate



MAIN: The Active Flow Control Vertical Tail test at AEDC's NFAC 40 x 80ft wind tunnel (NASA)



planning as soon as possible. Frequent technical interchanges with the customer are needed, and are the key to success. Documents defining roles and responsibilities, specifically calling out any modifications to the tunnel to add instrumentation or other support hardware, must be written and agreed to. Funding must be secured, schedules coordinated, and test components delivered. "It's a very delicate dance with a lot of moving parts," Waltermire says.

Rogers adds, "In reality with the unique nature of tests that we conduct, we have to be flexible with the way we handle the test planning process. In each case we customize the process to deliver the project for the customer according to their timeline."

VERTICAL TAIL TEST

A typical example of how uniquely the process can play out was showcased toward the end of 2013 when the 40 x 80ft test section was employed to house a full-sized tail from a Boeing 757, which was modified and equipped with tiny jets called sweeping jet actuators that blow air across the rudder surface – an example of active flow control technology.

A major objective of the tests was to show that active flow control can enhance the performance of a vertical tail enough to enable future designers to reduce the size of the structure for a whole family of airplanes. That could reduce the penalties related to the vertical tail that aircraft currently pay in drag and weight.

Getting such a large and unwieldy object with a challenging center of gravity into the 40 x 80ft test section, and mounted to the floor in precisely the right spot, required more planning and verification of distances and clearances than usual.

Rotating the tail from its horizontal position at delivery to the vertical, and back again, was practiced in a staging area about a half-dozen times over as many weeks before the actual lift into the wind tunnel took place. Once inside and firmly anchored inside on its specially designed stand, a four-week test period began.

The full run of planned tests was accomplished as engineers measured how active flow control via the jet actuators changed the side force on the tail. "There were several days spent just doing baselines, and exploring envelope expansion. And then we got more specific in testing to see if the system responded to input the way we expected it to," says Tony Washburn, the NASA Integrated Technology Demonstration Lead.

"As you can imagine, you like to succeed. And we consider the test a success since we achieved all our objectives. But as researchers, you are also challenged when there are some things that don't quite happen the way you expected, and we had some of those as well," Washburn says. "So there's more to be learned and understood, and we have a lot of data analysis to go through."

But with the data gathered during the wind tunnel testing of the 757 tail, project managers have learned enough to graduate to the next step in the process of expanding the knowledge envelope: a flight test on Boeing's ecoDemonstrator 757.

And isn't that what wind tunnel testing is all about in the first place? ∎

MAIN: **40 x 80ft wind tunnel testing of a modification to a A-26B airplane (rockets, bomb and wing)**

LEFT FROM TOP: **NFAC's 80 x 120ft wind tunnel has drive fans during its reconstruction process; Aerials showing the National Full Scale Aerodynamic Complex (NFAC) at Ames Research Center, Moffett Field, California; Data comes in from the vertical tail test**

Jim Banke is part of the NASA Aeronautics Research Mission Directorate based in Cape Canaveral, USA

300	The speed in knots that the 40 x 80ft wind tunnel can generate
2,300	The number of people who work at Ames Research Center
100	The speed in knots that the 80 x 120ft wind tunnel can test a full-size Boeing 737
355	The speed in ft/sec that the smaller Ames 7 x 10ft wind tunnel can achieve

Handy MANDI

Crawling robots are beginning to attract attention as a possible fast, safe and low-cost means of completing non-destructive inspection on aerospace structures

BY GARY GEORGESON

On-aircraft inspections are often required as part of the maintenance of aircraft. Alongside this, in-service aircraft structures, such as fuselage or wing skins, experience damage or degradation during their lifetimes.

In the commercial aircraft world, most of this inspection is done manually, with handheld probes connected to non-destructive inspection (NDI) instruments. Manpower and cycle times can be high, while inspection repeatability, reliability and record keeping is generally low. Also, access requirements for difficult and dangerous locations can lead to human injury or aircraft damage.

NDI scanning systems are currently used for inspecting some aircraft. These systems generally require human access to the structure to align, attach, move, re-attach and detach. Correlation of the scan data to aircraft structure can be challenging.

WHAT IS MANDI?

Mobile automated NDI (MANDI) is a new area of inspection that uses a mobile (crawling, flying, or swimming) robot to reduce the requirements for human interaction with the structure under inspection. MANDI can be applied to the exterior or interior of structures in the factory, depot, or field.

MANDI is different from traditional automated NDI that uses multi-axis scanning bridges, and even standing pedestal robots. Its main advantages over these systems are that systems are portable, have a small footprint, and are much lower in cost.

Of course, crawling robots of one form or another have been around for some time. They are used for surveillance, bomb assessment and disposal, access to unsafe or limited entry areas, and even window washing. Specific NDI applications for crawling robots include storage tank and pipe inspection.

WHAT MAKES THE SYSTEM WORK?

The requirements for carrying out in-service automated NDI for aerospace structures are quite different from those encountered during manufacturing or post-production. Unlike the large monument NDI systems, MANDI systems need to be as low cost as possible, since maintenance budgets are always a concern for airlines and MROs.

They need to be relatively easy to use and not require an advanced degree to operate. Minimal human interaction with the structure is preferred, and labor should, in principle, be traded-off for the speed and consistency of automation. The robot must be safe for the operator and other personnel in the area.

Care must be taken that the robot does not damage the surface it crawls on, while being able to maintain attachment, position and direction during inspection. Automated guidance or feedback control capability is preferred, as it removes the operator from the challenges and errors related to direct human guidance of a robot.

One of the key features for MANDI is that it should allow easy registration of the NDI data to the aircraft. Obviously, identifying the specific locations of damage indications is important to their proper disposition.

THE ROVER

Boeing has just completed a MANDI prototype system for aircraft inspection dubbed the Rover, which stands for 'remotely operated vacuum-enabled robot'. The Rover is a motorized, low-cost, lightweight robotic crawler that can carry various NDI sensors (UT, EC, etc) for the inspection of aircraft structures. It is extremely innovative in its design and represents the integration of a variety of advanced features. Several of its important

MAIN: **A holonomic vehicle with Mecanum wheels has four independently controlled motors**

elements are off-board, including path planning, navigation, and the control of the NDE data collection system. By putting these features off-board the crawler, the size and weight of the Rover can be minimized, making it more nimble and increasing its maximum payload. Attachment of the crawler to the inspection surface is accomplished using a set of onboard vacuum pumps that create a suction though a series of floating cups.

Simultaneous rotation and translation crawling motion (called holonomic motion) is made possible for the Rover using four independently powered and controlled Mecanum wheels.

