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NOVEMBER/DECEMBER 2011

AEROSPACE TESTING INTERNATIONAL

World first:
The F-35B's vertical take-off seaborne trials are up and running

Rise to the challenge
200 miles, one gallon of fuel: no mean feat for the first hybrid aircraft

Fortress Europe

Ambitious, complicated, successful: the launch of the US Missile Defense Agency's test program to defend Europe

SPACESHIPTWO • TRAILBLAZERS • K-MAX UAV • HEAT SHIELDS • AERIAL PHOTOGRAPHY • FIBER OPTICS

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Missile test and development has increased as the global threat has increased. In 2009 Barack Obama initiated a European ballistic missile defense program, which is undergoing vast resource tests in the Pacific right now (*see page 20*). Russia is threatening to ramp up its own counter-defense and has successfully test-fired an advanced intercontinental ballistic missile. The Bulava is able to carry up to 10 separate warheads with a range of 5,000 miles. President Medvedev stated at the end of November that if the USA continues to pursue its intention to test and deploy its European shield, it will deploy its own short-range Iskander missiles at US targets, despite the USA's insistence that the European defense architecture is to counter the threat from Iran.

Now, Iran… therein lies the greatest threat. War games were played out in July with the Israeli press accusing Iran of carrying out numerous missile test firings of its Shahab-3 missile, which puts Israel within easy reach, as well as further tests of the lower-range Shahab-1 and -2. Iran has admitted to nine test firings of the missile in July, saying that Israeli and US missile shields are no match for Iranian missiles. With sanctions in place, the threat is escalating.

The emergence of India and its missile capability must not be ignored either. It has poured vast resources into its test programs and has its own huge ranges. Only this month India successfully test-fired an advanced variant of the nuclear-capable Agni-II ballistic missile, which has a strike range of 3,000km.

On a different missile tack, the US Air Force Research Laboratory and Boeing successfully completed the CHAMP (Counter-electronics High-powered Microwave Advanced Missile Project) missile's first flight test in September. It is a completely new concept in missile design and capability. CHAMP is a non-lethal alternative to a kinetic weapon; it neutralizes electronic targets. At this point very little else is known about it, except that it possibly fires beams as it passes, neutralizing electronic points on its route.

In this short space it is impossible to mention everything else – the European test programs, NATO test exercises, the Koreans, Pakistan, even China… So I won't.

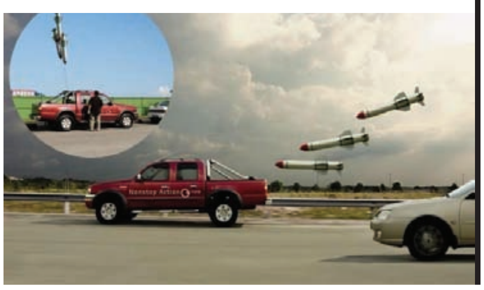
Despite an army career spanning almost a decade, my own experiences with missiles is fairly limited. I did once have the privilege of attending a NATO fire power demonstration, though. Like a football match, there was a large stand, but it was full of very senior generals, and was standing solitary in the middle of a vast plain, facing a hill. Over the hour that ensued, every type of screaming eagle aircraft exerted determined efforts to make the hill considerably smaller. The finale came when a squadron of A-10 Thunderbolts (Warthogs) slowly closed in and let off sidewinder missiles and their chain guns simultaneously. I am certain the recoil brought the gunships to a standstill; by the time the smoke cleared, the hill was indeed a hillock.

On another occasion, we were training on a new shoulder-mounted anti-tank weapon called LAW-80 – basically, an advanced technical piece of pipe with a rocket stuffed in it. I had my go; it was strange, because despite huge damage to the target and a dynamic exit, it had no recoil as the resulting blast was directed some considerable distance rearward of the launch tube. This meant a sensibly big safety distance, including the angle to avoid, had to be left behind the firer. My colleague who had just fired, withdrew safely behind and out of angle, took off his helmet, lit a cigarette, and calmly sat down to watch while the next candidate moved up into position. Sadly, the next firer, whose army career was made abruptly short, adjusted his firing position and aimed at the wrong target 20 crital degrees to the right, and let rip.

Officer cadet 'Smith' spent some time in hospital with severe burns to his face. Sadly, he looked like he'd been facing toward the wrong end of the afterburner of an F-16. Most of his hair grew back, but in odd directions – hence his nickname, 'Insect'.

I cannot go without mentioning this: while researching this subject I came across a new missile: balloons (see below). Tie to your fender, and try to outmaneuver your own three AIM-9X…

Christopher Hounsfield, editor



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COVER IMAGE: SM-3 missile launch (picture courtesy US Navy)

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Safety fears ground F-22 again

The US Air Force (USAF) has grounded dozens of its Lockheed F-22 Raptor stealth fighter jets for the second time in a year, after another pilot appeared to suffer from a lack of oxygen during flight.

The USAF "paused" missions at two of its air bases after an F-22 pilot at Joint Base Langley-Eustis in Virginia showed signs of hypoxia while in midair, according to USAF spokesman Lieutenant Colonel John Haynes.

This new grounding affected only the F-22 bases at Langley-Eustis and at Alaska's Joint Base Elmendorf-Richardson, suggesting that the USAF's ongoing investigation into the problem is near to getting to the bottom of the issue. Four days after the new flight ban, the Alaska-based aircraft were returned to flight status.

When the original grounding was lifted in September, USAF chief of staff General Norton Schwartz said, "We now have enough insight from recent studies and investigations that a return to flight is prudent and appropriate."

Schwartz approved a plan to allow the F-22s to fly above 50,000ft – the Raptor flies at 60,000ft in normal profiles – after an extensive inspection and tests of every aircraft's life support systems. The systems are being inspected daily. In addition, the plan calls for pilots to undergo physiological tests and to use additional protective equipment.

Since the first grounding was lifted, Haynes said the F-22s have completed 1,300 training and homeland defense missions without incident, save for the one at Langley-Eustis, and said any halts at local bases were at the discretion of the base wing commanders there. There are currently no plans for another nationwide halt as other bases are keeping a close eye on their pilots' safety in the air. "Everybody knows, everybody's watching," Haynes said.

The USAF has more than 160 F-22s stationed at seven bases across the USA. The Elmendorf-Richardson air base has not experienced an incident recently, but it is the home base of the late USAF Captain Jeffrey Haney, who was killed in an F-22 crash during a night-time training mission in November 2010. An investigation into that crash is ongoing under retired USAF General Greg Martin, but Schwartz said in September that the oxygen system was definitely not the cause of the crash, despite media reports to the contrary.

The latest grounding comes just over a month after the F-22s, which cost US$143 million each, were cleared to go back in the air following an almost-five-month grounding – also because of mysterious oxygen problems. In announcing that grounding, the USAF said that in 12 separate incidents pilots had experienced "hypoxia-like symptoms" while flying the aircraft over the past three years. Hypoxia occurs when the brain does not receive enough oxygen and can cause dizziness, confusion, and "poor judgment".

Expensive generation

The grounding of the F-22 was a major problem for the USAF because the Raptor is its most modern and advanced fighter aircraft. The Pentagon initially ordered more than 600 of the fifth-generation fighters, but ended up spending US$77.4 billion on procurement, with just 187 aircraft, leading to criticism that the F-22s were overpriced and long delayed.

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X-47B keeps cruising on

Northrop Grumman's X-47B Unmanned Combat Air System Demonstration (UCAS-D) aircraft showed off its distinctive 'stealth' shape to full effect for the first time on September 30, 2011 when it retracted its landing gear and flew in its cruise configuration.

The flight, conducted at Edwards Air Force Base in California, also helped validate precision navigation hardware and software that will enable the X-47B to land with precision on the moving deck of an aircraft carrier.

"[The] flight gave us our first clean look at the aerodynamic cruise performance of the X-47B air system… and it is proving out all of our predictions," said Janis Pamiljans, vice president and Navy UCAS program manager for Northrop Grumman's Aerospace Systems sector. "Reaching this critical test point demonstrates the growing maturity of the air system, and its readiness to move to the next phase of flight testing."

This latest flight was part of an ongoing 'envelope expansion' program for the first of two X-47B aircraft being produced for the US Navy's UCAS-D program. Envelope expansion flights are used to demonstrate aircraft performance under a variety of altitude, speed, and fuel load conditions.

The X-47B is being developed as a carrier-based unmanned aircraft offering a maximum refueled range of more than 2,000 miles (3,219km) and an endurance of more than six hours. The demonstrator carries no weapons, but has a full-sized weapons bay and is the same size and weight as the projected

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Dreamliner carries fare-paying passengers

Two years after its first flight, Boeing's much delayed 787 Dreamliner ultra-lightweight airliner has carried its first fare-paying passengers. Passengers paid up to US$34,000 for the privilege of flying on the special charter flight by Japan's All Nippon Airways (ANA) from Tokyo to Hong Kong in October. Boeing executives and shareholders will be relieved that they will soon be able to start to receive revenue to repay the US$32 billion invested in putting the Dreamliner into the sky.

The flight was a major media event after the Japanese population took the carbon-fiber Dreamliner to their hearts. Boeing's pitch has found a resonance in the land of the rising sun. "I want to try flying on it as it uses a lot of Japanese technology as well. I've heard that it's a pretty revolutionary plane and

Dream or nightmare?

After the first flight in December 2009, Boeing's headaches were not over and the company's planned nine-month flight test program proved rather over-optimistic. The US Federal Aviation Authority only certified the Dreamliner in August 2011, after test aircraft had flown a total of 4,828 hours in 1,707 flights. During testing the 787 visited 14 countries in Asia, Europe, North America, and South America to test in extreme climates and conditions, and to perform route testing.

ANA, the 787's launch customer, officially took delivery of its first aircraft in September 2011, some three years late. The airline expects to take delivery of seven Dreamliners by the end of 2011 and nine by March 2012. With some 797 aircraft on order and only two delivered, Boeing's focus is now on meeting its promises to customers.

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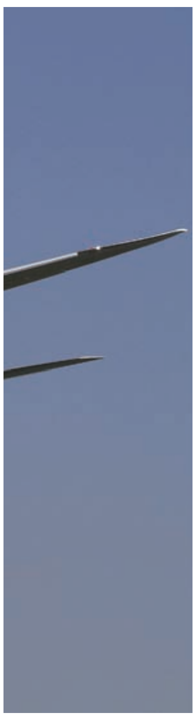
operational aircraft in order to provide realistic testing.

The first X-47B prototype rolled out from Air Force Plant 42 in Palmdale, California, on December 16, 2008. Its first flight was planned for November 2009, but the flight was delayed as the project fell behind schedule. On December 29, 2009, Northrop Grumman oversaw towed taxi tests of the aircraft at the Palmdale facility, with the aircraft taxiing under its own power for the first time in January 2010. The first flight of the X-47B demonstrator, designated Air Vehicle 1 (AV-1), took place at Edwards Air Force Base on February 4, 2011.

The UCAS-D program managers plans to begin transitioning aircraft to the US Naval Air Station at Patuxent River in Maryland in late 2011 to begin shore-based carrier suitability testing in 2012. The focal point of the program is to demonstrate in 2013 the first aircraft carrier launches and recoveries by a tailless, low-observable-relevant unmanned system.

Within range

The US Navy announced it would add equipment and software for aerial refueling to one of its two in-development X-47B armed drones. The change could extend, by thousands of miles, the useful striking range of the Navy's nuclear-powered aircraft carriers, starting in around seven years' time. That could put them beyond the effective range of the fast attack vessels, diesel-powered submarines, and anti-ship ballistic missiles.



so I really wanted to try it," said Naonobu Fujita while waiting to fly on the first flight. "I won the contest and decided to take a one-day holiday with my mother. As this is the first time in the world, I decided to take time off from work and come," said Takuya Miura, who won an ANA-sponsored contest to get a free seat on the flight.

Tickets for the flight were sold in an online auction, with the highest bidder paying US$34,000 for a seat. The 100 seats available to paying passengers on the flight sold out as soon as they went on sale, with 25,505 people scrambling online for the scarce tickets. A pair of tickets that ANA offered on the Yahoo auction website for charity sold for US$11,400.

Although Boeing's newest aircraft is being pitted against Airbus's A380 jumbo jet in a bid to boost their manufacturers' positions in the global airliner market, the two aircraft are aimed at different market segments. While the Airbus A380 is designed for longer trips with more passengers, the smaller Dreamliner is outfitted for large capacities for medium range distances.

This dream turned into a nightmare for Boeing as design and flight test delays put back the development and production program. Boeing had originally hoped to get the Dreamliner into the sky in August 2007, but suffered from excess weight and a shortage of 'fasteners' to enable the first aircraft to be completed. Five more delays of the first flight took place in 2008 as supply chain and production problems plagued the project, leading to senior management changes. More delays dogged the project during 2009 as excess weight had to be 'designed out' of the aircraft and the fuselage had to be strengthened.

Low-yield missile success in Libya

The role of so-called low-yield weapons in NATO's Libya operation is emerging as one of the big successes of the conflict, enabling UK and French aircraft to hit targets very close to civilian or rebel fighters with pinpoint accuracy. The MBDA Dual Mode Brimstone (DMB) and French Sagem Armement Air-Sol Modulaire (Air-to-Ground Modular Weapon) (AASM) or Hammer have been described as the stars of the Libyan conflict.

"When my American air force counterpart heard about our Dual Mode Brimstone and what it could do, he told me it must have been some sort of 'super-secret black' programme," recalled a senior UK Royal Air Force officer involved in running the recent Libya air campaign.

Both weapons had their origins in the 1990s when the UK and French air forces were looking at enhancing their precision anti-armor capabilities, but they soon had to be adapted to meet the needs of the "new world disorder". The two air forces were looking for high-accuracy and low-yield warheads to enable them to be used as precision strike weapons, rather than fired in large salvos against Cold War-era massed tank formations.

RAF Air Marshal Sir Stuart Peach, chief of joint operations, who led the UK's Libya effort, described the DMB as "phenomenally accurate". "It is British built and designed and is world class," he said.

Although the USAF has fielded its 250 lb warhead Boeing Small Diameter Bomb (SDB) and used it in Afghanistan and Iraq five years ago, Libya is the first time low-yield weapons have been used in large numbers in conventional warfare. The DMB with its 48kg (105 lb) warhead was particularly praised for its ability to be used to enable RAF jets to intervene in close-quarter fighting between Gaddafi troops and rebel fighters. Both the DMB and AASM were laser-guided to enable them to be used with great accuracy, with RAF officers saying the DMB fired from RAF Panavia Tornado GR4s achieved 98% accuracy, with "hundreds" being fired. The AASM was employed on Mirage 2000 and Rafale fighters, with one hit being recorded on a Libyan tank at a range of 55km.

Next-phase munitions

The RAF and French air force had already used their low-yield weapons in Afghanistan and had put in place plans to enhance them and sustain their inventories through the next decade. The UK Ministry of Defence has launched a program known as SPEAR Capability 2 to replace the legacy Brimstone missile's energetics and airframe with a new Insensitive Munition (IM) compliant warhead, rocket motor, and an improved airframe providing improved life and operator safety, and reducing the logistic burden imposed by non-IM systems. These enhancements will not change the outward appearance of the weapon but will dramatically reduce its cost of ownership.

French experience of AASM missions in Libya is also spurring interest in improving its performance to boost its attraction to export customers.

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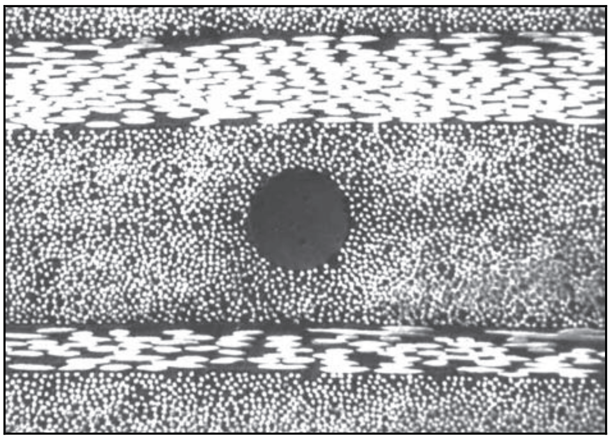
Image courtesy DRDO



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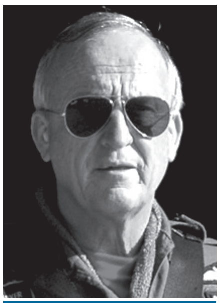


Pilot error?

IS ENGINEERING GETTING TOO FAR AHEAD OF THE PILOT'S COGNITIVE AND TRAINED HANDLING SKILLS?

BY DES BARKER

Calling all 'line pilots', test pilots, aircraft design engineers, and civil aviation regulators! Is there anyone out there who has noticed the irony of aviation's technological advances over the past 107 years of powered flight? There is no doubt that innovative engineering and technological advances have increased aviation efficiency and safety at a higher rate than any of the other sciences, but how we are actually directing the benefits and the training of this technology gain should be a concern to all. Likewise, regulators have, over the years, exercised their mandate in directing safety conventions in accordance with existing knowledge and experience. Are we facing a revolution in technological affairs that is beyond the scope of current regulators' understanding? Do regulators comprehend that pilot training is not keeping up with technological innovation?

Within the worldwide pilot community, a general concern prevails at the lack of basic situational awareness and handling capabilities appearing in the cockpits. In several accident cases, the causes could be traced back to pilots' inadequate 'hands-on' abilities or loss of situational awareness when operating the latest generation aircraft.

It is no secret that engineers seized upon the fickleness of pilot judgment to deliberately design 'pilot error' out of the cockpit. The universally accepted 72% of accidents attributed to 'error' spurred engineers on to introduce automation technology into the cockpit to ameliorate pilot handling and reduce judgment inadequacies.

The problem stems from the fact that smart avionics, smart aerodynamics, and smart flight control systems have made modern aircraft a lot easier to fly and consequently pilot workload has decreased to the extent that the 'pilot-out-of-the-loop' philosophy increasingly poses a threat to piloting skills. Engineers have led pilots to a place where a trust in technology has overwhelmed a faith in the ability of the pilots to recover from 'bad situations', and to a certain extent, the pilots themselves are complicit in this situation; the luxury of automation is turning pilots into 'better informed passengers' with inadequate physical cues to handle emergency situations in some cases.

Without passing judgment on piloting skills, the loss of the Air France Flight 447 Airbus over the Atlantic in June 2009 saw a series of 24 ACARS messages sent automatically over a timespan of four minutes, indicating among other speed measurement inconsistencies, the disconnection of the autopilot, and the airplane going into 'alternate law' flight control mode, which happens when multiple failures of redundant systems occur. A total of 228 people died. The simple failure of a radio altimeter led to the delayed attempts at stall recovery of the Turkish Airlines Boeing 737 Flight 1951 in February 2009; the investigators' preliminary report confirmed that the pilots allowed the automatic systems to decelerate the aircraft to a dangerously low speed as it approached Schiphol Airport. At 450ft AGL the pilots scrambled to accelerate out of the stall before the airplane crashed to the ground, killing the three flight deck crew and six others on board. The radio altimeter had 'informed' the automatic flight system that the aircraft was 8ft below the surface when it was still nearly 2,000ft in the air, which caused the auto-throttle to pull back the power to idle, as if the plane were touching down.

The accident findings intensified the debate over the dangers of pilots losing their basic flying skills as a result of relying on the sophisticated electronics that control airliners through most of their flights. Boeing was prompted to issue an unusual worldwide alert covering procedures that should already be second nature to aviators, "to carefully monitor primary flight instruments during critical phases of flight", such as take-offs and landings. Along with the technological threat from engineering, the emphasis on paper licenses by civil aviation authorities, without an equivalent focus on handling skills and decision making by the transfer of such knowledge from classroom to cockpit, has led many 'old hands' to question the future safety of manned aviation.

"The loss of major systems left the pilots with information overload and the inability to fly the aircraft manually"

**"The fad among modern pilots is to have as much 'technology' as possible as it reduces pilot error and reduces workload. However, failure of the 'technology' could result in a major loss of situational awareness"
Marc Ulm, Airliners. Net)**

The removal of stalling and spinning from the basic flying training syllabus as a mandatory basic handling requirement by some civil aviation authorities could contribute to the problem. It is not their fault but engineers offering an improvement to aviation accident safety statistics through stall- and spin-free handling qualities in their latest products are, in fact, indirectly producing pilots with deficient handling skills.

Inadequate crew knowledge of automated systems was a factor in more than 40% of accidents and 30% of serious incidents between 2001 and 2009. Presenting progress in her research, FAA human factors specialist Dr Kathy Abbott cataloged the evidence of disharmony between crews and their highly automated aircraft. The recurring handling problems pilots demonstrated included lack of recognition of autopilot/auto-throttle disconnect, lack of monitoring and failure to maintain energy/speed, incorrect upset recovery, and inappropriate control inputs. Abbot delivered the judgment: "Failure assessment is difficult, failure recovery is difficult, and the failure modes were not anticipated by the designers." ∎

Des Barker is the former senior test pilot for the South African Air Force

A dragon spreads its wings

SPACEX AND NASA'S COMMERCIAL SPACE MISSION HAVE GONE BACK TO GRASS ROOTS IN ORDER TO ACHIEVE THE FIRST VISIT TO MARS

BY MICHAEL BELFIORE

As NASA makes a transition from the government-owned vehicles it has always relied on for human space flight to private space taxis, (see *Space Travel Inc*, July 2011 issue, pp16-18), one service provider stands above the rest.

Space Exploration Technologies, based near Los Angeles Airport in Hawthorne, California, has the right combination of internal resources, commitment, and technical expertise to become the first private company to send astronauts into orbit. In fact NASA's whole effort to outsource routine orbital flight may well hinge on this one company. With its Dragon space capsule and Falcon launch vehicle, SpaceX is far ahead of its competitors.

Key to the Dragon's success is an aggressive design-and-test philosophy that brings SpaceX step by step to CEO Elon Musk's goal of reaching Mars. Starting with that lofty vision, Musk and company have taken a pragmatic approach to development that seeks to foster sustainability at every stage.

Step one was to develop a workhorse engine, the Merlin, that pays for itself with satellite launches. The first SpaceX launch vehicle, the Falcon 1, garnered the company its first contracts, allowing it to continue to improve the Merlin and scale up to the next-generation vehicle, the Falcon 9.

SpaceX Dragon milestones

June 2010
First flight of Dragon's launch vehicle, the Falcon 9. The rocket carried a dummy payload to stand for the Dragon's weight and size.

December 2011
Dragon's first flight test. The Dragon completed two orbits of Earth and then successfully re-entered to splash down in the Pacific Ocean off the west coast of Mexico.

Early 2012
If all goes as planned, the Dragon will test its solar panels in orbit for the first time and rendezvous with the International Space Station. A docking could be accomplished with the help of the station's robotic arm.

Later in 2012
Dragon will begin cargo deliveries to the International Space Station; 12 flights for a total of 20,000kg of cargo are planned.

2014
First launch of astronauts aboard Dragon.

The Dragon C-2 space capsule from Space Exploration Technologies on pallets

Just as a single Merlin in the first stage powers the Falcon 1, nine Merlins power the Falcon 9. Same engine, same development and test program; bigger, more powerful launch vehicle. The Falcon 9 enabled SpaceX last year to land the biggest commercial satellite launch contract in history, an order from Iridium to launch multiple satellites per flight for a total of US$492 million. This and other revenue pays for development of the Dragon capsule. First customer for the Dragon is NASA, which in 2009 awarded the company a US$1.6 billion contract to deliver cargo to the International Space Station.

Starting with engineering test versions, the company has perfected and tested the Dragon's pressure vessel and parachute recovery systems; in flight test last December it perfected and tested the guidance, navigation, and on-orbit control systems. The next flight, planned for early 2012, will test Dragon's solar panels in orbit and, if all goes well, its ability to rendezvous and dock with the International Space Station.

Since the beginning, Dragon has been designed with astronauts in mind, and to meet the company's own goals, not just NASA's, which is another key to its success. It is not completely dependent on the winds of political change. Even the cargo variant has windows – certainly not a NASA requirement under the cargo contract. Next step will be the development of an escape system that can rocket Dragon and its seven-person crew safely away from a launch mishap, along with crew accommodation, life support, and user-friendly onboard flight control systems.

True to form, SpaceX is already thinking even further ahead. The escape rockets, built into the sidewalls of the Dragon capsule, are also planned to function as a propulsive landing system that will enable the vehicle to set down on any rocky body in the solar system.

SpaceX has also begun development of its third-generation launch vehicle, the Falcon Heavy. Again, the company is building this vehicle under its own initiative, and on the foundations of its past development and test programs. Three of the nine-engine cores that make up the first stage of the Falcon 9 will power the Falcon Heavy.

If development goes as planned, the Falcon Heavy will be the most powerful rocket in existence, with 3.8 million pounds of thrust at launch and twice the mass-to-orbit capability of the Space Shuttle. If it succeeds, it will be because of a robust test program that builds on the success of previous vehicles that use the same engines, avionics, and other hardware. ∎

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

Sudden impact

THE USAF IS MAINTAINING ITS STRIKE EDGE WITH TEST AND EVALUATION OF NEW WEAPONS AND IMPROVEMENTS TO EXISTING HARDWARE

BY TIM RIPLEY

The United States Air Force was planning to spend US$27 billion on research & development, test, and evaluation this year, making it the world's biggest investor in new air power technology.

This has enabled the USAF to field some of the most advanced guided weapons and it has consistently been ahead of the curve in deploying revolutionary battle-winning weapons, such as the AGM-88 High-Speed Anti-Radiation Missile (HARM), the Paveway series of laser-guided bombs, and the satellite-guided Joint Direct Attack Munition (JDAM).

An integral part of the USAF's weapon fielding process is thorough and realistic test and evaluation to ensure new or improved air-launched weapons will work as advertised when delivered to frontline units.

The USAF's Material Command is responsible for weapons testing, with the Air Armaments Center at Eglin Air Force Base in Florida conducting test of weapons, and the Air Force Flight Test Center at Edwards Air Base in California handling the clearance of full airframes. The workload of these organizations varies over time as new procurement programs come to maturity and improvements to existing weapons are begun. Cooperation with the US Navy test community is extensive, particularly involving weapons used by both services, such as the Paveway laser-guided bomb family.

General Donald J. Hoffman, commander, Air Force Materiel Command, commented in October that, "New technology remains critical for today's fight and tomorrow's, and we must keep the right balance between basic research and more mature technology that is ready to move into weapons systems. Our researchers and scientists have transitioned technology that better enables us to anticipate, find, fix, track, target, engage, and assess enemy activity anytime, anywhere."

Maturing existing weaponry

The USAF is running an extensive demonstration and validation program at an annual cost of US$1.4 billion, with a significant element of that being for weapon systems. Much of this funding goes on supporting big tick programs, such as the F-35 Joint Strike Fighter, but some US$100 million is spent annually on air weapons activity. From the current portfolio of work, it is clear that the USAF is concentrating on maturing its existing weapons inventory rather than building new systems.

F-16 HARM targeting system

The USAF suppression of enemy air defenses and destruction of enemy air defenses capabilities are heavily reliant on the F-16 Block 50/52s fitted with the HARM targeting system (HTS) or AN/ASQ-213 pod. This allows the pilots of F-16s fitted with the pod to locate the position of enemy radars and then electronically download that information into an AGM-88 HARM. The USAF is relocating the AN/ASQ-213 HTS R7 pod to the F-16's left inlet hardpoint; the F-16 can simultaneously carry the HTS R7 pod and an advanced targeting pod that allows the pilot to look at enemy positions.

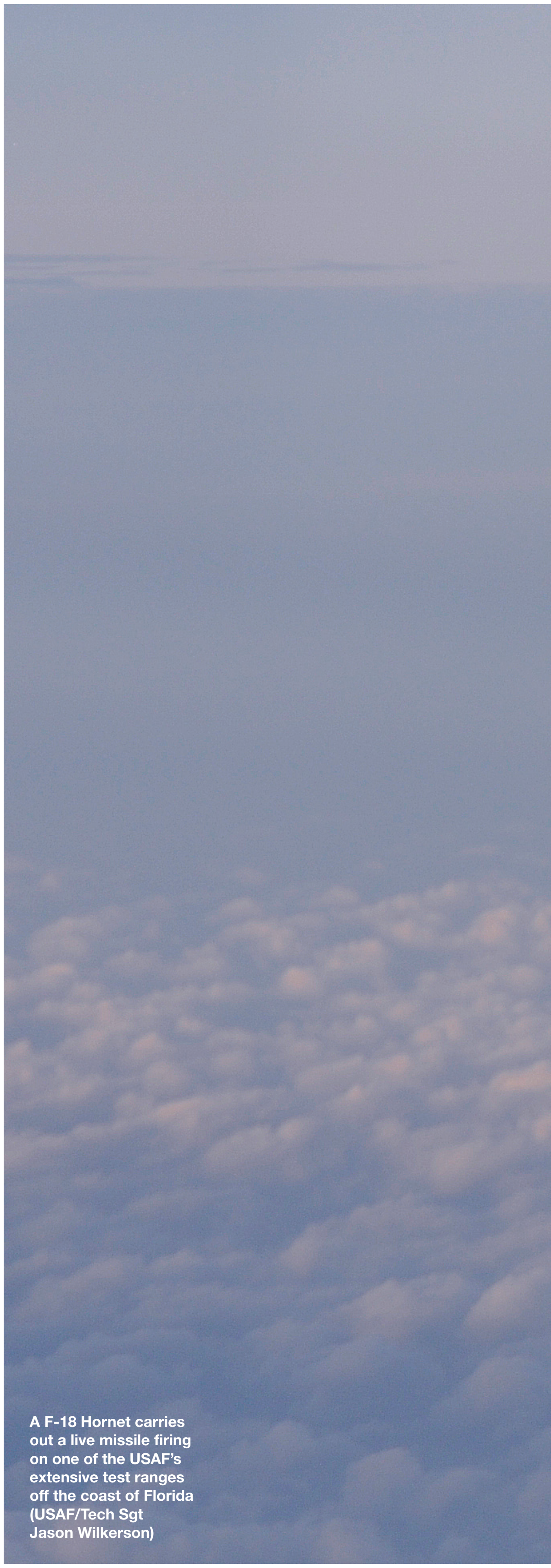
The USAF is still improving the HTS R7 and is currently spending US$12 million a year on tests at Edwards AFB. This includes ground testing, anechoic chamber testing, and an extensive program of flight testing.

AIM-9X

The USAF and US Navy are conducting an ongoing program to improve the AIM-9X Sidewinder short-range air-to-air or dogfighting missile. The AIM-9X is in full-rate production and as part of this, a series of preplanned product improvements that resolve critical obsolescence associated with the computer processors, as well as appropriate software updates, is underway. Some $61 million is still to be spent on development, test, and integration of software updates to the missile, insensitive munitions improvements, and aircraft platform integration.

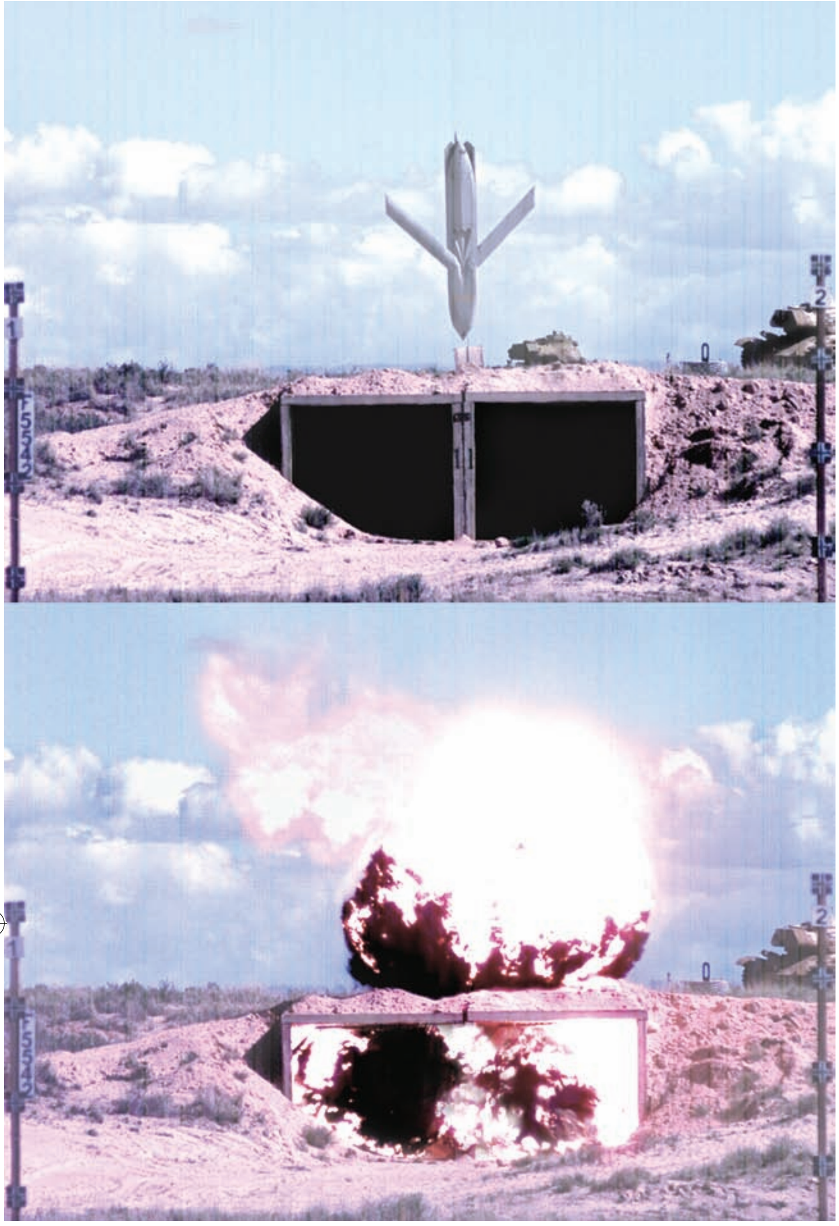
Advanced medium-range air-to-air missile

One of the largest USAF development and test efforts is the continued product enhancement of the AIM-120 Advanced Medium-Range Air-to-Air Missile (AMRAAM), which is running at nearly US$77 million this year.