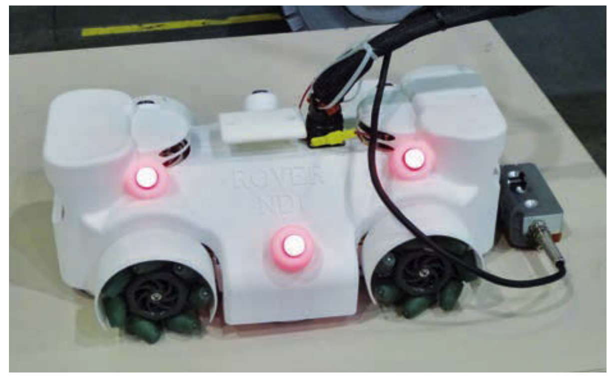
The Rover does not require a perfectly smooth surface; it is actually capable of traversing lap joints and raised or button-head fasteners without losing its attachment. It has an automated fall protection system to prevent damage to the crawler or injury to personnel working nearby. It also has joystick control for pre-scan positioning and post-scan removal of the crawler, and an optional onboard camera system for situational awareness, should the operator require it.

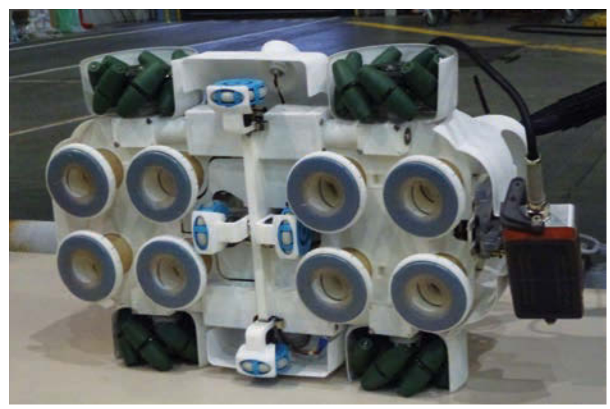
The Rover feedback control and NDE data registration is accomplished with one of two different methods: the local positioning system (LPS), or motion capture (MoCap).

The LPS is a Boeing-developed coordinate measurement device (with a motorized pan-tilt head, laser range meter, and video camera), with custom software to convert measured positions into the coordinate system of the target object. The system can be controlled remotely over the internet. The device can also be instructed to move the laser pointer to user-specified coordinates on the target. The LPS uses what is called an integration visualization tool (IVT), developed for 3D visualization on Boeing commercial airplane programs. The IVT allows display and manipulation of large amounts of CAD data for design reviews and analysis tasks. After an initial positional calibration, the LPS guides the Rover between points and checks, and adjusts its position at the end of each run. Several sets of encoder wheels track the Rover position temporarily between LPS checks. While accuracy depends upon the distance between the LPS and Rover, it is typically ±3mm at about 10m, which is generally sufficient for NDI scanning using an array. A slight overlap between scans is programmed in if an areas scan is required.

"ATTACHMENT OF THE CRAWLER TO THE INSPECTION SURFACE IS ACCOMPLISHED USING A SET OF ONBOARD VACUUM PUMPS"

RIGHT: **Motion capture system (MoCap) with illuminator**





ABOVE, FROM TOP: **Rover is shown crawling on the 737 test fuselage; Remotely operated vacuum enabled robot (Rover); The Rover has two onboard vacuum pumps drawing air through floating vacuum cups that ride on the surface of a structure and create an attachment force**

REASON BEHIND THE CRAWLER

Autonomy of NDE crawlers is a key technology for the automation of such devices for field scanning of complex aerospace structures. An autonomous crawler can be monitored remotely by centrally located experts equipped with know-how, databases, analytical tools, CAD drawings, and accept/reject criteria.

Such a capability will allow rapid response to inspection needs, particularly in cases of crisis where it is necessary to rapidly examine an entire flight of a particular aircraft model all over the world. An autonomous crawler can be operated during aircraft idle time – thus reducing the need to ground aircraft for inspection. A combination of visual, eddy current and ultrasonic sensors are expected to be the leading NDE methods that are used on autonomous crawlers.

THE MOCAP SYSTEM

The MoCap system can be used when greater positional accuracy is required for the Rover, or when multiple Rovers are running at the same time. MoCap uses off-the-shelf motion capture hardware initially developed for the movie industry, along with patented closed-loop feedback control technology developed by Boeing that leverages motion capture hardware for vehicle tracking and control.

This system consists of multiple stationary cameras with integrated illuminators on portable stands, or fixed-position mounts placed around the target object. This system tracks unique patterns of retro-reflective markers placed on the crawler to determine its position and orientation. The system is less portable than the LPS, and more costly, so its use may be more limited to production inspection.

FIRST DEMONSTRATION

The Rover was completed in December 2013 and a demonstration of the system was performed on a 737 test fuselage (see figure top right). Both the LPS (with encoders) and MoCap guidance methods were demonstrated, with the Rover independently following a pre-planned path. Visual and eddy current real-time data was collected, as the Rover stayed attached and crawled with holonomic motion around to the fuselage. A mobile boom, with a safety tether and power/communications cables, followed the Rover automatically as its base moved parallel to the fuselage, driven by its own Mecanum wheels.

REPLACING SENSORS

MANDI is a new approach to NDI, where robotic crawlers replace current methods of sensor placement and scanning. They are able to reduce or eliminate the human interaction in the data collection process, and eventually, the analysis process as well.

MANDI has the potential to reduce labor costs and inspection times, provide improved data quality, and support ongoing maintenance management. It also ensures a safer working environment for inspection personnel and reduces the potential for damage to the aircraft during inspection.

Boeing's Rover is a breakthrough MANDI system aimed specifically at the in-service inspection of aircraft structure. The development has involved the advancement and/or integration of multiple technologies into a system that has worked surprisingly well. The Rover is the first MANDI system to integrate off-board navigation, direct correspondence to the location on structure, an automated mobile safety/tether boom and onboard vacuum attachment. Future Boeing efforts will be focused on refining the Rover and identifying new applications for its use in the broader aerospace community. ∎

Gary Georgeson is a technical fellow for Boeing Research and Technology in non-destructive evaluation (NDE) based in the USA

SATELLITE QUALIFICATION

Brazil's space research organization, INPE, provides satellite design, qualification and acceptance testing services using a complete installation from a single supplier

During their launch into space, satellites experience extremely high levels of vibration and acoustical sound pressure that can damage or destroy components, so it is vital that all satellites and their subsystems are thoroughly tested.

A unit of the Brazilian Ministry of Science and Technology, INPE is Brazil's civilian research center for aerospace activities, and offers testing services to other satellite manufacturers. INPE's complete satellite test facilities include EMC/EMI test chambers, thermal test chambers, and highly specialized acoustic, vibration and shock test facilities for evaluating the vibration behavior, acoustic fatigue strength and structural integrity of satellites, subsystems and components.