A F-18 Hornet carries out a live missile firing on one of the USAF's extensive test ranges off the coast of Florida (USAF/Tech Sgt Jason Wilkerson)

"Work underway in the coming year includes continuing developmental hardware in loop testing and captive flight test missions"



LEFT: **A joint air-to-surface stand-off missile, or JASSM, is seen prior to impact and in the very early phase of the warhead detonation. Instrumented test ranges allow USAF experts to fully understand all elements of munition employment**

ABOVE: **A BLU-109X/B, a 2000 lb class munition being delivered for testing at Elgin AFB in Florida by USAF munition experts**

RIGHT: **The GBU-43/B Massive Ordnance Air Blast bomb prototype moments before it makes contact with a ground target in a March 2003 test. The detonation created a mushroom cloud that could be seen from up to 20 miles away**

The AIM-120D (Phase 4) preplanned product improvement program is intended to deliver improved performance via GPS-aided navigation, a two-way datalink capability, and improved network compatibility, and incorporates new guidance software that improves kinematic and weapon effectiveness performance. Dedicated operational tests started this year, with the intention of initial operational capability (IOC) on the F/A-18 E/F and F-15 C/D expected next year.

In addition to integration on these IOC platforms, the program includes integration of the missile onto F-16, F-15E, F-22A, and F-18 C/D aircraft. To continue testing, an estimated US$255.7 million is required up to 2017.

Work underway in the coming year includes continuing developmental hardware in loop testing and captive flight test missions, completion of software design, and completion of the critical design review.

The AIM-120D systems improvement program continues candidate evaluation and selection and preliminary design activities, including lab and/or captive flight tests to provide data necessary to evaluate performance and feasibility of potential upgrades, improvements, parts obsolescence issues, and cost reduction initiatives.

Joint Air-to-Surface Standoff Missiles

The Joint Air-to-Surface Standoff Missile (JASSM) is the USAF's next-generation stealthy long-range, conventional air-to-surface, autonomous, precision-guided, standoff cruise missile. There are two variants: the baseline JASSM and an extended range JASSM (JASSM-ER). The program has been dogged by cost overruns and technical delays. Operational tests are underway at the 46th Test Wing at Eglin AFB and these are expected to continue into 2012 to prove the weapon's maturity for production.

Seek Eagle

The USAF operates a variety of combat aircraft that carry numerous and varied stores (munitions, missiles, fuel tanks, targeting pods, range pods, electronic countermeasures pods, and so on). Aircraft stores combinations differ as operational plans and tactics change and new stores are developed and fielded. Before operational, training, or test use, the USAF must certify these configurations for safe loading, carriage, and separation (jettison and normal release); as well as verify ballistics accuracy under the user-certified carriage and employment parameters.

The US$20 million annual rolling Seek Eagle program completes certification recommendations and recommended flight clearances through combinations of engineering analysis, wind tunnel testing, modeling, and simulation, and ground/flight test and evaluation. In support of certification, the program recommends about 1,000 aircraft/store combinations for flight every year, with analysis and testing requiring from weeks to years depending on the complexity.

Seek Eagle funds are currently budgeted to support certification testing and analysis for new weapons programs (and all new variants) including, but not limited to: small diameter bomb, laser joint direct attack munitions, JASSM, AIM-9X, AIM-120 AMRAAM, miniature air-launched decoy, BRU-57 (smart bomb rack), low collateral damage warhead (BLU-129), wind-corrected munitions dispenser, sniper targeting pod with video datalink, LITENING targeting pod with video datalink, laser-guided bombs, laser-guided Maverick (AGM-65L), F-22 travel pod (MXU-1010), practice bomb (BDU-50), and aircraft instrumentation pod (AN/ASQ-T50).

Future work

As the F-35 transitions from its flight test phase into operational test, it is expected that USAF Material Command will begin ramping up work on the JSF's weapons. This will become the majority of its workload in the middle years of this decade. ∎

Ready for all eventualities

SIMULATION OF ENVIRONMENTAL CONDITIONS AT MBDA'S LABS ENABLES IT TO REFINE THE DESIGN OF ITS MISSILES TO ENSURE THEY MEET CUSTOMER REQUIREMENTS FOR SAFETY AND RELIABILITY

BY WALKER CONAL

Environmental engineering is an activity associated with the definition of natural and induced environmental conditions that a product may encounter during its service life. Engineers consider, by test or assessment, the effects of these environments on the performance of their missiles against the level of performance required by the customer.

Missile manufacturer MBDA's team has extensive experience in the definition and development of cost-effective proving methods to ensure the design meets the technical requirements specification in the contracted environment.

Test programs have to demonstrate missile safety, survival, operation, and reliability against a full range of service environments and all perceived credible accidents after a degree of environmental conditioning, in advance of the in-service date.

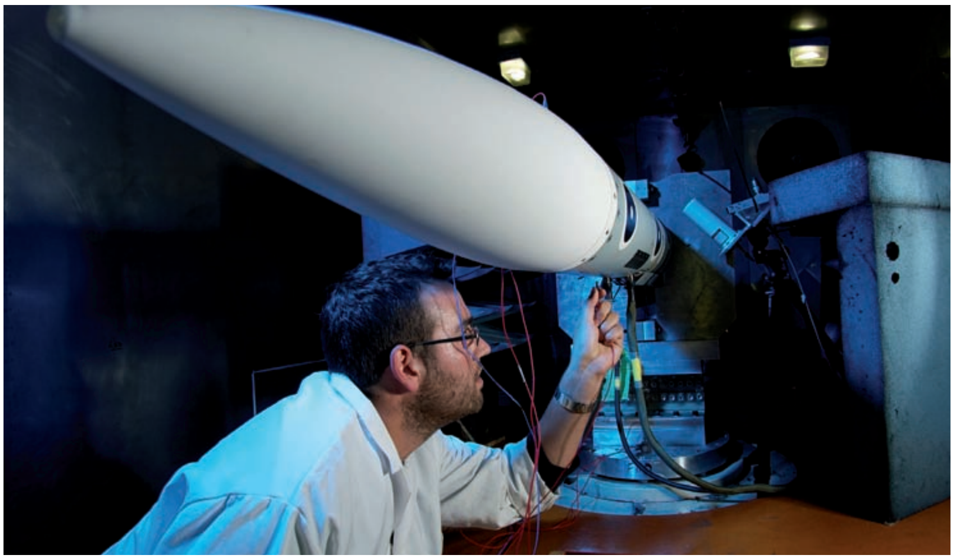
To achieve this, the company's environmental engineering function has a wide range of unique capabilities and skills to support product development and formal qualification. Many of the techniques to enhance the simulation of the real environments have been developed in the UK and France. The expertise covers the areas of environmental conditions (climatic, vibration, and shock), structural, mechanical and fatigue testing, with thermokinetic heating, acoustic testing, radiation effects, electromagnetic compatibility (EMC), and hazardous testing (explosive test items).

MBDA operates a number of environmental engineering laboratories in the UK and France, each complying with the appropriate quality control requirements of AS 9100 and/or ISO/IEC 17025 for a wide range of tests. The facilities are also accredited by their national bodies (UKAS in the UK; COFRAC in France) for the scope of tests defined in their schedules of accreditation.

Environmental conditions

Synthesizing a realistic environment is one of the most challenging tasks in an environmental engineering laboratory. Specifying the most suitable simulation, designing the necessary rigs and fixtures, and providing the required instrumentation and control are key capabilities of MBDA.

The company's environmental laboratories can simulate a range of natural conditions (for example, humidity, temperature, pressure, sea spray) and intrinsic environmental mechanical conditions (mainly shocks and vibration) that are likely to be encountered on land, at sea, or in the air. They specialize in carrying out combined environment simulations as would be found in the real world, for example, vibration in hot desert conditions, or aircraft descending from high, cool temperatures down into warm clouds.



Meteor missile undergoing vibration testing in Stevenage, UK

Special trials facility

MBDA also operates a trials facility in Bourges, France, that enables it to perform a wide range of specific tests for the entire missile range. The company's specialists are skilled in performing live missile flight trials and experiments, including pyrotechnic and dynamic tests on subassemblies, with measurement of all physical parameters and analysis, including high-speed video, inertial measurements, launch and sustained acceleration, launch velocities, pressures, temperatures, and so on. The facility enables MBDA to examine a missile's launch phase and up to 180 miles of flight against a fixed or moving target, as well as various specific tests.

Electromagnetic compatibility

The EMC facilities within the UK and France offer a comprehensive test, design advice, prediction and analysis, and computational electromagnetic service.

Special laboratories in both countries have large, screened anechoic chambers and reverberation chambers, which simulate intense electromagnetic radiation environments. They ensure that defense and aerospace systems are immune to electromagnetic threats arising in their environments, and that they do not unintentionally create any such threats to other systems in their vicinity.

Radiation effects

Ionizing radiation is a survivability threat in defense environments, but it is also a major reliability threat at aircraft cruising altitude and in space due to high levels of natural background radiation. Modern electronic systems are increasingly sensitive to interference and damage by individual interactions of neutron particles (known as single event effects, or SEE). Such neutrons are plentiful in military contexts and in the natural background in the atmosphere.

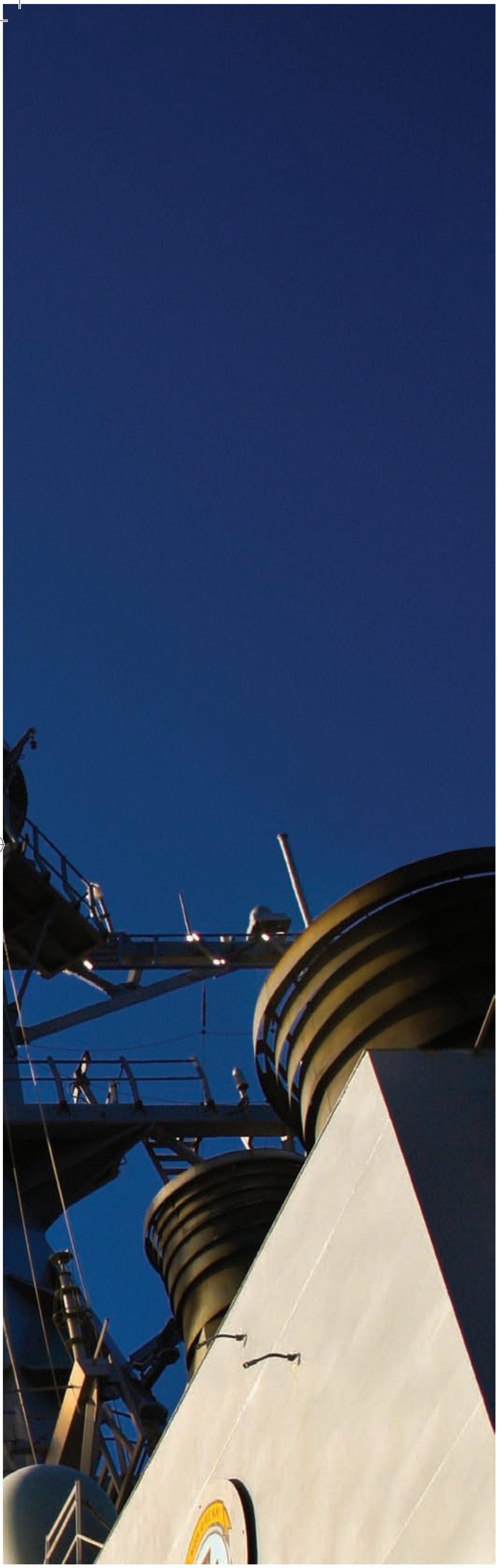
The radiation effects team has developed international expertise in protecting electronic systems against SEE and other radiation and nuclear weapon threats, such as nuclear electromagnetic pulse, thermal flash, and air blast. This includes laser simulators for the effects.

The environmental facilities enable it to support the design of missile hardware by demonstrating and refining design principles with respect to critical environmental conditions. This contributes to the overall design and qualification/validation process, leading to the certificate of design that the customer requires, while boosting missile reliability and lowering the cost of ownership. ∎

Walker Conal is from media relations for MBDA, UK

Euro-vision

ENGAGE ON REMOTE: THE US MISSILE DEFENSE AGENCY (MDA) INTEGRATED TESTING HAS DEMONSTRATED ITS MISSILE DEFENSE CAPABILITIES FOR ITS NEW EUROPEAN ARCHITECTURE



A Standard Missile - 3 (SM-3) is launched from the USS Hopper (DDG 70) in the latest Missile Defense Agency test in conjunction with the US Navy

BY GBADEBO S. ODUTOLA

On the night of April 14, 2011, while most of the United States of America slept peacefully, the US Missile Defense Agency (MDA), US Navy sailors aboard the USS *O'Kane* in the Pacific Ocean, and soldiers from the 94th Army Air and Missile Defense Command, operating from the 613th Air and Space Operations Center at Hickam Air Force Base, Hawaii, successfully conducted the first operational test of the initial phase of a new approach to missile defense in Europe.

This event, designated Flight Test Standard Missile 15 (FTM-15), was one of the most challenging to date for the US missile defense program and incorporated many significant technological and operational firsts. The MDA's commitment to the missile defense mission and recent changes to testing policy are what made these advancements possible.

The mission of the Missile Defense Agency is to develop, test, and field an integrated, layered Ballistic Missile Defense System (BMDS) to defend the USA, its deployed forces, allies, and friends against all ranges of enemy ballistic missiles in all phases of flight.

In 2008, the MDA worked closely with the US military operational test agencies (OTA) to modify the MDA test approach and improve confidence in developing BMD capabilities, and to ensure the capabilities that are transferred to the military are operationally effective, suitable, and survivable.

Subsequently, in 2009, President Barack Obama announced the decision to implement a phased adaptive approach to deploy missile defenses in Europe and, with the United States Congress, directed the Department of Defense to conduct a comprehensive review of US policies, strategies, plans, and programs. Published in February 2010, this Ballistic Missile Defense Review helped to shape the future of the MDA test program.

Integrated Master Test Plan

This new, jointly developed test approach resulted in an event-oriented Integrated Master Test Plan (IMTP). The IMTP lays out a combination of ground and flight tests that extends until all identified data is collected to ensure adequate test investments. A series of operational test events and assessment objectives are also incorporated into the IMTP.

Flight tests provide data for the purpose of validating independently accredited models and simulations, demonstrating crucial performance elements that cannot be modeled successfully, and addressing system and component-level reliability and maintainability. A multitude of sensors and sensor-enabled vehicles, such as high-altitude observatory aircraft, space-based sensors, sea-based x-band radar, land-based radars, and optics, are used to collect this information throughout the execution of each test.

MDA analyzes data collected on a 'hit-to-kill' intercept and the resulting debris to assess the interceptor performance and characteristics of intercept debris. With knowledge of its performance, development of the missile can continue to extend capabilities and prevent anomalies. Debris data is analyzed to determine the effectiveness of the interceptor in destroying the target and the behavior of any debris entering the atmosphere. As the results from every test event are finalized, the IMTP is updated twice a year to accommodate test results, emerging threats, and new strategic directions, such as the phased adaptive approach for missile defense in Europe.

The purpose of this new, phased adaptive approach is to address the threats facing every region, the capabilities available, and the available technologies best suited for deployment.

During 2011, Phase One of the European Phased Adaptive Approach (EPAA) missile defense architecture will have incorporated three major key components: the sea-based

"The purpose of this new, phased adaptive approach is to specifically address the threats facing each region"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Aegis weapon system using the Standard Missile-3 (SM-3) Block IA interceptor; the forward-based US Army Navy/Transportable Radar Surveillance system (AN/TPY-2); and the Command, Control, Battle Management and Communications (C2BMC) system.

Each of these assets plays a role in providing an optimized and layered regional protection against short (<1,000km) to intermediate- (3,000-5,500km) range ballistic missile threats. After developmental and operational testing, subsequent phases of the EPAA will deploy more advanced sensors to improve threat alert and discrimination capabilities, upgrades to the C2BMC system for improved interoperability, upgrades to the Aegis weapon system for increased engagement capabilities, and more capable versions of the SM-3 interceptor in sea-based and a totally new, land-based configuration.

ABOVE: This SM-3 successfully intercepted a medium range target that had been launched minutes earlier from the Pacific Missile Range Facility, Barking Sands, Kauai, Hawaii

RIGHT: A Standard Missile-3 (SM-3) is launched from the USS O'KANE in a joint Missile Defense Agency, US Army and US Navy test conducted April 15, 2011

Interception

As a keystone to the EPAA, Aegis BMD has proven to be operationally effective and suitable, with 22 successful at-sea test intercepts out of 26 attempts, including the intercept of a non-functioning US satellite during Operation Burnt Frost in February 2008. This weapon system has demonstrated the capability to intercept short to intermediate-range, unitary and separating, midcourse-phase, ballistic missile threats with the SM-3 Block IA interceptor.

There are currently 22 Aegis BMD-capable ships. Each ship integrates the planning, detection, engagement, control, and kill assessment functionalities of BMD into the Aegis weapon system for the purpose of maintaining its multi-mission role. This naval fleet of Aegis BMD capable ships is composed of Ticonderoga class cruisers and Arleigh Burke class destroyers.

Several components provide BMD functionality onto these Aegis cruisers and destroyers. The main components are the BMD 3.6.1 computer program, the AN/SPY-1 radar, a modified MK41 vertical launching system, and the SM-3 Block IA interceptor. The AN/SPY-1 is a multifunction, phased-array S-band radar that performs threat surveillance, threat tracking, characterization of ballistic missile targets, and fire control. Additionally, there are four fixed array faces on each Aegis BMD-capable ship, allowing for 360° of effective radar coverage. The AN/SPY-1 radar is essential to the Aegis weapon system as it provides invaluable target information to the BMD 3.6.1 computer program.

The second key component in the missile defense architecture of the EPAA, the forward-based AN/TPY-2, plays a vital role by detecting ballistic missiles early in their flight and providing precise tracking information for use by the entire BMDS. The utilization of this high-resolution, x-band, phased array-radar as a forward-based sensor extends the battlespace for the purpose of enabling earlier detection by other sensors, earlier fire control solutions, and the launching of interceptors based on remote track data. This capability allows a weapon system the opportunity to attack earlier, at longer ranges, and provides the increased opportunity to re-engage a ballistic target. The capabilities afforded by this sensor, in addition to other components within the missile defense architecture of the EPAA, significantly decreases the likelihood of a ballistic missile threat reaching its target.

Plan behind the system

As the final component crucial to the management and operation of the EPAA missile defense architecture, the C2BMC system is the hub that takes each of the aforementioned BMD components and integrates them into the BMDS, which draws on the capabilities of space, land, and sea-based assets operated by the services.

This operational system enables the US president, secretary of defense, and combatant commanders at strategic, regional, and operational levels to systematically plan ballistic missile defense operations, collectively observe the battle as it develops, and dynamically manage designated networked sensors and weapon systems to achieve global and regional objectives. C2BMC globally links, integrates, and synchronizes individual missile defense elements, systems, and operations, and is an integral part of all system ground and flight tests.

Each of these systems played a critical role in the April 14 and 15, 2011, operational test. FTM-15 was executed in response to the Office of the Secretary of Defense, director of operational test and evaluation's recommendation, in his fiscal year 2010 annual report to Congress, that the "MDA should demonstrate the Aegis BMD capability to conduct cued and launch-on-remote engagements in live intercept missions against medium to intermediate-range ballistic missiles." As the first BMDS operational test of the phased adaptive approach architecture, the successful execution of FTM-15 was crucial to the deployment of Phase One of the EPAA.

FTM-15 began with the launch of a representative intermediate-range ballistic missile (IRBM) target from the Ronald Reagan Ballistic Missile Defense Test Site, a site located on the Kwajalein Atoll in the Marshall Islands for the purpose of providing missile testing and space operations support. As this target flew in a northeasterly trajectory, a forward-based AN/TPY-2 transportable radar, positioned on Wake Island, detected and tracked the IRBM target. Trajectory data from the radar was received and processed by the C2BMC system, which also transmitted the remote target data to an Arleigh Burke class destroyer, the USS *O'Kane*. As the USS *O'Kane* received the target data from C2BMC, the BMD 3.6.1 program used this information to perform a search using the AN/SPY-1 radar, develop a fire control solution, and launch the SM-3 Block IA interceptor.

As the IRBM target continued in its flight, the USS *O'Kane*'s AN/SPY-1 radar acquired the ballistic missile target and provided additional trajectory data to the BMD 3.6.1 program. The Aegis weapon system uplinked this target track information to the inflight SM-3 Block IA interceptor. The SM-3 maneuvered to an exo-atmospheric location as designated by the fire control solution and released its kinetic warhead (KW). Using its infrared seeker, the KW acquired the ballistic target, diverted into the path of the target's trajectory, and successfully destroyed the threat in a 'hit-to-kill' intercept using only the force of a direct impact between two high-velocity objects.

RIGHT: A Standard Missile – 3 (SM-3) is launched from the Japanese Ship KIRISHIMA (DDG-174) in a joint missile defense intercept test with the Missile Defense Agency in the mid-Pacific. The SM-3 successfully intercepted a separating 1,000km class ballistic missile target

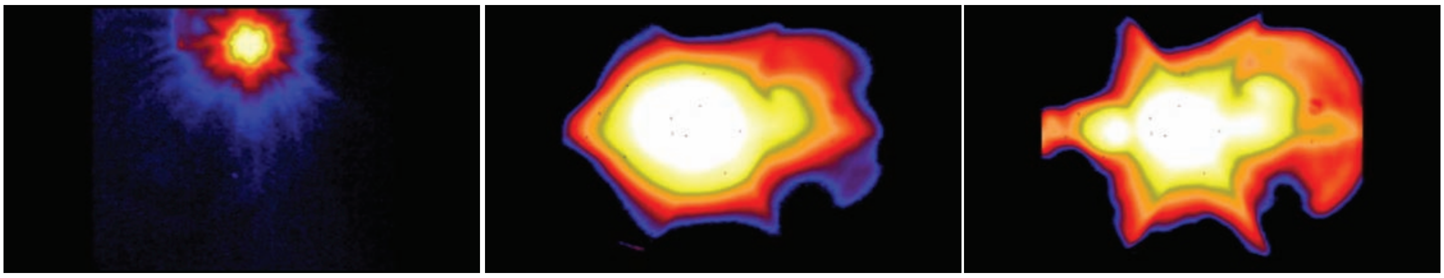
BELOW: The SM-3 successfully intercepted a target missile launched from the Reagan Test Site, located on Kwajalein Atoll in the Marshall Islands

Missile engagement

FTM-15 was the first Aegis BMD intercept of an IRBM target and the first Aegis BMD engagement relying on tracking data from a remote sensor. This test extended Aegis BMD's original design to intercept a longer-range target using the data provided by a forward-based sensor and demonstrated the enormous capabilities of the AN/TPY-2 radar, the Aegis weapon system using the SM-3 Block IA, and the C2BMC system. FTM-15 verified the ability of every component to successfully implement Phase One of the EPAA and serve as building blocks for future phases of the EPAA.

As more advanced sensors, more capable SM-3 interceptors, upgrades to the Aegis weapon system, upgrades to the C2BMC system, and more weapon systems are developed, the MDA will continue to test these technologies, proving their operational capabilities as components of future phases of the EPAA and a larger integrated and layered BMDS. ∎

Gbadebo S. Odutola is a general missile engineer with the Missile Defense Agency, USA



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Patriot games

ADVANCED TESTING AND DEVELOPMENT OF THE PAC-3 AIR DEFENSE MISSILE SYSTEM IS PREPARING TO COUNTER ANY EVOLVING THREAT

BY RICHARD MCDANIEL

On November 1, 2011, the PAC-3 (Patriot Advanced Capability) missile successfully detected, tracked, and intercepted an aerodynamic tactical ballistic missile target in a flight test at White Sands Missile Range, New Mexico, USA.

The test included a ripple fire engagement, utilizing a PAC-3 cost reduction initiative (CRI) missile as the first interceptor and a PAC-3 baseline missile as the second interceptor. The CRI missile includes block upgrades to the PAC-3 baseline missile for performance improvement.

"We continue to improve the capability of the PAC-3 missile, staying ahead of the evolving threat," says Richard McDaniel, PAC-3 programs vice president in Lockheed Martin's Missiles and Fire Control business. "This flight test success completes the validation of PAC-3's latest software and hardware updates as we continue to provide this extremely capable hit-to-kill weapon to the warfighter."

A missile ahead

PAC-3 is one of the world's most advanced, capable, and reliable theater air defense missiles. It defeats advanced tactical ballistic and cruise missiles, and fixed- and rotary-wing aircraft. As the most technologically advanced missile for the Patriot air defense system, PAC-3 significantly increases the Patriot system's firepower, because 16 PAC-3s can be loaded in place of only four legacy Patriot PAC-2 missiles on the Patriot launcher.

Lockheed Martin is producing the battle-proven PAC-3 under a production contract for the US Army Air and Missile Defense Program Executive Office. One hundred per cent effective in Operation Iraqi Freedom, PAC-3 missiles are now deployed across the US armed forces.

Prime missile upgrade

Lockheed Martin is the prime contractor on the PAC-3 missile segment upgrade to the Patriot air defense system. The upgrade consists of the PAC-3, a highly agile hit-to-kill interceptor, the PAC-3 missile canisters (in four packs), a fire solution computer, and an enhanced launcher electronics system. These elements are integrated into the Patriot system, a high- to medium-altitude, long-range air defense missile system providing air defense of ground combat forces and high-value assets.

In 2009, Taiwan became the fifth international customer for the PAC-3, joining the Netherlands, Germany, Japan and United Arab Emirates in fielding the system.

PAC-3 is a high-velocity interceptor that defeats incoming targets by direct, body-to-body impact. It uses a solid propellant rocket motor, aerodynamic controls, attitude control motors, and inertial guidance to navigate. The missile flies to an intercept point specified prior to launch by its ground-based fire solution computer, which is embedded in the engagement control station. Target trajectory data can be updated during missile flyout by means of a radio frequency uplink/downlink.

Shortly before arrival at the intercept point, the PAC-3's onboard Ka-band seeker

> "The MSE is a true spiral development that will enable a very capable interceptor to grow to the requirements of defeating new and evolving threats"

acquires the target, selects the optimal aim point, and terminal guidance is initiated. The attitude control motors, which are small, short-duration solid propellant rocket motors located in the missile forebody, fire explosively to refine the missile's course to ensure body-to-body impact.

PAC-3 MSE

The PAC-3 continues to evolve. The newest version is the PAC-3 missile segment enhancement, or PAC-3 MSE. This provides performance enhancements to the missile that will counter evolving threat advancements.

Under the PAC-3 MSE initiative, Lockheed Martin is incorporating a larger, more powerful motor into the missile for added thrust, along with larger fins and other structural modifications for more agility. The modifications will extend the missile's range by up to 50%. The larger fins, which will collapse to allow the missile to fit into the current PAC-3 launcher, give the interceptor greater maneuverability against faster and more sophisticated ballistic and cruise missiles.

These enhancements are the natural, pre-planned evolution of a system that was baselined in 1994. The MSE is a true spiral development that will enable a very capable interceptor to grow to the requirements of defeating new and evolving threats.

The PAC-3 MSE is packaged in a single canister that stacks to provide flexibility for the Patriot or Medium Extended Air Defense System (MEADS) launcher load-out requirements. PAC-3 MSE was selected as the primary interceptor for the multinational MEADS in September 2006. The MEADS program completed critical design review in 2010 and is now integrating and testing the radars, launchers, tactical operation centers, and reloaders needed for system tests at White Sands Missile Range in 2012.

Homing overlay experiment

Lockheed Martin achieved the first-ever hit-to-kill intercept in 1984 with the homing overlay experiment, using force of impact alone to destroy a mock warhead outside of the Earth's atmosphere. Further development and testing resulted in today's PAC-3, which won a competition in 1993 to become the first hit-to-kill interceptor produced by the US government. The PAC-3 has been the technology pathfinder for today's total conversion to kinetic energy interceptors for all modern missile defense systems. ∎

Richard McDaniel is vice president, PAC-3 programs, Lockheed Martin

The PAC -3 missile uses kinetic energy (its own body to run into the incoming missile)

MEADS launcher

Just this November, the PAC-3 missile segment enhancement (MSE) performed a successful intercept test, the first time it was fired from the Medium Extended Air Defense System (MEADS) lightweight launcher, which employed the MEADS system battle manager. The PAC-3 MSE interceptor is the certified missile round for the NATO MEADS air defense system. The first test firing of PAC-3 MSE was conducted in February 2010.

Two additional intercept flight tests are scheduled to commence in the next two years, including intercepts of an air-breathing threat and a tactical ballistic missile target, preceded by a sensor characterization test. The test series will also demonstrate engage-on-remote, plug-and-fight capabilities, netted/distributed functionality and interoperability through Link 16.

The test included a ripple fire engagement, utilizing a PAC-3 Cost Reduction Initiative (CRI) Missile as the first interceptor and a PAC-3 Baseline Missile as the second interceptor

Warhorse

A SUCCESSFUL QUICK REACTION ASSESSMENT CLEARED THE K-MAX UNMANNED HELICOPTER TO DEPLOY WITH US MARINES IN AFGHANISTAN. FRANK COLUCCI RECAPS MORE THAN A DECADE OF TEST AND DEMONSTRATION

BY FRANK COLUCCI

The US Navy plans to deploy a cargo resupply unmanned aircraft system (CRUAS) with US Marines in Afghanistan in November 2011. A detachment from Marine Unmanned Aerial Vehicle Squadron 1 (VMU-1) will take two Lockheed/Kaman K-MAX helicopters to Operation Enduring Freedom (OEF) for a six-month military validity assessment.

Early in 2010, a non-competitive demonstration sponsored by the Marine Corps Warfighting Laboratory (MCWL) saw two different autonomous helicopters fly generic resupply missions at Dugway Proving Ground, Utah.

In August this year, at Yuma Proving Ground, Arizona, a quick reaction assessment (QRA) managed by VMU-1 and supervised by the Commander Operational Test and Evaluation Force, tried the K-MAX in environments and missions representative of OEF.

According to Eric Pratson, cargo UAS integrated product team lead at the Naval Air Systems Command, "The MCWL designed Dugway demos to prove technology existed. The QRA tested a system under operational scenarios against the joint urgent operational need statement requirements to determine suitability for deployment."

The joint service need statement reflects the grim cost of resupplying forward operating bases and smaller combat outposts in Afghanistan. In the first quarter of 2010, six marines were wounded in the course of 299 fuel/water supply convoys – one casualty for every 50 convoys. An unmanned aerial resupply system promises to take some marines off roads and away from ambushes and improvised explosive devices. It can also offload busy MV-22 and CH-53 crews and reduce their exposure to groundfire and brownout. The critical QRA requirement was to deliver 6,000 lb of cargo a day. The K-MAX hauled 33,400 lb over five consecutive days, including 3,700 lb in a single mission.

The QRA also for the first time gave control of the pilotless K-MAX to enlisted marine air vehicle operators (AVOs).

"The VMU guys were controlling the aircraft from their forward operating base location," explains Kaman UAS general manager, Terry Fogarty. "They're fully trained; they're ready to deploy also."

VMU-1, which is based at Twentynine Palms, California, took the RQ-2 Pioneer UAS to operations Desert Shield and Desert Storm in 1990 and today uses the RQ-7 Shadow and leased ScanEagle for intelligence, surveillance, and reconnaissance. With contractor support, the CRUAS detachment will use the K-MAX to resupply marines day and night.