Brüel & Kjær has provided INPE with a complete satellite vibration test system for mechanical qualification and acceptance testing, which was delivered in two stages. First was the installation of two LDS electrodynamic shaker systems set on huge, concrete 'seismic' mounts. The second was when INPE needed to integrate a large data acquisition and analysis system for acoustic fatigue, transient, random and swept-sine vibration testing.

SAFETY FIRST

Large-scale tests validate the structural behavior of these heavy and very expensive objects, ensuring they match design parameters. Avoiding the application of excessive force is absolutely essential, so satellite test engineers must ensure that over-testing with too much vibration or shock never occurs. Even before recording begins, measurements start so that unplanned events – like tools being dropped – can be tracked, and testers can ascertain that the satellite doesn't receive too much force.

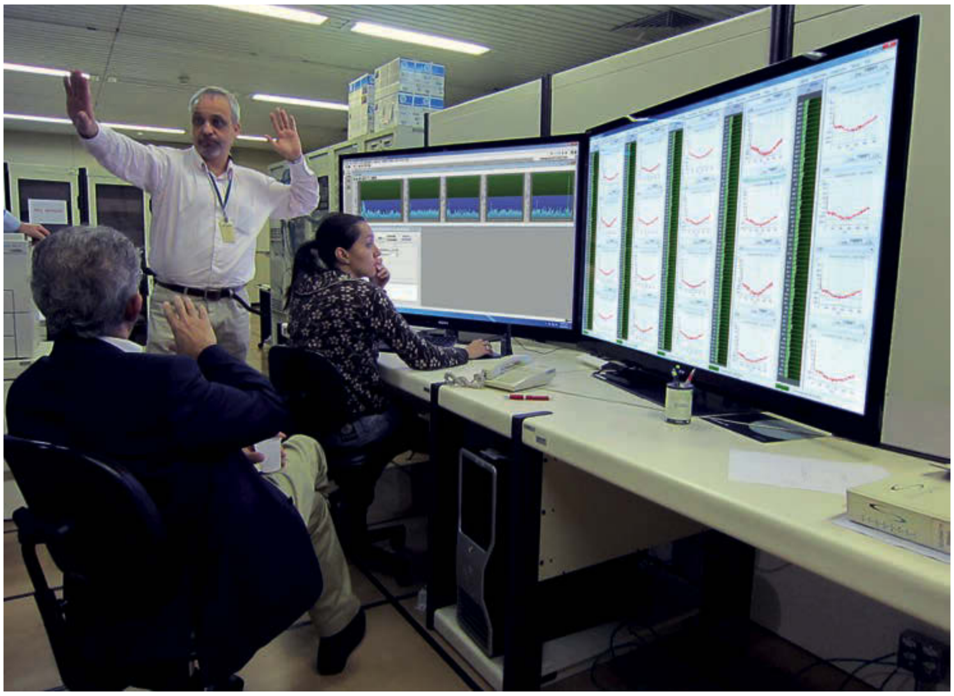
Test safety requires that engineers can see how every possible point of the structure behaves during testing, and is not overloaded. A traditional 300+ channel system can easily require over 15km of sensor cabling, which would necessitate lengthy and exacting setup procedures. INPE's mobile LAN-XI data acquisition system gives 324 channels in wheeled cabinets that follow the satellite through different tests, allowing short analog cabling that can remain securely attached. So lengthy accelerometer setups only need to be done once, while further benefits come from avoiding long cabling, which is expensive, decreases the signal quality, and increases the risk of cable failure.

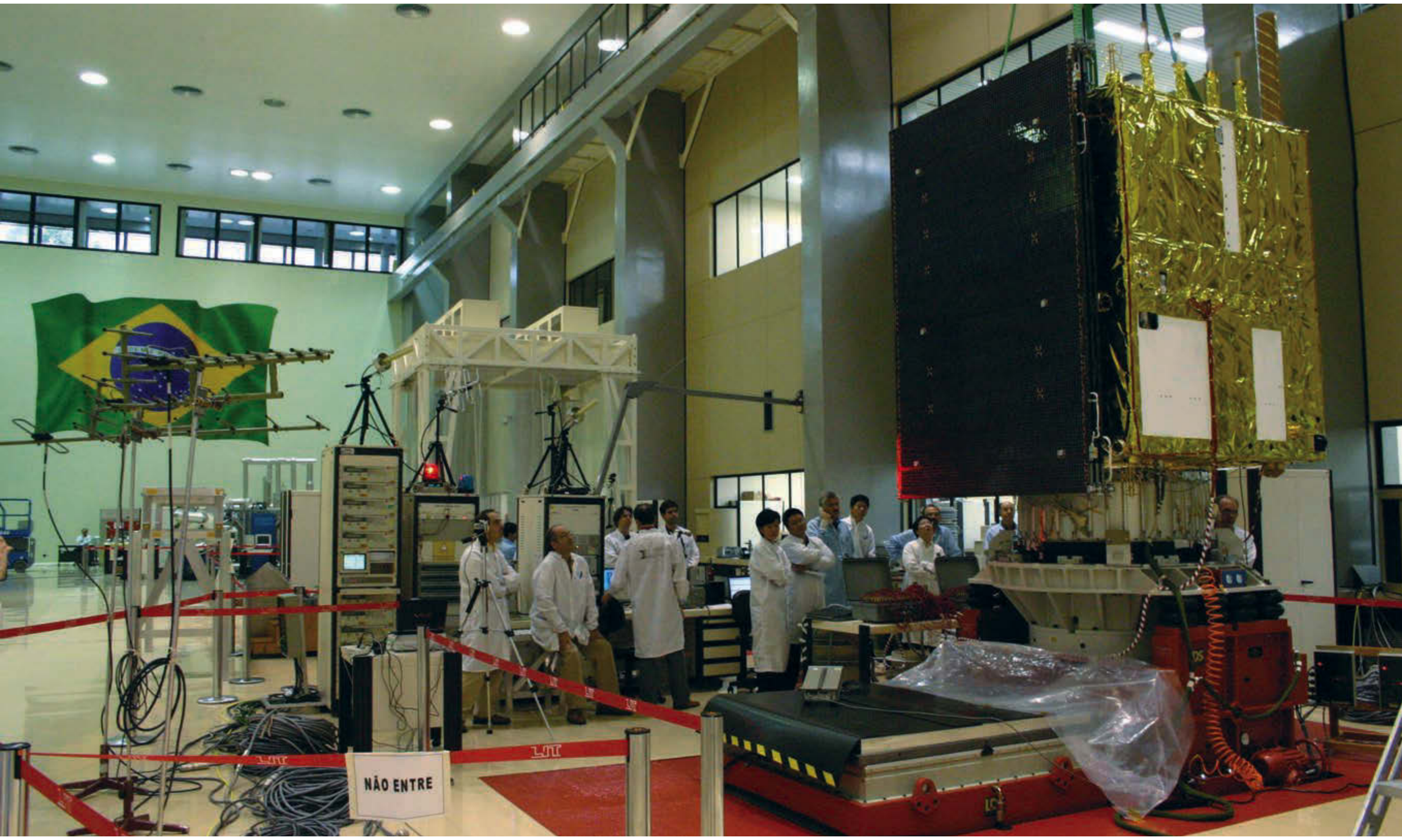
For INPE, avoiding over-testing also means they must be sure to get quality test data recorded the first time. "Safety, data quality and test reliability are the essential criteria that the system provides," says Heyder Hey, head of the Data Acquisition Department at INPE.

DATA HANDLING

Hundreds of channels generate an enormous amount of data. For example, recording 320 channels at 131kHz sampling frequency for 10 minutes will produce a file of 96GB. Such large systems can be very heavy to handle in terms of setup, calibration, recording and analysis, so efficiently managing it was a key requirement for INPE.

With so much data, efficiency requires effective overview control software. The overall test sequence is organized through an 'umbrella' data handling application – called DAQ-H. This unites all of the analyzer applications in use (based on Brüel & Kjær's PULSE analyzer), to give a dedicated and simplified user-interface that efficiently manages all setup, calibration, measurement, analysis, data management and reporting. DAQ-H is configured for specific test types to ensure mistake-free, repeatable testing. According to Hey, "The ease-of-use features





A satellite sits on an LDS shaker, using a custom adapter that reproduces the interaction between the satellite and its launcher, measuring the force interaction with embedded transducers

come from the specific expertise of Brüel & Kjær's people, and take the system over and above what we were hoping for."

The complete test workflow is organized at a dedicated control console. Here the test engineers pre-plan the test, set up the data acquisition and the required analyses, calibrate the system, initiate and monitor the recording, initiate post-processing, visualize the results, create reports and archive the data.

To set up tests, INPE's engineers use a Microsoft Excel file to pre-define channel setups, sensor sensitivity and other specific front-end setup parameters. The data recording length and bandwidth is also setup here. Data input is intelligently automated wherever possible to minimize manual inputs and their potential errors. All this information is then automatically incorporated in the DAQ-H control software, which sets up the underlying PULSE system in seconds. Then data recording is initiated with a single button.

USER-SPECIFIC DISPLAYS

Test safety calls for focused attention to detail from a large team with diverse interests and skills, requiring different data in different areas. For this, real-time FFT, time and n^{th} octave analysis is performed on all channels during recording. In addition, INPE's test customers wish to quickly receive reports and relevant data, in order to make their own analyses.

To achieve this, all test data is digitised immediately, and made available on a local area network (LAN) so it can be accessed from all around the facility. Then, from the centralized master console, just the relevant data is sent to each tailored display – respectively for shaker control, in the test area, for data acquisition and recording, and in a dedicated client room. Each one needs different information, and not too much – focused displays make their job clearer. As Hey says, "Clients only need top-quality data, and this delivers it reliably."

The view of INPE's clients is structured so they can compare the tests and data in many different ways, and includes smart features to assist with data handling efficiency, such as color-coded comparison data. It shows only the post-processing and reporting functions, which take place in the PULSE Reflex post-processing environment. Results (data) can be quickly processed and sent elsewhere for specific analysis. "Processing and display/analysis of processed data is so fast that one can easily make and analyze the results from many satellite tests per day," says Hey.

DATA POST-PROCESSING

Data is stored automatically in a standard Windows folder tree, and is searchable according to test, date and other metadata parameters. Data transfer is simply a matter of copying folders to the desired network destination. ∎

AUTOCODING SATELLITE SOFTWARE

Satellite computers have to handle a whole range of monitoring and control tasks. Thales Alenia Space has integrated a production code generator into the development process for complex onboard computer software

The aggressive environment in Earth orbit (cold, heat, radiation) demands the meticulous monitoring and control of all onboard systems to ensure that the satellite operates correctly. To ensure the reliability of all the satellite software, engineers have to cope with several challenges.

The first is that onboard computers have low performance compared with other modern computers. This is because the hardware has to be 'radiation-hard', a property found only in less densely packed microchips, whose performance is correspondingly weak. CPUs with a low clock rate (20MHz) and little memory (4MB) are typical. The second is that the satellite is not physically accessible in space, so it has to be remotely maintained (patches are transmitted by radio). Finally, the software has to manage numerous onboard interfaces and also maintain the link to the ground station. This complex data flow necessitates a finely coordinated architecture.

REASONS TO AUTOCODE

At the start of the millennium, the drawbacks of the traditional handcoding of satellite software were becoming obvious at Thales Alenia Space (for example, it was difficult to retrieve information from earlier projects, perform software maintenance and so on). Thales Alenia Space therefore decided to establish a model-based development process.

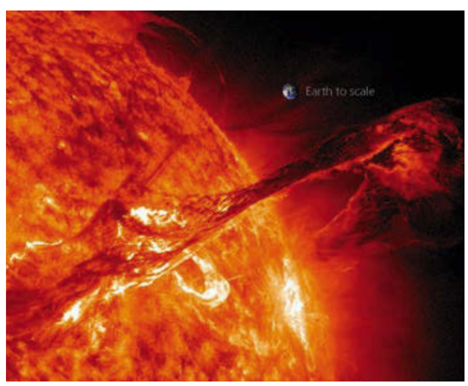
For functions requiring strong algorithm parts such as the attitude orbit control system (AOCS), the process is based on Simulink in conjunction with the automatic code generator TargetLink from dSPACE. This process enables the exchange of information between development teams in a defined, unambiguous format and with clear separation of responsibilities for function development and software development.

STREAMLINED DEVELOPMENT PROCESS

The process begins with the AOCS system team developing a floating-point Simulink model, which they test with model-in-the-loop (MIL) tests in the second step. Then they pass the model to the software developers, who carry out the third step – configuring the data types, variable names, function names and function interfaces. The fourth step is automatic code generation with TargetLink, followed by software-in-the-loop (SIL) testing in the fifth step. If the result of the SIL test indicates that the model needs reworking, the software developers pass it back to the AOCS system team again. This is where the new process reveals its great strength, because although the model has to go back to the drawing board, the work already done by the software developers is not lost – thanks to the cleanly defined exchange formats and work steps.