Pilot optional

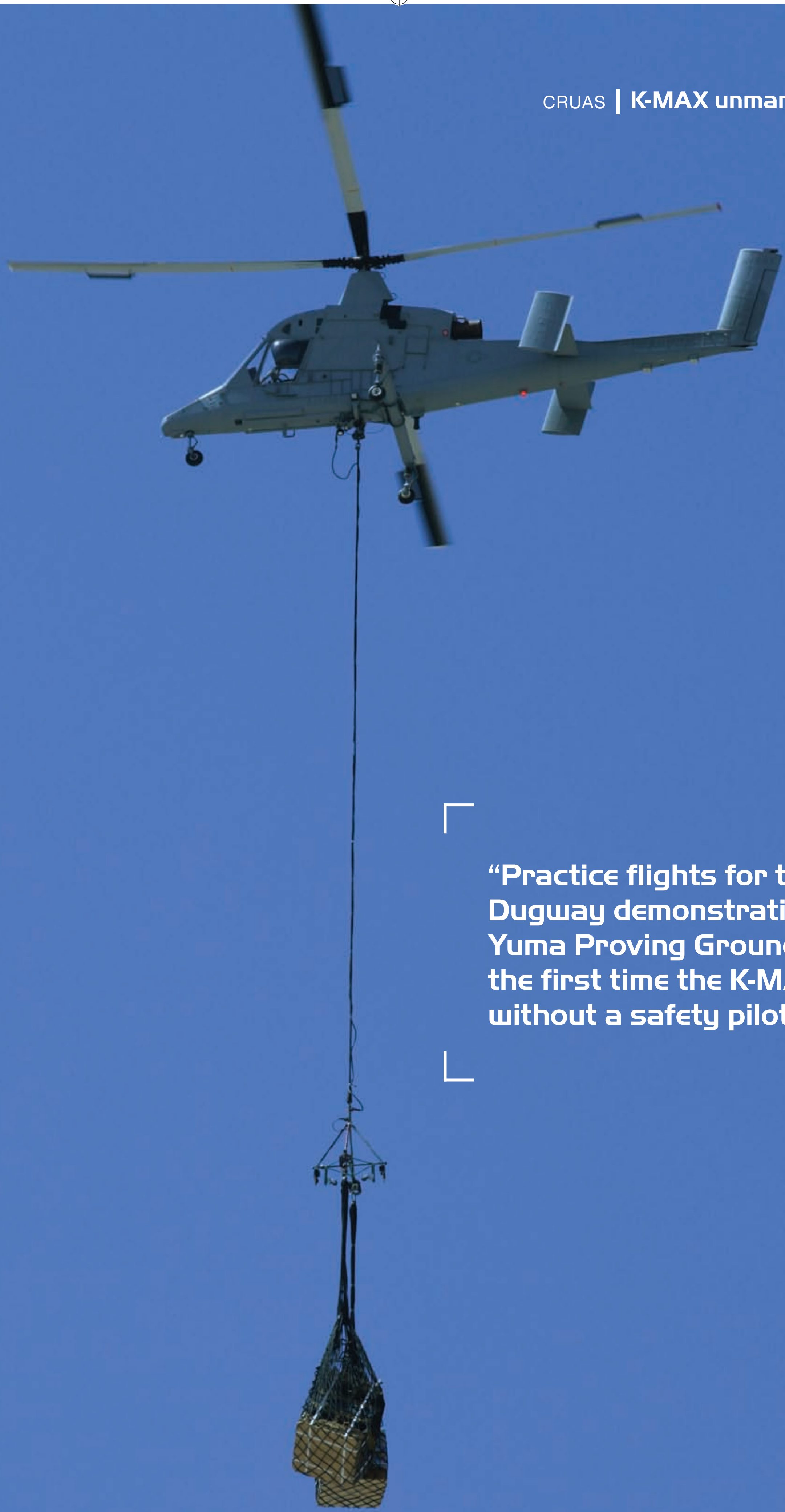
The single-seat, civil-certified K-MAX was designed for sling-load cargo and found commercial applications in construction, logging, and firefighting. The 12,000 lb helicopter, with a Honeywell T53-17A-I turboshaft, carries payloads up to 6,000 lb at sea level.

Kaman foresaw unmanned applications for the K-1200 Multi-Mission Intermeshing Rotor Aircraft demonstrator first flown in 1991 and ultimately flew the K-MAX hands-off with a safety pilot aboard in 1999 for the US Marine Corps BURRO (Broad-area Unmanned Responsive Resupply Operations) demonstration. The optionally manned K-MAX gave Kaman a low-risk UAS demonstrator that could transit unrestricted airspace without FAA certificates of authority.

Under the BURRO contract, Kaman engineers repackaged control actuators from their UH-1 target drone helicopters in a cockpit floor pallet that worked the standard K-MAX cyclic, collective, and pedal linkages. They also introduced automatic load stabilization technology that integrated load weight with center-of-gravity and the rate of load movement.

A limited technical assessment at Quantico, Virginia, in January 2000, saw the first recorded short or long-line external cargo flights by an unmanned aerial vehicle. Kaman subsequently developed a sling carousel that enabled the helicopter to deliver multiple payloads along a programmed path. Autonomous flight control software hosted on a Hamilton-Sundstrand computer developed for the Kaman SH-2G(A) naval helicopter took the K-MAX through programmed GPS coordinates.

In 2005, the unmanned K-MAX air vehicle launched and recovered an unmanned ground vehicle in the Phase I Family of Unmanned Systems Experiment sponsored by the US Army Aviation and Missile Research, Development, and Engineering Center. Kaman teamed with Lockheed Martin Systems Integration (now Mission Systems & Sensors – MS2) in 2007 to market the military K-MAX. In 2008, the team flew the cargo UAS at Fort Eustis, Virginia, for the Army and at Quantico, Virginia, for the



"Practice flights for the Dugway demonstration at Yuma Proving Ground marked the first time the K-MAX flew without a safety pilot"

With servo-flap controlled counter-rotating Synchromesh rotors and no power-hungry tail rotor, the 12,000 lb K-MAX can carry significant payloads at high-density altitudes

Pictures courtesy of Lockheed Martin

RIGHT: The rugged system can lift and deliver a full 6,000 lbs of cargo at sea level

LEFT: The Hummingbird at Dugway carried 1,250 lb sling loads and hovered at 15,000ft

Marine Corps, and demonstrated the ability to change flight plans en route via a ground control link.

A year later in the Colorado Rockies and at Yuma Proving Ground, the autonomous helicopter took 3,000 lb loads to 15,000ft density altitude and delivered cargo day and night to landing zones beyond line-of-sight links.

Dugway demo

Early in 2010, the Marine Corps Warfighting Laboratory (MCWL) at Quantico, Virginia, sponsored a cargo UAS resupply demonstration at Dugway Proving Ground. Two contractors each brought two aircraft to the experiment. Boeing effectively demonstrated the Optimum Speed Rotor A160T, and Lockheed/Kaman the Synchromesh K-MAX. Both types demonstrated exceptional performance at high density altitudes. Dugway is 4,400-4,500ft above sea level, and the unmanned aircraft had to hover out of ground effect with cargo at 12,000ft for at least a minute to simulate Afghan mountain landing zones.

The unmanned helicopters on programmed paths also had to maintain beyond line-of-sight communications 75 nautical miles from the launch point for rerouting in flight. In addition, they had to demonstrate an automatic lost-link recovery in flight and a lost-link emergency landing. Exercise rules called for loads to land within 10m of intended drop points, and for an on-scene operator to move a drop point with a forward operating base control station. MCWL wanted dynamic retasking capability to divert, wave off, or otherwise redirect the autonomous vehicles from a forward operating base under fire.

Practice flights for the Dugway demonstration at Yuma Proving Ground marked the first time the K-MAX flew without a safety pilot. To enhance reliability and responsiveness of the system, Kaman gave the helicopter redundant flight controls with faster-acting actuators. Lockheed Martin, meanwhile, provided software updates and refined the unmanned cargo concept of operations.

An exercise to restock a notional US Marine company, the Dugway experiment supposed an unmanned aerial resupply system able to move 10,000 lb a day over a 150 nautical mile round trip. The demonstration translated into moving 2,500 lb in a six-hour period with a minimum load of 750 lb. Simulated loads of sandbags and water in 40in cardboard containers were hooked on helicopter slings by contractor personnel with the aircraft on the ground. On one sortie, the K-MAX with cargo carousel delivered four 750 lb loads to different locations. The first three loads were delivered autonomously, the last under operator control at the simulated forward operating base about 30m from the drop point. The forward operating base had a full-sized ground control station with tactical common datalink.

QRA

The Dugway demonstration in 2010 showed technology available for an unmanned cargo concept of operations. A subsequent Army exercise with the Natick Soldier Research, Development and Engineering Center saw the K-MAX drop parachute loads from 300-400ft and in one instance release four loads from the cargo carousel in the same sortie.

In December 2010, the Naval Air Systems Command (NAVAIR) bought the two unmanned K-MAX demonstrators and three ground stations for a quick reaction assessment at Yuma.

"We have flight clearance for the unmanned configuration," says Terry Fogarty. "They've been deregistered from the FAA once NAVAIR procured the aircraft."

The Dugway demonstrators need no significant modifications for the QRA. NAVAIR put the K-MAX test aircraft through electromagnetic environmental effects testing at Patuxent River, Maryland, in July.

The Commander Operational Test and Evaluation Force (COMOPTEVFOR) at Norfolk, Virginia, and Air Test and Evaluation Squadron One (VX-1) at Patuxent River formulated QRA scenarios for the marines of VMU-1. Independent COMOPTEVFOR testers design mission-based tests and advise the chief of naval operations on the warfighting capability of new systems.

Eric Pratson at NAVAIR explains, "The QRA was under the direction of COMOPTEVFOR, with personnel from a marine unmanned aerial vehicle squadron providing service-specific operational control."

CRUAS deployment plans calls for government-owned assets to be operated by the contractor in coordination with military personnel in theater. Pratson adds: "With the intent of demonstrating a week in the life of a

LEFT: The K-MAX Cargo Resupply Unmanned Aircraft System (CRUAS) completed a quick reaction assessment at Yuma Proving Ground in August. Marine air vehicle operators were able to replan flight paths and cargo delivery points at a simulated forward operating base

BELOW: At Yuma, the K-MAX moved 33,400 lb over five days, including 3,700 lb in a single mission

Hummingbird support

The non-competitive cargo UAS demonstration at Dugway Proving Ground in March 2010 also saw the Boeing A160T Hummingbird with Optimum Speed Rotor fly cargo missions on behalf of the US Marine Corps Warfighting Laboratory. In December 2010, Boeing received a NAVAIR contract for cargo UAS services to support the US Marine Corps with the A160T and continues to work with the Navy toward a QRA. The Hummingbirds built for the Navy were the first two aircraft off the low-rate initial production line in Mesa, Arizona. They remain at the company's flight test facility in Victorville, California.

The Hummingbird at Dugway carried 1,250 lb sling loads and hovered at 15,000ft to simulate an approach to a 12,000ft forward operating base. For the MCWL demonstration, Boeing engineers showed they could reroute the Hummingbird inflight via satellite link. The UAS flew different auto-return profiles with and without a load to show it could continue the delivery autonomously or return cargo to the launch point. The A160T also delivered cargo with operators using a remote terminal developed by Boeing specifically for the demonstration and follow-on deployments. A160T tests continue at Victorville with the Autonomous Real-time Ground Ubiquitous Surveillance – Imaging System (ARGUS-IS) in an 11ft long cargo pod.

cargo UAS, military participation was necessary to show that these operations are sustainable in theater. Service members were able to train on the K-MAX so they know how to interact with the system once deployed."

Though enlisted marines trained with Lockheed Martin and Kaman personnel over a three-week period prior to the assessment, contractor personnel still hooked loads up at Yuma. Rules for most ground operations around the CRUAS are similar to those around other marine aircraft, except for a flight clearance limit that prevents personnel from coming within an unspecified distance of the hovering K-MAX.

VMU-1 expects night operations to reduce the vulnerability of the helicopter to small arms fire. QRA flights by day or night followed the same range and system safety rules. Personnel around the K-MAX used night vision goggles during low-light flights to improve safety. The CRUAS aircraft had an infrared strobe in place of their standard aircraft anti-collision light, but carried no electro-optical payload.

The QRA K-MAX flew 12 missions in five consecutive days, carrying loads from 1,200-3,700 lb over distances to 50 nautical miles one way. Specific scenarios have not been disclosed, but compared with the Dugway experiment, operating temperatures, flight profiles, and the terrain at Yuma closely approximated Afghanistan.

Fogarty notes: "This time we were flying with 115°F during the day and 98°F at night. It was a big temperature difference." At one dusty landing zone, the K-MAX accurately delivered its cargo while immersed in total brownout conditions. The basic K-MAX has an engine inlet particle separator and needed no engine modifications for the QRA.

The scenarios

In another scenario, marine air vehicle operators rerouted the K-MAX in flight around a newly discovered threat. Another time, marines at the forward operating base used a laptop ground control station to respot a delivery point. The US Marine Corps expects most VMU-1 personnel will operate the deployed helicopters from a main operating base, and air vehicle operators will reside at the forward operating bases where cargo will be delivered. Air vehicle operators with portable ground control stations can see the aircraft flight plan and operating parameters, but according to Fogarty, "They will not have all of the capability at the forward operating base location that is available at the main operating base location."

The QRA report enabled NAVAIR to approve the CRUAS deployment to the combat theater. The marine detachment will include three officers as mission commanders and five enlisted air vehicle operators. The size and composition of the Lockheed Martin/Kaman support element were not disclosed. Kaman has a lengthy K-MAX maintenance history to support the aircraft in theater.

"We created a pack-up of spares that will go with the aircraft when it deploys to Afghanistan," says Fogarty, adding: "The manned K-MAX has more than 266,000 flight hours. We used that experience for the pack-up for the basic aircraft. We also used mean time between failure rates and our own experience to come up with the spares level."

The Navy has the option to extend the six-month deployment.

Separate from the Navy's CRUAS military validity assessment, the US Army has its own unmanned cargo aircraft analysis underway, and NAVAIR is sharing data with the Army Aviation Applied Technology Directorate and the Project Manager's Office for Unmanned Aircraft Systems to advance the concept.

Kaman has 21 K-MAX helicopters available for UAS conversions and stands ready to put the helicopter back into production with various improvements for multiple UAS missions.

Fogarty concludes: "We have a system that is there to carry cargo. It can do that mission very well. There are suggestions to add additional capability, but that's not what the customer wants right now." ∎

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

Personal space

VIRGIN GALACTIC'S QUEST TO PROPEL THE MASSES INTO ORBIT IS CONTINUING, ALBEIT WITHOUT A DATE FOR THE FIRST FLIGHT. JOHN CHALLEN CHARTS THE PROGRESS OF SPACESHIPTWO, THE VEHICLE AT THE CENTER OF THE PROGRAM

> "There were rudder issues early on during WhiteKnightTwo work that got publicized in the media, but it was nothing we didn't expect"

BY JOHN CHALLEN

Richard Branson has proved time and time again that he is very adept at making a success of his start-up businesses. Virgin Galactic, his 'spaceflight for the people' initiative – established in 2004 and based in New Mexico – seems to be no exception to that rule. Despite no official launch date set for the start of the flights into space, more than 500 bookings – at US$200,000 a pop – have been made, one of the most recent being a US$1 million deal for a Singaporean businessman to go beyond the earth's atmosphere with his wife and two children.

Branson's vision is to offer a fleet of half a dozen six-seater vehicles known as SpaceShipTwo, a craft that will feature a 100% carbon composite construction, and be launched in flight from its mothership, WhiteKnightTwo. The unconventional mid-air launch of the space craft will allow Virgin Galactic to "go to space from any runway", it says. Those runways available, however, will still be restricted to the USA. "If we were to fly outside the US we would need to go through a process to get export clearance for the technology to take it outside," says Stephen Attenborough, Virgin Galactic's commercial director. "We haven't applied for that, I don't know whether we would get it," he admits.

Given SpaceShipTwo's final destination, not to mention the complexities in safety, and lack of historical data to refer to, the vehicle's test program has been long and challenging. Before the development team could entertain the thought of building the aircraft itself, it had to think about White-KnightTwo, which was unveiled in July 2008

and made the first of more than 70 flights at the end of that year. As the name suggests, WhiteKnightTwo is a development of WhiteKnight, which itself was a development of Proteus, a tandem-wing, high-endurance aircraft. "The mothership has already completed 72 test flights, and has proved an invaluable part of the test program," explains Enrico Palermo, VP operations, The Spaceship Company, a joint venture between the Virgin Group and Scaled Composites, which is responsible for the aircraft test program. "WhiteKnightTwo climbs to 50,000ft and then releases SpaceShipTwo and its rocket ship," explains the Australian.

(Space) ship ahoy!

SpaceShipOne – the vehicle that completed the first manned private spaceflight in 2004 – was, in turn, used as a basis for SpaceShipTwo. While the testing team learned plenty from the first iteration of the vehicle, which completed more than 40 flight tests during 2003/4, the second generation required a different approach. "The primary safety features and construction techniques used on SpaceShipOne have been carried across to SpaceShipTwo," says Palermo. "But a key difference is that we now deploy the feathering system, one of the key safety features, so that the pilot can be hands-off during re-entry into the atmosphere. The fundamental features [of SpaceShipOne] are still there, but the vehicle is much larger, so the payloads grow much faster. Keeping it simple was very important to the project."

The design has been improved based on what Scaled Composites found out during the original flight test program. "SpaceShipOne was designed so that passengers remained strapped in their seats, but with the Virgin Galactic flights, they can move around the cabin," explains Palermo. "We are in the process of making the vehicle bigger, so that customers can get out of their seats and enjoy the full experience of zero-g.

"We rolled-out the first SpaceShipTwo, named Enterprise, in December 2009, and that really kicked-off the test program," recalls Palermo, a former student at the International Space University. "In early 2010, Scaled Composites started testing landing gear, and in March of that year, for the first time, the craft was airborne in a 'captive carry' flight." This three-hour flight,

BELOW LEFT: The spaceship can be thought of as an air launched glider with a rocket motor and a couple of extra systems for spaceflight

BELOW RIGHT: VMS Eve and VMS Enterprise over the Mojave Desert

The wait for weightlessness

Virgin Galactic admits that some passengers have been waiting more than six years for the opportunity to go into space, but safety issues are heightened, even compared with a standard or commercial aircraft's development.

"I think if you spoke to our customers, many of them have been waiting for maybe longer than expected when they first signed up," says Stephen Attenborough, adding that money from passengers hadn't been used to fund the program.

"I think these people will tell you, firstly, that they absolutely don't want us to rush. This [project] must take as long as it takes to get there safely. As long as they can see that we're keeping to our side of the deal, as the milestones are ticked off one by one, they are happy."

Happy they may be – but for how long? Virgin Galactic is staying tight-lipped about maiden passenger voyage dates, but at least remains committed to seeing the project through: "Safety first – we are not in a race – we will launch only when we are content that it is safe to do so."

ABOVE LEFT: The aerodynamics of SS2's pivoted wings act like a shuttlecock, slowing and controlling the spaceship's re-entry

TOP RIGHT: Virgin Galactic's bullet-nosed rocket, SpaceShipTwo, coming together in the hangar of Scaled Composites in Mojave, California

ABOVE RIGHT: Sir Richard Branson and model of SpaceShipTwo

LEFT: Inside the SpaceShipTwo simulator

explains the 32-year-old, comprised WhiteKnightTwo and SpaceShipTwo taking off and landing together, admittedly with the latter unmanned. "The purpose of these tests was to evaluate the systems on the vehicle [rather than fly SpaceShipTwo]," he continues.

Take to the skies

The first recorded test for SpaceShipTwo took place on June 14, 2010. Over the course of three hours, the aircraft remained on the runway, performing five essential checks. These were: condition of the brakes; landing gear evaluation; brake steering work; skid shoe performance; and general ground handling. According to Scaled Composites, the vehicle performed as expected. "After the captive carry flights, and before we released SpaceShipTwo (on its own), we did more captive carry flights using pilots from Scaled Composites," explains Palermo. "At this stage, SpaceShipTwo was a living, breathing aircraft doing final system checks, and on October 10, 2010, it glided for the first time. WhiteKnightTwo climbed to 32,000ft and released SpaceShipTwo, which was phenomenal," he recalls of the 90-minute flight.

Flight test notes from Scaled Composites read: "All objectives achieved. Very positive and controllable release from mothership at 46,000ft. Slowed to first stall indication. Pilots evaluated the handling and stability through several maneuvers. Expanded envelope to 180 KEAS and 2g's. Evaluated performance with speed brake in and out. Full stop landing executed to the target aim point. Great flying airplane (spaceplane)." Fifteen test flights later, and a number of testing milestones have been reached, including window heater evaluation (January 13, 2011), shortened runway approach and landing validation (May 25, 2011), and post maintenance functional check flight (September 29, 2011).

Palermo admits to problems in the aircraft test phase, but says it was nothing that the development team couldn't handle. "We expected the issues that came up," he says. "There were rudder issues early on during WhiteKnightTwo work that got publicized in the media, but it was nothing we didn't expect. On the same craft, one of the gears collapsed on the left-hand side last year, but it could be easily addressed and fixed.

In the lab

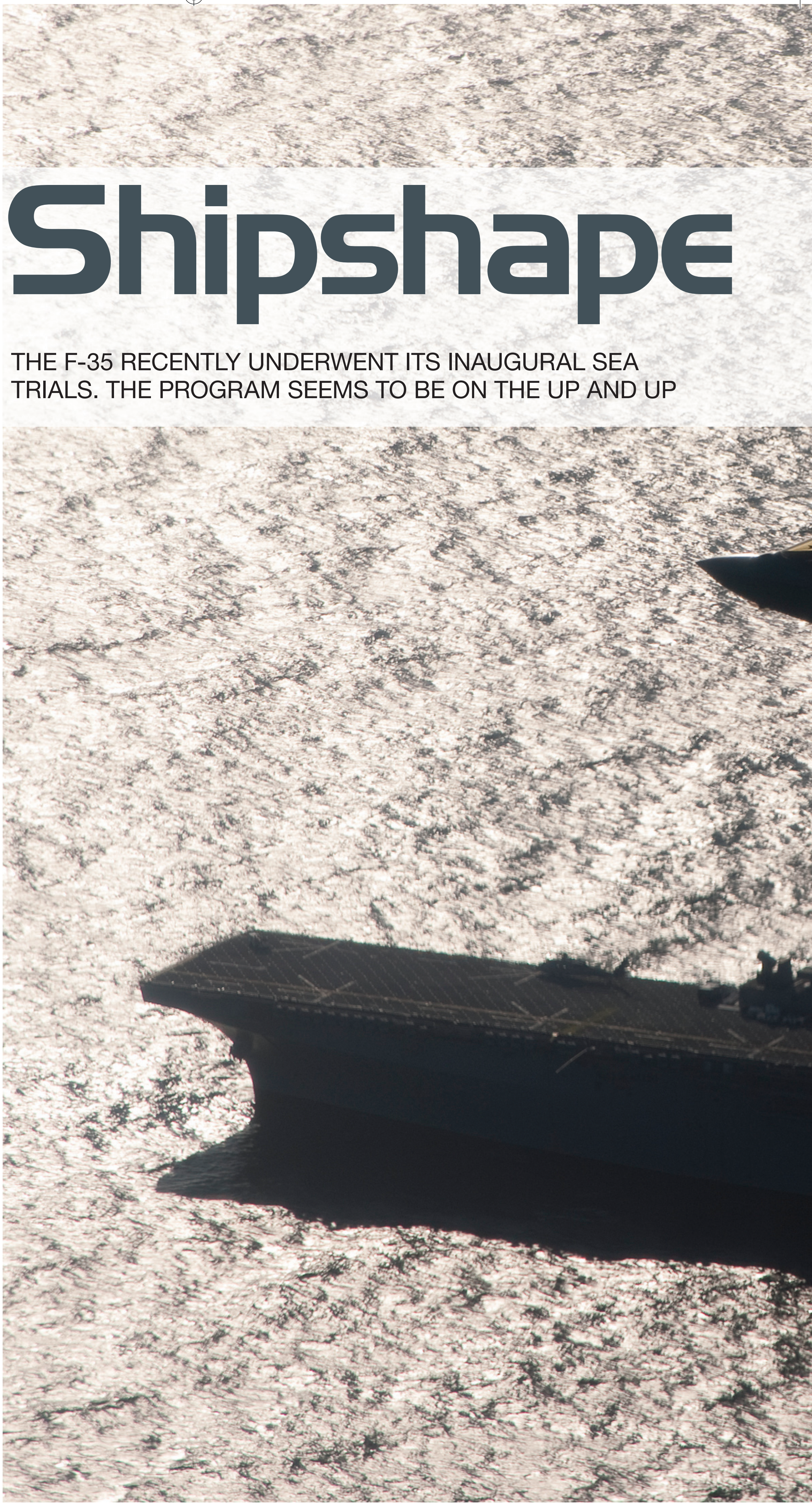
Aside from the data and information gleaned from test flights, computer-based work is still a vital part of the development of SpaceShipTwo. "The test program for SpaceShipTwo has a high-fidelity simulator that was developed at the same time as the aircraft, where many hours have been, and will be, spent before every mission by the crew looking at every scenario and development program," says Palermo. Despite Scaled Composites conducting the flight test programs, Palermo reveals Virgin Galactic will also have a bespoke simulator that will be used for training and proficiency of their pilots who include ex-US Air Force pilot Keith Colmer.

For Scaled Composites pilots, such as former Virgin Atlantic and RAF man David Mackay, special attention was paid to the cabin to aid their training "The cabins on WhiteKnightTwo and SpaceShipTwo have been developed to the same specification, with the mothership having the ability to simulate a lot of the profile of SpaceShipTwo," explains Palermo. "This means before any glide flights, a lot of time was spent on WhiteKnightTwo for proficiency training." In total, WhiteKnightTwo has accumulated more than 200 hours of flight time, the longest journey of which was close to nine hours.

"There are still areas of development for SpaceShipTwo, but the main work is done," admits Palermo. He explains that 2012 will bring plenty more flight testing, with rocket-ready flights also taking place in the coming months. ∎

Shipshape

THE F-35 RECENTLY UNDERWENT ITS INAUGURAL SEA TRIALS. THE PROGRAM SEEMS TO BE ON THE UP AND UP



BY SAUL WORDSWORTH

Operational testing for the F-35 Lightning II may not begin in earnest until 2015, but its test schedule is very much in full swing. Five years after its maiden flight, the fifth-generation multirole fighter continues to make sound progress.

J. D. McFarlan is vice president of F-35 Test and Verification at Lockheed Martin. His role is to oversee flight testing for the three F-35 variants: the F-35A CTOL (conventional take-off/landing) intended for the US Air Force, the F-35B STOVL (short take-off/vertical landing) for use on amphibious ships, and the F-35C CV (carrier variant), the US Navy's first stealth fighter. "We have had a lot of successful testing of late," says McFarlan. "It's been a pretty good year for the F-35."

October was the busiest flying month in the history of the F-35 flight test program, with 122 flights executed. Overall, the cumulative flight test activities for 2011 (as at November 3) were 407 for the F-35A, 296 for the F-35B, and 134 for the F-35C.

"Our objective was to make 872 test flights this year," says McFarlan. "As of November 3, 2011, we are at 837 and closing in. In addition, 6,622 test points was our commitment and we've reached 6,472. The CTOL even achieved the F-35's maximum design speed limit of Mach 1.6 for the first time in October."

STOVL trials

Alongside catapult testing (see *On the Catapult*, far right), the most recent and largest scale trial undertaken in 2011 was the completion of the F-35B STOVL ship suitability testing aboard the USS Wasp off the coast of Virginia.

"This may have been a 19-day test program," observes McFarlan, "but the event was the result of more than a year's worth of planning, training and the overcoming of logistical challenges. The moment we had our first touchdown we knew that all that hard work had paid off and the ship trials for the F-35B, the world's first supersonic STOVL fighter, were finally underway."

According to McFarlan, every aspect of the operation required perfect execution. The logistics of testing two jets (the BF-2 and BF-4) on a short-deck vessel for the first time were in his words "daunting" – the omission of one small detail could result in long delays.

Progress made

It was back in the summer of 2010 that work began that would culminate in the successful vertical landing of the F-35B. The F-35 Integrated Test Force (ITF) based out of Naval Air Station Patuxent River, Maryland, began meeting on a regular basis to discuss what equipment should be used aboard the amphibious assault ship.

"From air coolers to laptop computers, every item of equipment had to undergo testing at the Naval Electromagnetic Radiation Facility," says McFarlan. "This was to determine whether its interaction with the F-35 and the ship would stand up to the highly charged electromagnetic environment of a ship at sea." The ITF team also worked with

"We completed an extremely successful program with a total of 72 vertical landings and the same number of take-offs. We always like it when the numbers tally!"

On the catapult

Lockheed Martin's F-35 carrier variant designed for the US Navy recently completed its inaugural catapult testing. The F-35C test aircraft CF-3 returned to Naval Air Station Patuxent River in mid-October with all test personnel satisfied that the two major catapult test events went according to plan.

"The testing went very well," said Tom Chaillou, lead government ship suitability engineer. "The aircraft completed the structural survey and the steam ingestion was a non-factor."

More than 50 launches were conducted by the test team in order to collect the necessary data. The steam ingestion data produced strong enough results to allow the number of test launches to be reduced by four. Future catapult testing at Lakehurst and Patuxent River will include launches at varying weights and stores with increased mission system functionality.

USS Wasp and her sister ships are the first specifically designed to accommodate Vertical/ Short Take-Off and Landing (V/STOL) jets

"We didn't blow any sailors off the deck and we didn't warp any decks on the ship, which obviously everyone was very pleased about"

F-35 testing timeline

1997	– Lockheed Martin and Boeing selected for Joint Strike Fighter concept demonstration phase
October 2000	– X-35A completes first flight in Palmdale, California
February 2006	– first F-35 is produced in Fort Worth
December 2006	– maiden test flight
January 2008	– first military test pilot evaluates the F-35 on 26th flight
March 2008	– first aerial refueling testing on 34th flight
November 2008	– first time F-35 reaches supersonic speed
June 2008	– maiden test flight of the F-35B
November 2008	– CATBird begins inflight integration of F-35 avionics
January 2010	– testing of the STOVL propulsion system begins
March 2010	– first vertical landing performed
June 2010	– first flight of F-35 carrier variant
February 2011	– first flight of first production F-35, AF-6
April 2011	– SDD F-35 fleet surpasses 1,000 flight hours

the Navy and Marines to ensure the USS *Wasp* was ready to receive the F-35. Special monitoring stations and additional instrumentation were loaded onto the ship – which typically accommodates the AV-8B Harrier – so that engineers and analysts could track how the F-35 and the ship were performing, as well as how the two were interacting.

"This was of course vital to the testing process, but just as important was the training and education involved," he says. "The ITF team coordinated with the ship's crew to develop a training schedule for every participant, from the engineers right through to the pilots."

Testing on a ship is not the easiest of environments. To make life more straightforward for the engineers, the ITF team created mock-up control rooms in advance to reflect those they would encounter on board. As for the pilots, McFarlan elaborates: "We simulated a ship on the ground and conducted testing operations as if we were doing vertical landings and short take-offs," he says. "An outline was painted on the runway surface at Pax River to imitate those that are found on the USS *Wasp*. Each pilot was required to conduct four short take-offs and four vertical landings from the painted deck in order to qualify for the ship trials."

Program success

During testing, the two F-35B Marine Corps jets successfully accomplished vertical landings and short take-offs under various conditions. By the third week, the BF-2 and BF-4 were operating simultaneously.

"We completed an extremely successful program with a total of 72 vertical landings and the same number of take-offs," said McFarlan. "We always like it when the numbers tally! All our objectives were accomplished, including understanding how the aircraft performed in the operational scenarios around the ship with all the different wind conditions you get aboard, along with various techniques for vertical landings and short take-offs." A further goal was to collect environmental data to measure

the F-35B's sound, power, and thermal impact, and capture its effects on the flight deck and superstructure components. This was successfully completed by 31 engineers from the Naval Sea Systems Command. Also tested was Thermion, a new non-skid deck surface supported by a mechanical bond of ceramic and aluminum. Thermion is designed to make surfaces more resistant to heat and wear and tear. The new material showed no signs of heat stress, another good result for the F-35 and possibly for all ship surfaces in the future.

"We didn't blow any sailors off the deck and we didn't warp any decks on the ship, which obviously everyone was very pleased about," says McFarlan. "Now the jets are back and we move on."

The next F-35 sea trial, DT-2, is scheduled for 2013 after the USS *Wasp* receives additional modifications for F-35B operations.

The future

"Coming up in 2012 we will focus on two types of testing," says McFarlan. "The flight sciences testing including envelope expansion and drop testing, and mission systems testing."

The mission systems on the F-35 include the most advanced and unique sensors ever developed for a tactical fifth-generation aircraft. Infrared radar including the Electro-Optical Targeting System (EOTS) and Electro-Optical Distributed Aperture System (EO DAS) are set to be fully trialed next year.

"DAS is unique for a fighter aircraft," says McFarlan. "With six sensors positioned around the aircraft at 360°, a total spherical situational awareness system is created. As part of DAS we have a helmet-mounted display system (HMDS), which projects missile warning and situational awareness information onto the visor. We've started testing the HMDS in the last week."

Latest challenges

McFarlan believes that to date, nothing the test team has come across could be characterized as anything other than normal development learning. On the STOVL aircraft they had a minor problem with the auxiliary air inlet doors – two doors that open behind the lift fan that provide air to the main engine.

"We had to make very small changes to that door to allow us to continue testing, which we have done. So far we have completed 266 vertical landings and the doors have opened every time."

On the CTOL program, the learning curve has been in the area of flight control software. However, it has always been the test team's plan to upgrade the software as they expand the flight envelope and learn how the aircraft flies.