As soon as all the model modifications are complete and the SIL tests have run successfully, the sixth and final step is to integrate the finished code on the system platform computer.

The first project with TargetLink was the development of software for two infrared Earth observation satellites (SPIRALE), which were launched into orbit in 2009 by an Ariane 5. That same year, Thales Alenia Space also decided to use TargetLink for a new project called Sentinel 3. This project is part of Global Monitoring for Environment and Security (GMES), a mission of the European Space Agency (ESA). Thales Alenia Space has already generated 12,000 lines of code for it.



TARGETLINK FIRMLY ESTABLISHED

Model-based design and automatic code generation have since become the established practice at Thales Alenia Space. Using models that can be shared by different teams makes work very efficient. And with TargetLink, the code structure and naming rules can be configured flexibly.

Thales Alenia Space was therefore able to integrate the code into its existing framework without having to modify it. The new process has already considerably boosted productivity and is expected to produce further major benefits when earlier models are reused in future projects. ∎

ABOVE RIGHT: One cause of disruption in satellite electronics is solar flares that hurl charged particles as far as Earth. The photo shows a large flare that occurred on August 31, 2012 (Photo: NASA)

RIGHT: Satellite electronics need to withstand aggressive in-orbit conditions such as cold, heat and radiation (Photo: NASA)

BACK TO ENVIRONMENTAL BASICS

A look at the fundamentals of environmental testing, including the standardization of aerospace test procedures and the three essential stages of vibration trials

Environmental dynamic testing is a technical discipline that includes all vibration tests conducted on most engineering structures. The goal is to simulate the effects of the operational environment on a given object. A car clutch, a dishwasher pump, or an airplane altimeter are just a few objects required to pass a dynamic environmental test prior to use.

Engineers use different terms according to when the test is performed during the product lifecycle – these include development, qualification, functional, endurance, durability, reliability and worthiness.

In 1945, the US Army issued the Army Air Force Specification No. 41065 – 'General Specification for Environmental Test of Equipment'. This is regarded as the first document to attempt to standardize testing procedures so that items and components could be tested and a lifespan predicted for various operational environments. After 20 years of trial work, in June 1964, these recommendations were issued in what has become the world's most authoritative standard: the MIL-STD 810. Since then, the original 60-page A version has become an 804-page G release. LMS acoustic and vibration solutions from Siemens PLM Software focus only on the dynamic environmental test area.

THE FIRST STAGE OF VIBRATION

In general, there are three main stages in vibration tests: first, is test setup. This phase is crucial to test success and the actual component lifespan relies on a good test setup. Two tasks need to be accomplished: define a test profile that represents the operational vibratory environment; and fix the test item to the shaker in a way which represents its real operational mounting. In many cases, test profiles are taken from standards. In others, the manufacturer provides a pre-tested component. However, it is important to ask how are these approaches relevant to my case? Am I under- or over-testing? LMS solutions and experts take into account the specific dynamic environment of each application. LMS Test.Lab Mission Synthesis lets engineers take hours and days of operational field measurements, and transform them in a lab test, which maintains real damage potential.

STAGE TWO

The second stage is the test itself. During the test, the vibration controller is the main player. And there are lots of questions. Single or multiple inputs? Response limiting? How many statistical degrees-of-freedom (random test) or which compression factor (sine test)?

A vibration controller is a two-part system. Various vibration controller vendors offer control software with similar features and characteristics. LMS solutions emphasize system safety: the controller provides a number of user-definable parameters that ensure the test item's safety at all times. This includes features such as self-check, drive output voltage, notching, and abort limits. At the same time, there is more diversity on the hardware side.

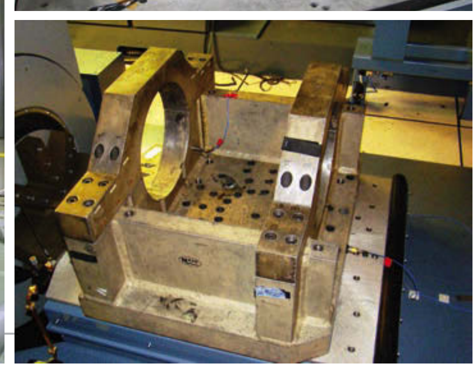
Hardware specifications are extremely important for conducting a successful test: signal conditioning and processing, sensor types, reliability and versatility in channel expansion, and mobility, are all decisive factors. LMS solutions have always pioneered the integrated LMS Test.Lab software-LMS SCADAS hardware approach. The success of these two platforms results from continuously implementing customer feedback over the past 30 years.

STAGE THREE

The final stage is post-test and analysis. At the end of a dynamic environmental test, there is a vast quantity of data available. During these tests, which can last for hours or even days, different data is acquired: the drive signal, time traces of the control and measurement channels, and different spectra formats. This wealth of data contains valuable information used to further analyze and understand the system dynamics of the test item.

Analyzing large quantities of data becomes necessary when structural failures occur. Unfortunately, understanding Physics of Failure does not seem to be as a widespread as it should be. This is why LMS state-of-the-art tools for signal processing and dynamic analysis, such as time-frequency analysis and modal analysis, are highly appreciated by engineers.

Even though standards provide most testing guidelines, engineering insight is needed to conduct a correct and successful dynamic environmental test. Even the best engineer needs the right tools, which is why LMS solutions are highly appreciated by experts the world over when it comes to carrying out safe and reliable dynamic environmental testing.



CLOCKWISE FROM LEFT:
Preparing BepiColombo for vibration testing, ensuring the spacecraft will survive the brutal start of its journey to Mercury atop the Ariane 5 launch vehicle (Courtesy ESA)

Electrical thrust vectoring control systems (TVC) for the VEGA program undergoing vibration testing at SABCA (Courtesy SABCA)

Optimizing vibration test fixtures using a quick operational deflection shapes analysis

HYDRAULIC HIGH POINT

One company has designed and manufactured a universal test stand to support a multinational fighter development program

The Eurofighter project required just one single testing solution for hydraulic components. On top of this, the customer required a multiplatform capability. The universal hydraulic component test stand was developed to provide the engineering solution, as well as to deliver a sustainable business case that provided excellent value for money.

In military aviation, the necessity for component testing has many special requirements. Every nation has different weapons systems and the maintenance process and specification is provided by the individual nations. In the 1980s, the UK, Germany and Italy started to fly the Tornado fighter/bomber and the maintenance equipment for this aircraft was purchased.

In early 2000, these nations started to put a more complex weapon system into service – the Eurofighter Typhoon – together with the corresponding maintenance equipment.

COMBINATION DEVELOPMENT

Test-Fuchs, a global specialist in customized test equipment, reacted quickly and designed a universal hydraulic component test stand that can be used for Eurofighter and Tornado components at the same time.

The German Air Force was the first to use this rather complex test stand, which fulfills the tasks of various hydraulic test stands. Up to 28 components for the Tornado can be tested, including actuators, selector valves, hydraulic tank and door locks. The same test stand is also capable of testing up to 56 hydraulic components for the Eurofighter Typhoon. Among these are primary and secondary flight controls, actuators, break manifolds, servo valves, filter packages and landing gear. These test stands operate with three individual and independent workstations, using one hydraulic power unit, meaning different components can be tested at the same time.

Workstation 1 has a horizontal loading mechanism for actuator testing and an external, vertical loading mechanism for undercarriage testing.

Workstation 2 has a load unit for steering motors and components with high flow.

Workstation 3 features a hydraulic quick fixing plate including seven internal, free connectable elements.

EC&MU

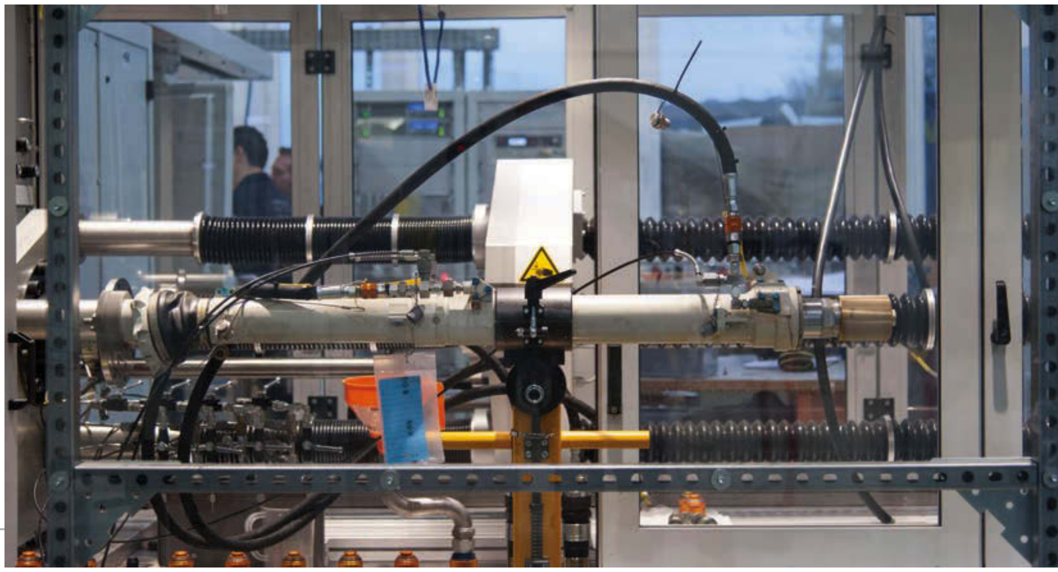
An important feature that has been included for the primary actuator tests is an electronic and monitoring unit (EC&MU).

To reduce test time for each workstation, a new innovative quick clamp device saves time mounting the components. Each workstation can be operated manually or with fully automatic test runs, which is extremely user-friendly and intuitive. The software is Windows-based and easy to use.

After the first one of these unique test stands had been delivered to Germany, the other nations that were using the Eurofighter started to show an interest in this extraordinary development. The economic crisis and the reorganization of air forces have led to drastic cuts in budgets, and this investment will help to save money in the long term, due to lower circular flow of spares and shorter turnaround time. Additionally, all the tools, adapters and test hoses are available in the scope of delivery. The test stand also has low maintenance requirements, high reliability and a proven track record.

According to clients, this test stand is an ideal solution because it is flexible and can easily be adapted for components of other aircraft types, and new component programs can be installed via remote maintenance. The UK version of this test stand has already been put into service and is used to test the hydraulic components of the Eurofighter Typhoon. The delivery, installation and commissioning can be carried out in less than three weeks; considering the size and complexity of the equipment, this is very quick.

The Italian version of the test stand will be delivered in spring 2014 and will help to cut down maintenance costs for the Italian government in the future. ∎



ABOVE RIGHT: **Aircraft landing gear trials**

RIGHT: **Inflight refueling probe under test**

EXISTING TESTBED UPGRADE

In the 1980s, Astrium, a leading company in Europe's civilian and military aerospace industry, with 18,000 employees worldwide, built its testbeds with amplifier modules from two companies. Now, more than 30 years later, Astrium was confronted with the problem that these amplifiers were no longer available.

The company therefore looked for a new provider and made a broad market evaluation. Among other companies, it finally found Dewetron and received a DEWE-30 rack with several DAQP-STG amplifiers for benchmark tests.

After a several-month rigorous selection process, Dewetron won the contract to provide the best technical solution according to Astrium's test-bench requirements. Astrium found that the isolated universal DAQP-STG amplifiers have the best price-performance ratio among all the analyzed amplifiers.

An additional attraction was that the amplifiers can be used for about 95% of all analog input types and were originally developed for NASA. At the end of 2008, Dewetron built a 600-channel system with STG modules for NASA's mobile launch platform.

Currently, Astrium, DLR and others in the aerospace industry replace their old amplifiers with the Dewetron universal DAQP-STG amplifiers in their European test centers for rocket and satellite engines. They are used for testing of satellite positioning control systems in Lampoldshausen, Germany, as well as for the Ariane testbeds for rocket engines.

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ARINC429 – TESTING ON THE RUN

A smart toolset for avionics databus handling, using nothing more than a standard application with today's latest available technology, is available from AIM. It comprises standard AIM hardware and software, plus a commercial off-the-shelf computer platform. The core component of this toolset is AIM's ANET429-x Ethernet-based databus interface with 4, 8 or 16 fully programmable ARINC429 channels operated via the optional wireless Ethernet interface. The AIM ANET family has an onboard LINUX OS and is also available for one or two dual-redundant MIL-STD-1553A/B and STANAG3910 buses.

The platform hosting the standard AIM PBA.pro software framework application is a Windows 8.1-based commercial off-the-shelf tablet computer. Various models are available, but as an example, an 8in Quad Core IntelAtom platform provides a suitable offering and a good trade-off for size, weight and performance for handheld applications, explains the German-based company.

The key advantage of using the AIM Standard PBA.pro on such a platform is the execution of dedicated application-specific PBA.pro projects with panels/GUIs (e.g. for maintenance tasks, quick check, datalogger) as well as using existing panels like the AIM PBA.pro-Light or customer-created panels.

Various options of host platforms, as well as the use of an encrypted wireless network, offer maximum flexibility and mobility of applications.