"Then we give the data back to the engineers and they modify their software," says McFarlan. "This is very typical development learning. In the flight test programme our priority is always to give the engineers the data they need to either say their configuration performed as intended or provide them with the data to make the necessary changes. Everything has gone fine so far. We just need to keep looking to the future," he concludes. ■

F-35 integrated test force personnel and F-35C test aircraft CF-3 returned to NAS Patuxent River last week after completing two major catapult test events. The goal was to complete an initial structural survey of the aircraft to withstand launch stresses and the impact of steam ingestion into the engine

Up and running

THE NEXT GENERATION VERTICAL LIFT PROGRAMME (NGVL) IN THE UK IS A COLLABORATIVE PROJECT THAT FOCUSES ON THE LATEST HELICOPTER BLADE TRIALS

BY DAVID OLIVER

In a time of diminishing defense budgets, UK contractors are downsizing their workforces. One of these is the UK's largest helicopter manufacturer, AgustaWestland, which is cutting up to 375 jobs at its Yeovil factory. Although the defense sector continues to account for the bulk of its output, the company is looking at innovative new ways of restructuring its operations.

In July the UK government announced that it was investing £32 million in AgustaWestland, to help introduce its new civil twin-turbine medium-lift helicopter, the AW169, that was launched at the 2010 Farnborough International Air Show.

Allied to this initiative is the company's Next Generation Vertical Lift (NGVL) program that will encompass three research and development projects focusing on main and tail rotor blades, transmission systems and flight trials. The three-year collaborative program will build on the success of two earlier projects supported by the UK Technology Strategy Board's Rotor Embedded Actuator Control Technology (REACT) and Rotorcraft Technology Validation Programme (RTVP), both of which are focused on developing features that greatly improve helicopter blade performance, vibration control and vehicle

AgustaWestland has received government funding for the production of its new civil AW169 multirole helicopter (Picture courtesy of AgustaWestland)

> **"In most machines, vibration is an unwanted side effect of moving components, which causes undesirable discomfort, noise and unreliability"**

health management. The Technology Strategy Board, a business-led government body sponsored by the Department for Business, Innovation and Skills (BIS), brings together business, research and the public sector to support and accelerate the development of innovative products and services that meet market needs, tackle major societal challenges and help build the future economy. The government funding to AgustaWestland is divided into a £22 million loan on market terms to assist production, along with a £10 million grant toward rotorcraft research and development through the Technology Strategy Board.

The NGVL program will also be instrumental in helping to secure key vertical lift research, design, development and manufacturing jobs in the UK for the current and next generation of apprentices, graduates and engineers. Technologies to be researched, developed and delivered as part of the program include soft beam main rotor blades, innovative blade damper technology, fit-and-forget gearboxes, real-time rotor blade health monitoring, and greener, more sustainable helicopter transmission systems.

Rotor collaboration

AgustaWestland will collaborate with SMEs including Shearline Precision Engineering Ltd, a Cambridgeshire, UK-based company that specializes in laser technology and rapid prototyping, and with the Universities of Bristol and Liverpool, which will lead on specific R&D activities. The program will strengthen AgustaWestland's engagement with other leading manufacturers as a Tier 1 partner in the recently formed National Composites Centre (NCC) in Bristol, which has been selected to become part of the new High Value Manufacturing Technology Innovation Centre (HVM TIC), delivered by the Technology Strategy Board.

The HVM TIC will provide an integrated capability and embrace all forms of manufacture using metals and composites, in addition to process manufacturing technologies and bioprocessing. It will draw on university research to accelerate the commercialization of new and emerging manufacturing technologies.

The Bristol Laboratory for Advanced Dynamics Engineering (BLADE) is part of the dynamics and control research activity at the University of Bristol concerned with research problems relating to engineering dynamics, including flight dynamics, bifurcation analysis, active vibration control, rotating structures, laser measurement and nonlinear modal testing, computational fluid dynamics and experimental aerodynamics, and control engineering including adaptive, distributed and autonomous control systems. Simulation of rotor flows is extremely expensive, as the rotor wake, and its effect on the following blades, needs to be captured accurately. Hence the development of appropriate flow-solver and grid generation technology is vital.

The AW101 BERP IV testbed jointly funded by AgustaWestland and the MoD (Picture courtesy of David Oliver)

The production line at AgustaWestland's Yeovil plant (Picture courtesy of AgustaWestland)

The GKN-fabricated Wildcat airframe assembled from monolithic machined aluminum structural parts (Picture courtesy of GKN)

"In most machines, vehicles and structures, vibration is an unwanted side effect of moving components"

For many years the Aerospace Engineering Department at University of Bristol has had close links with AgustaWestland in its teaching and research activities. One of the strong themes of the research collaboration has focused on the many vibration and structural dynamic problems that plague helicopters more than almost any other man-made structure.

In most machines, vehicles and structures, vibration is an unwanted side effect of moving components, which causes undesirable discomfort, noise, unreliability and – in more extreme cases – structural failure through fatigue. However, in helicopters there is an in-built first-order dynamic loading that results from the inherent non-symmetry of the large aerodynamic forces on the rotor blades. This is particularly acute when the helicopter is in forward flight as well as hovering. As a result, the levels of vibration in a helicopter tend to be much higher than those experienced in other vehicles, hence the strong interest in the structural dynamics expertise that can be found among the many research groups that are active in the BLADE laboratories.

Partnerships

This is the background to the creation of a strategic partnership between the University of Bristol and AgustaWestland, which is modeled on the University Technology Centre (UTC) format developed over the past 20 years. Although the UTC is primarily concerned with the prosecution of a large research program, it is intended that as a strategic partnership there will be many more interactions between the university and the company than merely those dealing with the core research tasks.

UTC teams will become involved in other technical activities at AgustaWestland including participating in vibration testing of a new helicopter – a major milestone in the development of any new aircraft and an event rarely observed by 'outsiders' to the company that builds it.

AgustaWestland has already benefited from working with its academic partners, which has led to the adoption of innovative new production methods in its military product range. These include the development of the composite British Experimental Rotor Programme (BERP) IV main rotor blades for the AW101 multirole medium-lift helicopter, and the new fatigue life airframe fabricated by GKN at Yeovil for the AW159 Wildcat, which will replace the British Army and Royal Navy Lynx fleets.

The AW169 – aimed at the EMS/SAR, law enforcement and oil support markets – will be the first AgustaWestland helicopter to benefit directly from the NGVL program. Scheduled to make its maiden flight in mid-2012, the AW169 has already attracted orders from the Warwickshire & Northamptonshire Air Ambulance service as well as customers in Canada, New Zealand and Spain, which will go some way to ensuring the UK maintains a healthy, vibrant helicopter industry for the foreseeable future. ∎

Composite forming at the GKN Aerospace plant, based at Yeovil (Picture courtesy of GKN)

CAD/CAM of the AW159 Wildcat, the replacement for AgustaWestland's Lynx range of military helicopters (Picture courtesy of AgustaWestland)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BY CHRISTOPHER HOUNSFIELD

About two years ago, the people at NASA came up with the Green Flight Challenge, a competition that was hosted by the CAFE Foundation (Comparative Aircraft Flight Efficiency), which promotes more environmentally friendly means of aircraft transportation.

The prize? US$1.5 million handed out by NASA. The challenge? Wanting to see exactly how far the idea of electric-powered airplanes could go, NASA asked competitors to build an airplane that could travel 200 passenger miles in less than two hours, on the equivalent of less than one gallon of fuel per airplane occupant – or the equivalent in electricity.

The competition was held in late September 2011 at the CAFE Foundation Flight Test Center at Charles M. Schulz Sonoma County Airport in Santa Rosa, California.

Originally, there were 13 entries. But after two years of work, only five finalists achieved qualification to take part, due to lack of funding or technical failures. The field then further diminished to just three contenders, after the GFC team had to drop out with mechanical problems and Embry-Riddle Aeronautical University's team faced disqualification because of a conflict between the contest and the team's own operational rules.

And the winner is...

Team Pipistrel-USA.com's winning four-seat, electric-powered aircraft, the Taurus G4, flew nearly 200 miles non-stop while achieving 403.5 passenger mpg. Its astounding efficiency was more than twice that of the piston-powered aircraft in the competition.

Equally promising was team e-Genius, which won the Lindbergh Prize for Quietest Aircraft, with a peak take-off noise of only 59.5dBA at 250ft.

Embry-Riddle entered a two-seat aircraft and competition rules require both seats to be occupied. However, the team brought only one qualified occupant, since the university's flight operations rules do not allow more than one person in a university aircraft that is certified in the experimental category. The aircraft also does not have a ballistic chute, which is a contest requirement. Officials later ruled that the team would be allowed to compete using ballast in place of a person, but would not be eligible for any prize money.

Embry-Riddle's pilot, Mikhael Ponso, explains to *Aerospace Testing International*: "It was because of two rules. There are pages and

Going electric... the hybrid challenger

TWO YEARS AGO, NASA THREW DOWN THE GAUNTLET AND SET UP A COMPETITION TO FIND AN AIRPLANE THAT COULD FLY 200 MILES ON ONE GALLON OF FUEL. ONE CONTENDER'S OFFERING WAS A CONTENTIOUS HYBRID AIRCRAFT

"The first time that an electrical motor actually worked in flight – that was really cool"

pages of rules and one of them is, if you have two seats you must have two pilots in the aircraft, and that is against university policy. We use one pilot to minimize risk.

"The other rule was about the ballistic parachute, but for that one we basically just ran out of time to test it before we could get to the competition."

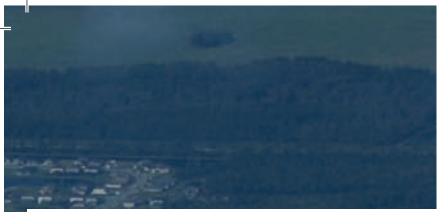
But they still competed. "We did. We showed up there – there are 200 students involved in this project, about 20 of whom worked really hard on it for about two years, so we decided to show up to see what they could accomplish."

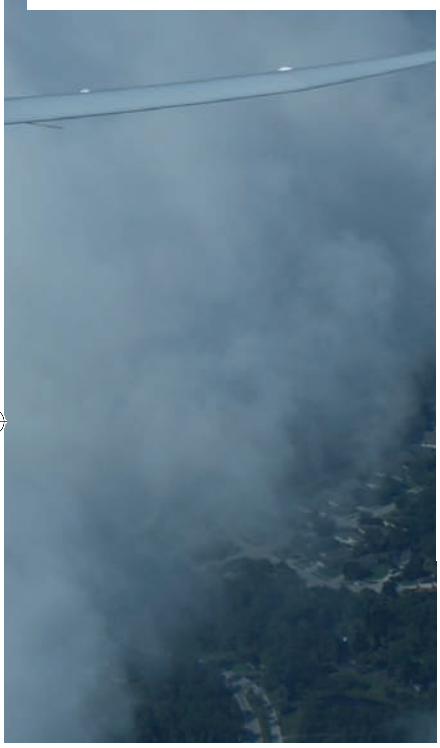
The 31-year-old Ponso is an affable man. The Brazilian was an alumnus of the university less than 10 years previously, and hardly seems to have left his student years far behind, despite being chief test pilot and the university's associate director of the Eagle Flight Research Center.

"After I graduated, I started working there as an instructor. Then I became a check pilot, giving the check rides for all the licenses. I started doing flight testing for flight training devices,

ABOVE: The Eco Eagle's 75ft wingspan gives it a 50:1 lift-to-drag ratio

RIGHT: Mikhael Ponso, who piloted the airplane for all of its test flights, is also an alumnus of Embry-Riddle University





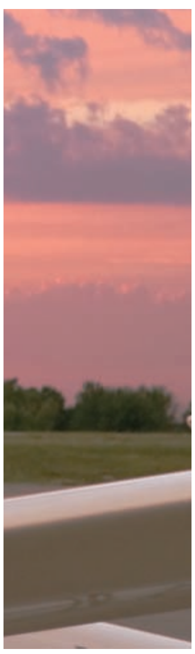
Beyond the Eco Eagle

Embry-Riddle Aeronautical University is the world's largest, fully accredited university specializing in aviation and aerospace. It has just introduced a BS in Unmanned Aircraft Systems (UAS) Science degree program.

Mikhael Ponso also says there are a number of projects his department is due to get involved in, particularly with regard to green power and UAVs: "The next thing we're looking to do is set records. We are talking with SAI and the National Aeronautic Association and there are some other projects that Embry Riddle is looking into... mostly in the direction of green aviation and unmanned aviation.

"I think we're very close to going electric. Those guys at the competition proved that it can certainly be done. We have an electro-aeroplane here that flies well and I think batteries are improving by the day and there's a lot of money being spent. So I think once the batteries arrive, the aircraft will follow."

ABOVE: **The Eco Eagle is expected to enter other national green aviation expos, and will be developed further**



collecting data to create the aerodynamic models of the flight training device.

"It's really diverse, which is what I like the most. Some days I will come in and do mostly office stuff – meetings, creating contracts, or a proposal, or trying to get sponsorship deals. Then I'll spend whole days in the hangar doing mechanical work on the aeroplanes. And on other days, I'll spend the entire day flying."

The Embry-Riddle entry

The university achieved an aviation first by flying in a hybrid propulsion aircraft. A team of nearly 200 worked on the Eco Eagle, which combines an efficient gas motor in the airplane with an electric propulsion system powered by batteries.

Embry-Riddle based its design on a Stemme S10 motor glider, but had to change the entire propulsion system. Austrian company Rotax donated the engine, with a German company donating an electrical motor.

Ponso continues: "We got a company from Switzerland to donate the motor controller and then we implemented that together with the Rotax engine. There was a clutch system that we designed in-house, which was connected through a shaft to the propeller. So then we could either run the Rotax engine or shut it off and run the electrical engine, so it's pretty unique. The first time an electrical motor actually worked in flight – that was really cool."

The Rotax 912 ULS 100hp engine creates the propulsion needed for take-off, and when the aircraft reaches cruising altitude, the electric prototype engine takes over. The Eco Eagle's 75ft wingspan gives it a 50:1 lift-to-drag ratio, which helps it to achieve maximum efficiency. One of the biggest challenges is the 200 lb of batteries it carries to power the electric engine. The battery packs are housed in two troughs in a section of each airframe. Each battery pack is wired via an extensive network to the engine.

As the first test pilot to fly the airplane, what is Ponso's view?

"On take-off, we use the Rotax because it has 100hp. The electrical motor has only 40hp, so you can't get the speed and the climbs that you can get from Rotax. Once we're up at altitude, we can switch to the electrical motor. To do that we actually shut off the Rotax, glide for a couple of seconds, and then we turn on the electrical motor.

"With full power on the Rotax, we can get probably close to about 135kts. On the electrical motor, we'll probably get around 90kts, maybe 100kts."

Next stage

Despite its disqualification from the competition, team Embry-Riddle is not downhearted and is keen that the unique project continues.

"We were very happy," says Ponso. "The university was really not after the money; it was more about wanting the students to learn and to have an opportunity to work on a hands-on project instead of just being in the classroom.

"There were about 200 students that saw this project through. A lot of them worked long hours, so the amount of knowledge and experience that they got from this you can't teach in the classroom. Plus, the project has gained a great deal of exposure, even in Europe," Ponso enthuses.

To advance the Eco Eagle project, a number of improvements and adaptations will need to be made. Ponso is eager to break more records with his hybrid airplane, and to take it to Oshkosh, the world's biggest airshow. He says they need to concentrate most on the electrical component.

"There needs to be a bit of improvement of our electrical side, mostly concerning the software and the coding for the electrical motor. The battery system can possibly be improved, too. We have a test flight before the end of the year, where we have implemented a sort of wireless system, so that now everyone in the hangar will be able to see the instrumentation I can see – instant telemetry, which is cool," he says.

The airplane managed only five official problem-free test flights before it was shipped off to the competition. What problems did Ponso encounter before this meager number of take-offs?

"There were two big ones. One was cooling – there were cooling problems before, but when we put the Rotax in, that didn't change. The Rotax was also running hot. We spent more than a week doing flight tests trying to figure out how to cool it, before we realized it was actually running too cool.

"The other problem was that the electrical motor didn't work in flight. We had run the electrical motor and tested it multiple times on the ground, but up in the air we couldn't get it to run. Then we figured out really late that because the prop was windmilling so fast before with the Rotax, the electrical motor wouldn't turn on, so that took us another week. We solved it just before the competition," he explains.

What is next for the university's chief test pilot?

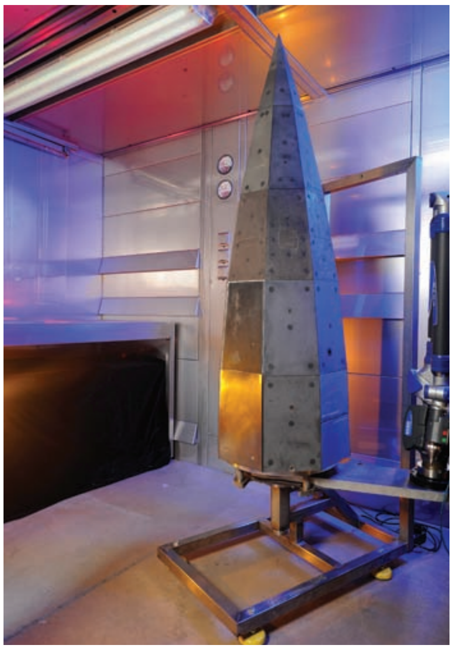
"I really enjoy what I do, but sometimes I think about going into an airline or getting a corporate job, but I don't think you can get such a diverse role as I have here," says Ponso. "I get to talk to the engineers and give engineering input, and I get to do flight tests on really exciting aeroplanes, so I'm really happy where I am and don't foresee a job change anytime soon. I just hope to help aviation go more green."