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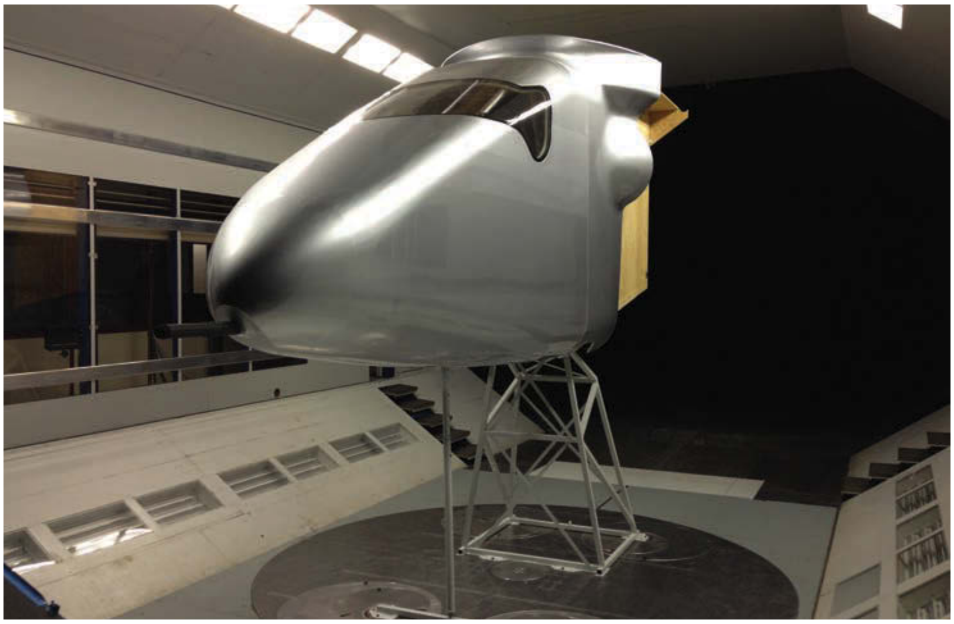
SOLAR IMPULSE INTO THE TUNNEL



The Solar Impulse 1 (HB-SIA) solar-powered prototype aircraft has proved itself in demonstration flights in Europe, as well as with a successful solar-powered flight across the USA. These accomplishments paved the way for the next milestone in the innovative Solar Impulse project – the development and manufacture of the long-range and larger Solar Impulse 2, destined to fly around the world.

Extensive tests were required to ensure the new design's soundness, including a wind tunnel campaign conducted in RUAG Aviation's Large Subsonic Wind Tunnel Emmen (LWTE).

Using a full-sized mock-up installed in the LWTE, RUAG tested the cockpit section at different wind speeds, angles of attack, and yaw angles. The cockpit's extremely lightweight construction – comprising primarily of polyurethane-foam walls over a tubular structure – necessitated testing to ensure that deformations of the cockpit walls remain within a specific range, and that no leaks exist. Also vital was verifying the emergency door ejection system. With the pilot seated in the cockpit, the emergency door release system was triggered at various wind speeds – the door had to be captured at the end of the test section to avoid damaging the wind tunnel.

RUAG Aviation's advanced testing capabilities have prove invaluable in developing this groundbreaking aircraft.

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WELDING STRAIN SENSORS

Sciaky Electric Welding Machines is using Kistler piezoelectric strain sensors to meet the demands of the aerospace industry for the precise monitoring of the welding process. Unlike the load cell, the piezoelectric strain sensor measures the force at the electrodes indirectly by reference to the strain on the main body of the machine. The conversion from strain to force is achieved using a Kistler Type 5073A single channel industrial charge amplifier mounted on the machine remotely from the sensor.

In addition to fitting the sensors to new welding machines, Sciaky now retrofit the Kistler strain sensor whenever the old-style load cell needs replacing. According to Sciaky managing director, Louis Kunzig, the strain sensor is now fitted as standard to all Sciaky Resistance welding machines supplied for aerospace applications and for critical applications, such as manufacturing steering components, in the automobile industry.

MICROPHONES FOR NOISE SOURCE IDENTIFICATION

PCB Piezotronics' aerospace and defense division was recently awarded a contract by The Boeing Company for its Model 378A13 pre-polarized condenser microphones, which will be used in Boeing's aircraft noise-reduction program.

The program's objective is to identify aircraft noises that may be displeasing to crew and passengers, as well as to detect noises, often imperceptible to the human ear, that indicate part-wear or malfunctions that require service.

PCB's microphones demonstrate a high level of measurement sensitivity, consistency and durability. PCB met the aggressive schedule for this program because it maintains stock levels on most of its microphones and provides 24/7 technical assistance. Boeing uses PCB's ICP accelerometers for ground vibration testing and modal analysis of aircraft and satellites.

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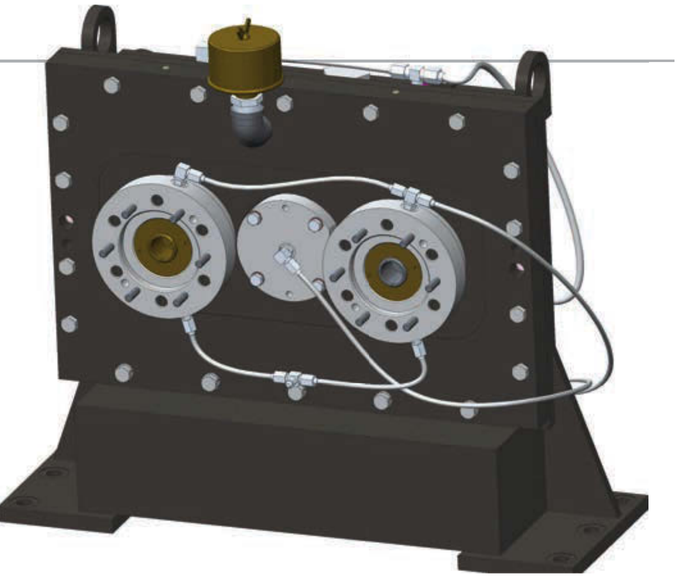
HIGH-SPEED TRANSMISSION

Cotta has developed a new high-speed transmission that provides maximum application flexibility for repair depot and multi-unit test stands. The new dual-output SN2291 high-speed gearbox features a nominal power rating of 300hp, 25,000rpm output speed, and ratios up to 5:1, with the option to have different output ratios. The SN2291 has a horizontal shaft design, single-stage gearing, and comes with a lubrication system.

Cotta's high-speed transmissions are used extensively for R&D and production testing of components such as generators, constant-speed drives and pumps, in the automotive and commercial/military aircraft industries.

Cotta also designs and manufactures precision-engineered transmissions for a wide range of specialized mobile and stationary applications. Models are available in a wide range of output speeds (up to 80,000rpm). Modified-standard and custom models are also available to meet specific requirements.



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EXTENDED LOW-FREQUENCY RESPONSE ACCELEROMETERS

Dytran Instruments has expanded its sensor offering to include a new generation of acceleration measurement instruments that combine two technologies, which until now have only been used separately.

Also referred to as the ELF (extended low frequency), the accelerometer contains a piezoelectric and a variable capacitance element with respective filtering, whose outputs are electrically superimposed over one another.

The Dytran 7705A series features a hybrid design, combining the most desirable features of piezoelectric sensors and variable capacitance accelerometers, which result in a flat frequency response from 0-10,000Hz.

The main principle of operation for the Dytran 7705A series is the instrumentation amplifier at the output buffer. The positive input is provided by the variable capacitance element and the negative input is provided by the piezoelectric element. Both elements are filtered appropriately (low-pass single pole for the variable capacitance element, and high-pass single pole for the piezoelectric element) to provide the corner frequency of both filters precisely matched at around 30Hz. Both signals are also out of phase as they enter the instrumentation buffer. Accelerometers are powered through the power point with a 5-28V DC power and require 7-9mA of current.

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GENERAL-PURPOSE ISOTRON ACCELEROMETERS

Meggitt Sensing Systems has introduced a major extension of its Endevco brand Isotron accelerometers. This new line of general-purpose IEPE accelerometers is designed to meet the needs of a wide range of aerospace test applications with the highest quality, plus low cost and availability, as needed by today's test professionals.

Key features of the new Endevco general-purpose line include: multiple sensitivity options; wide-band frequency response; hermetically sealed; signal ground isolation from case; low noise floor; TEDS capable (IEEE P1451.4); and CE marked.

The new single-axis models – 41A, 42A and 43A – are available in 10, 25, 100, 500 and 1,000mV/g sensitivities (41A and 42A); and 100, 500 and 1,000mV/g (43A). Amplitude response of ±5% is 1 to 10,000Hz. A new triaxial model 45A features a 20mm cube shape with 500mV/g (±10g range) and 1,000mV/g (±5g range) options. Amplitude response of ±5% is 1-6,000Hz for the y- and z-axes; and 1-3,000Hz for the x-axis. In addition, new model C general-purpose cable assemblies allow user-selectable cable configurations.

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INDEX TO ADVERTISERS

Going for gold

Joe Holdsworth is the software systems engineer for the SSC Bloodhound, the British car that aims to smash the land-speed record by travelling at more than 1,000mph. Most of the technology is from the aerospace industry and it all needs testing – even for a vehicle that will never leave the ground

BY CHRIS HOUNSFIELD

WHAT DOES BEING SOFTWARE SYSTEMS ENGINEER ON SSC BLOODHOUND ENTAIL?

The majority of the time I'm either doing software or electronics, which sees me getting the Eurojet EJ200 or other components off the Eurofighter and then integrating them all together to reproduce a system that Andy [Green, driver] can use to control the jet power. It handles supply power, and there's electrical power and hydraulic power to the systems in the car.

HOW MUCH OF SSC BLOODHOUND IS A CAR AND HOW MUCH OF IT IS AN AIRCRAFT?

It's a car that uses components from an aircraft and obviously at high speeds it is subjected to a lot more aerodynamic forces. Yes, it's a car – but with a lot of aerospace technology used in it. In terms of the stress and components, we use aerospace standards.

HOW MUCH OF THE SOFTWARE SYSTEM IS BESPOKE?

A fair amount, so we've got something in the region of 400 to 500 sensors on the car. There are four or five computers on the car – all of them are running a real-time operating system and they all need to speak to each other. So all that has to be written in-house and developed specifically for the car.

IS THE ENGINE THE SAME AS YOU WOULD USE ON AN OPERATIONAL EUROFIGHTER TYPHOON?

We will be driving at an elevation that is around 4,000ft above sea level, so we're essentially very low relative to an aircraft and that means the inlet pressures on the jet are higher than the aircraft would see in operation because the aircraft is capable of supersonic flight – but not at those levels. So the fan blades at the front have to be checked by Rolls-Royce to check that they will survive at the slightly higher pressures.

SURELY THE ENGINE IS DESPERATE TO LEAVE THE GROUND! HOW DO YOU TEST THE AERODYNAMICS TO STOP THIS HAPPENING?

First off, we have the shape of the car, and we've spent some time getting that perfected through computational fluid dynamics. Obviously we've modeled the car to the speed ranges and we're reasonably confident from the modeling that the lift or downforce on the car remains neutral enough throughout the run for it to remain on the ground. There's a couple of things going on in this area of testing, so we've actually got 192 pressure sensors just for this.

YOU ARE USING CARBON FIBER. ARE YOU USING NEW TEST TECHNOLOGY TO DEAL WITH THE MATERIAL SPECIFICALLY?

Yes, we are. Interestingly, there are many points in this area so it's quite hard to discuss. I am not a stress engineer, but I know in some ways it can be very hard to model carbon fiber because of the way it deflects and what you use it for. I cannot comment on how the stress engineers are dealing with it exactly, but I can say that there's going to be lots of debris hitting the carbon fiber at the bottom of the car, so we have to look at perhaps protecting that to stop the fibers getting damaged.

We have fired light solid particles at the car to see what coatings would best protect it from a desert surface or the debris. There are various coatings they've looked at, and that's one solution, or else some sort of metal plating in areas where we're going to see a kick-up of debris.

WHAT'S THE BIGGEST PROBLEM FACED ON THE PROJECT SO FAR?

It's strange; it's about getting information because there is so much from the military side. The components on the car are military, so getting information is incredibly easy, but because you need to get a sign-off from lots of companies, it can take some time to get the information. It's a time thing – the time penalty of not having the information.

WHAT IS NEXT FROM A TEST AND DEVELOPMENT POINT OF VIEW?

We've got a gearbox that runs off a jet engine and that provides electrical hydraulic power. It means you can start the jet. So now we've got the jet engine running down the testbeds really well; so now we've got a power plant! But what is next is that we need to be able to start that and provide power in the car.

So now I'm working on the AC electrical power generation in the car and also on hydraulic power generation in the car. Once we've got that, it means we can start the jet; we can power all systems so the car will start to become alive! It allows us to use the jet, start the jet, run the car, get power, get hydraulics!

WHEN ARE YOU GOING TO RUN AT 1,000MPH?

In 2016, so we're aiming to go out to the desert at the end of 2015 for tests. I don't think we're aiming to break a record at that point. Maybe we will… that would be good. But then we aim to go back out, fix any problems with the car, change the CFD, make adjustments, do more tests. Then we'll look to get the record that we said we'd get! ∎

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