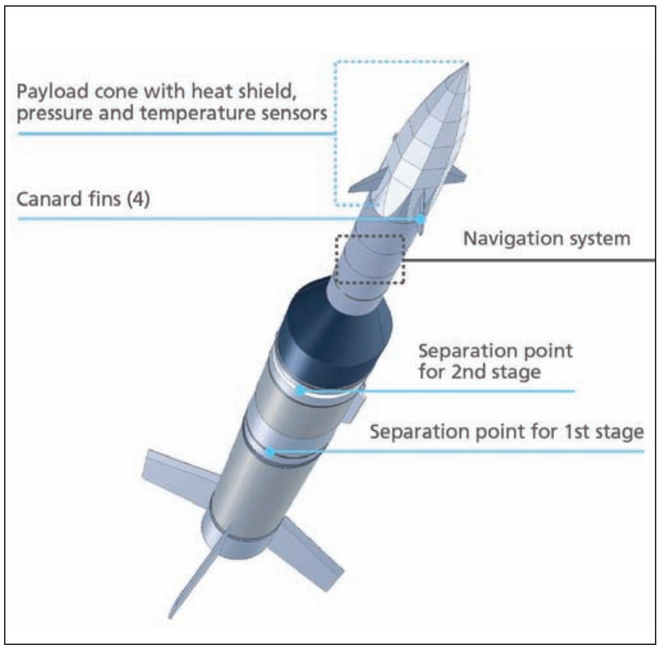
His concluding words and thoughts about the Eco Eagle? "This is the first true hybrid out there. This is history, so it's pretty cool." ∎

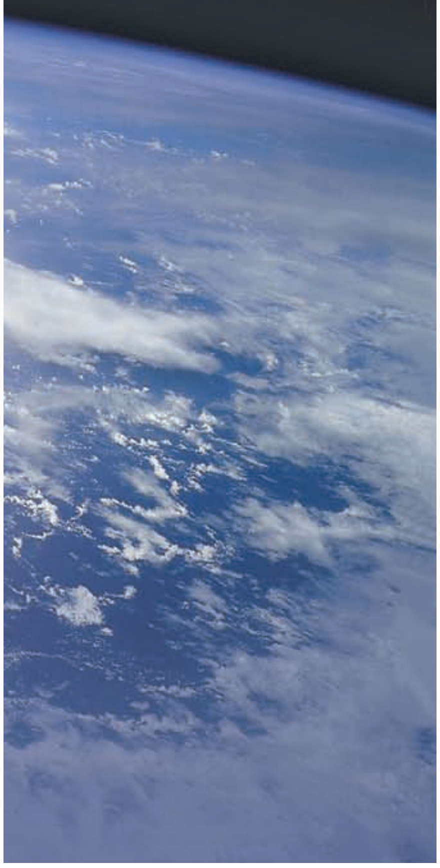
> "The IMU can be used for navigation throughout the entire flight, unlike the GPS, which is anticipated to fail for a short time during re-entry into the Earth's atmosphere"

Beat the heat

A HIGH-ALTITUDE ROCKET IS DUE TO TAKE OFF IN 2012 AND WILL DEMONSTRATE AND TEST THE LATEST INNOVATIONS IN HEAT-RESISTANT PANELS







BY DSPACE AUTHOR

While developing a new space glider, the German Aerospace Center (DLR) has been investigating new heat shield technologies in its SHEFEX II (Sharp Edge Flight Experiment II) program. A high-altitude test rocket is scheduled for launch in early 2012. Its nose will carry a new type of heat shield constructed from flat panels, which will be much less expensive and easier to maintain than the heat shields on current spacecraft. All the panels on the innovative heat shield are flat, and there are only a few basic shapes. This simplifies manufacturing and requires less maintenance work. Moreover, the heat shield's faceted form, with its sharp corners and edges, has better aerodynamic properties. With the SHEFEX technology the space glider is simple to assemble, is therefore less expensive, and can touch down with the same precision as the Space Shuttle.

Three types of measurements

At the end of the test flight, the payload nose cone will be guided back down to Earth by four small fins called canards. Its speed, position, and attitude (alignment of its longitudinal axis with the direction of flight) have to be known at every point in time.

Three different instruments are used to measure these variables: an inertial measurement unit (IMU) monitors the attitude, a GPS system measures the position, and a star tracker helps navigate by the stars with the aid of a camera. Combining these three systems ensures high precision and reliability. A dSPACE system will simulate the flight sequence, including instrument signals, in order to test the interaction between all the components before the actual flight takes place. Because of the rocket's high speed, time delays in position measurements (GPS) would seriously affect the navigation solution. Synchronizing the measurement signals with the navigation computer's internal clock is therefore a major focus. The control models are developed with MATLAB/Simulink. The signals and settings of each test are observed and visualized during run time by the experiment software dSPACE ControlDesk.

Falling back to Earth

The rocket is due to be launched from the Andøya test site in Norway in early 2012. The flight will reach an altitude of 140km and will last for approximately 10 minutes. The IMU can be used for navigation throughout the entire flight, unlike the GPS, which is anticipated to fail for a short time during re-entry into the Earth's atmosphere. This is because the payload nose cone will be split to bring it down abruptly from hypersonic to subsonic. It will go into a fast spin during this procedure, making it practically impossible for the GPS antennas to continue receiving signals. At the apogee, the star tracker will be activated to compare the positions of the stars with the stored star maps and thus to determine the attitude of the payload nose cone in relation to the trajectory.

Reusable space glider goal

In the re-entry phase, the approximately 160 sensors in the payload nose cone will collect a wealth of data about the distribution of pressure and temperature on the heat shield. SHEFEX engineers are investigating several different thermal protection technologies, most of them are the DLR's own fiber ceramic developments. One of them will be active cooling, in which a gas is ejected from pores in the thermal protection panels to form a heat-insulating layer. This will be the first time active cooling is used in the history of space travel.

These tests on new heat shield technologies are part of a long-term development project. The ultimate goal is to create a completely new kind of space glider, called the REX Free Flyer, which could become available around 2020 to bring experiments back to earth from a zero-gravity environment. ∎

Author withheld, dSPACE GmbH, Rathenaustrasse 26, D-33102 Paderborn, Germany

ABOVE LEFT: The 2m payload nose cone is used to simultaneously test several brand-new heat shield technologies

ABOVE MIDDLE: The Brazilian two-stage solid fuel VS-40 rocket is just over 12m long. It carries the nose cone with the heat shield and the navigation system to an altitude of approximately 140km

ABOVE: Mounting the heat shield panels. Underneath the panels lie temperature sensors, pressure sensors and other devices for inflight measurements

MAIN: A high-altitude test rocket is used for the DLR's SHEFEX II heat shield experiment

Bird's-eye view

THE GERMAN AEROSPACE CENTER (DLR) HAS DEVELOPED A CAMERA THAT CAN TAKE 3D PICTURES OF EARTH. AND IT CAN DO IT FROM A JET AIRPLANE TRAVELING AT VERY HIGH SPEED

BY BERND MÜLLER

Three-dimensional images can be created from two-dimensional pictures by shooting various overlapping shots and deriving information about the elevation from various perspectives. In the field of geo-informatics, this procedure is widespread. It helps scientists measure the elevation profile of a certain area.

More recently, however, this technique has also been used to create realistic views of towns and cities, similar to what we know from Google Earth. The images are taken partly from satellite photographs, but more frequently from photographs shot from airplanes, because these reveal a lot more detail.

But pictures taken from an airplane have one problem: only if the airplane is traveling slowly enough will the images overlap sufficiently afterward. An overlap of at least 50% is needed; even better is a ratio of 60-80%. Every point on Earth is captured in two or more pictures, and therefore from various perspectives. Until now, however, aerial survey cameras could not be used in airplanes that were faster than a propeller-driven airplane.

Images from a jet airplane

But things are changing, as the German Aerospace Center (DLR) has demonstrated. The Department of Optical Information Systems, an institute within the DLR, has developed a camera called MACS (Modular Airborne Camera System), which overcomes this speed limitation. Instead of having to travel slowly enough, the camera takes more images per second at a high resolution. As a consequence of the faster image sequence, a sufficiently large number of overlaps can be created, making it easier to derive information about elevation and enabling the synthesis of extremely precise three-dimensional photographs with ground resolutions accurate in the centimeter range.

The camera developed by the DLR team has already been used successfully on jet planes traveling at speeds of up to 750km/h. This has not been achieved anywhere else in the world.

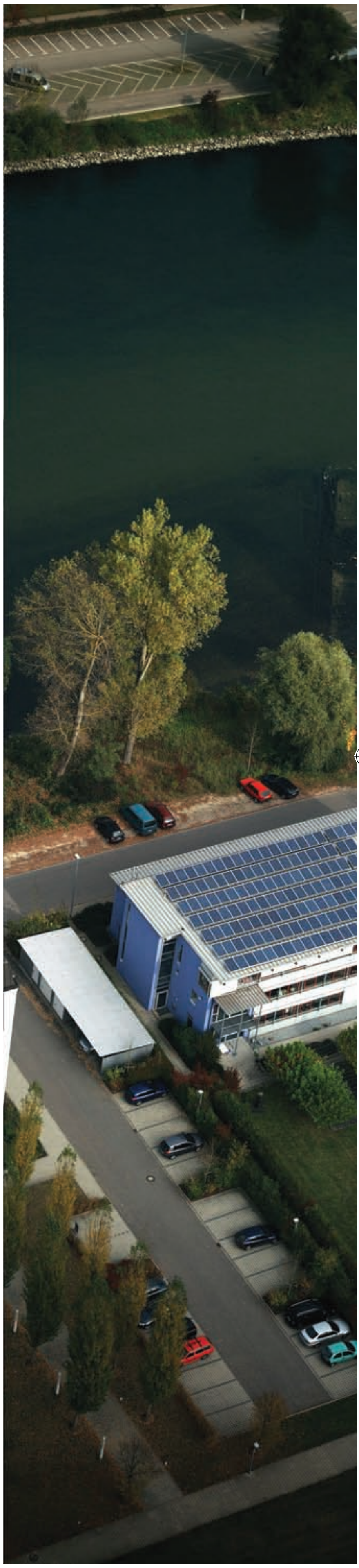
The camera system utilizes built-in camera modules from PCO AG in Kelheim, Germany. The camera body contains three modules of the type pco.4000. In total it weighs 8kg. Each module has a resolution of 4,008 x 2,672 pixels and is capable of taking up to five frames per second at this resolution. Two of the cameras with a telephoto lens take high-resolution pictures of Earth's surface. From the pictures shot with the third camera, which has a wide-angle lens, the orientation of the camera system can be calculated with an angle accuracy of 0.004°, so that the software can later align the individual images to overlap exactly. The deviation of individual pixels, which can be found on several photographs, should not exceed half a pixel.

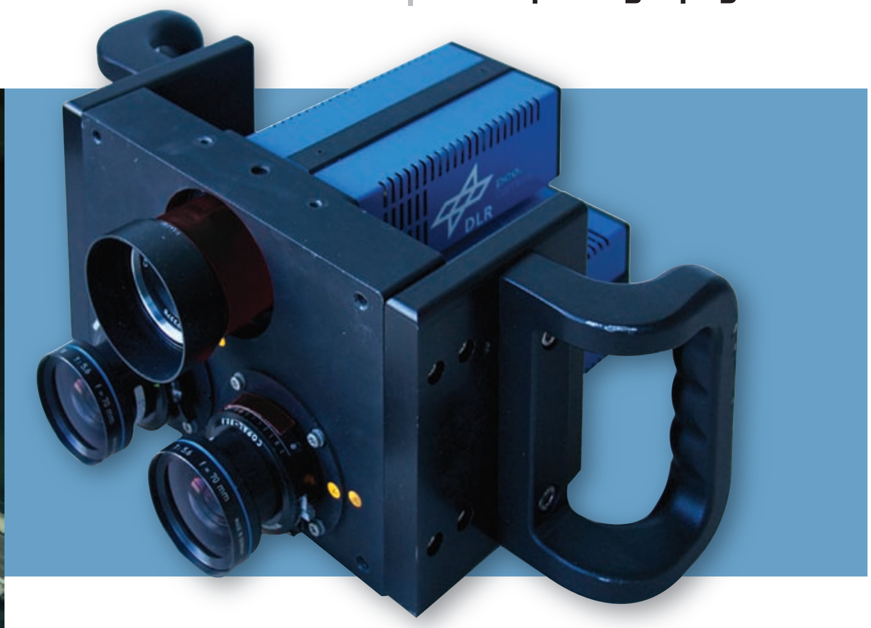
The DLR decided to use a PCO camera because it combines several favorable technical characteristics. "There are many similar cameras on the market, some of them even with the same sensor chip, but none of them combines all of our requirements within one model," explains Sebastian Pless, head of the sensor technology team in the Department for Sensor Concepts and Applications.

Two characteristics in particular distinguish the pco.4000 from the models of other manufacturers. The first is how the sensor is cooled. A Peltier element reduces the temperature of the sensor by 45°C below the surrounding temperature. This greatly improves the signal-to-noise ratio and keeps the 'offset' constant, therefore enabling images to be taken even when lighting is poor or when there are strong contrasts between shadows and reflecting surfaces (for example in densely populated areas).

The second key characteristic is that the pco.4000 has an electronic shutter, whereby only the read-out time determines the amount of light that is collected in the chip. This is more precise than mechanical shutters and, more importantly, makes it completely free of wear and tear. When using MACS, the DLR scientists use shutter speeds of 1/500 to 1/2000 seconds. Even at high speeds, these shutter speeds create pictures that can later be evaluated and assessed extremely well.

BELOW: This digital surface model was created from data from the MACS camera system. Pictured is the Wista technology park in Berlin





"The photographs taken by the special camera capture the Earth's surface from up to 16 different perspectives"

Earth from 16 perspectives

The camera can take five images per second with full resolution. As a result, overlaps of up to 98% can be achieved, depending on the airplane's speed and its distance from the ground. These photographs capture Earth's surface from up to 16 different perspectives.

MACS is not meant to replace commercial aerial photography. "It's a tool for scientific research, which enables us to further develop our software," says Pless. It has already been helpful in planning mobile phone networks, because the elevation profiles have helped determine where to place radio masts so that they optimally cover the required area.

In future, Pless's team wants to produce more three-dimensional pictures, because in reality the photographs are so far only 2½-dimensional. On pictures of a skyscraper or a bridge, for example, only those points that are closest to the camera are visible – for example the roof or the street. The vertical walls of the building or even the pillars under the bridge cannot be seen, even though this information is already embedded in the images due to the use of different perspectives. The DLR plans to create genuine 3D pictures that can even look under objects. This would be extremely useful during natural disasters, for instance. The aerial images could help monitor the erosion of dykes during a flood or judge the feasibility of various rescue options, for example from collapsed buildings after an earthquake. Tourists are also likely to be interested in the possibility of viewing three-dimensional pictures of popular attractions on the internet.

Bernd Müller is a freelance journalist based in Germany

ABOVE: The camera developed by the DLR team has already been used successfully on jet airplanes traveling at speeds of up to 750km/h. The camera is so fast due to built-in camera modules from PCO AG in Kelheim, Germany

CENTER: Photographs of Earth's surface can be captured from up to 16 different perspectives. The camera can take five pictures per second with full resolution. In the picture you can see the buildings of PCO AG in Kelheim, Germany

Ride like the wind

SONIC WIND LSRV, A SUPERSONIC RESEARCH AUTOMOBILE, IS SLOWLY BUT SURELY BUILDING UP SPEED USING AEROSPACE TECHNOLOGY AND CFD

BY WALDO E. STAKES

The Sonic Wind LSRV (land speed research vehicle) design is the latest refinement in supersonic vehicle concepts. The bi-propellant liquid rocket automobile is currently in the build phase of the program. It is 48ft long, 79in wide from canted out tail fin tip to tail fin tip, is 5ft tall at its highest point at the top of its T-tail, and has an overall frontal area of slightly over 8ft^2. It is powered by an XLR-99 rocket engine originally designed and built by Thiokol Motors for the North American X-15 rocket aircraft. The X-15 holds the official air speed record for aircraft that was set in 1967 at over 4,520mph. To this day no manned aircraft has officially flown faster than the X-15 rocket airplane.

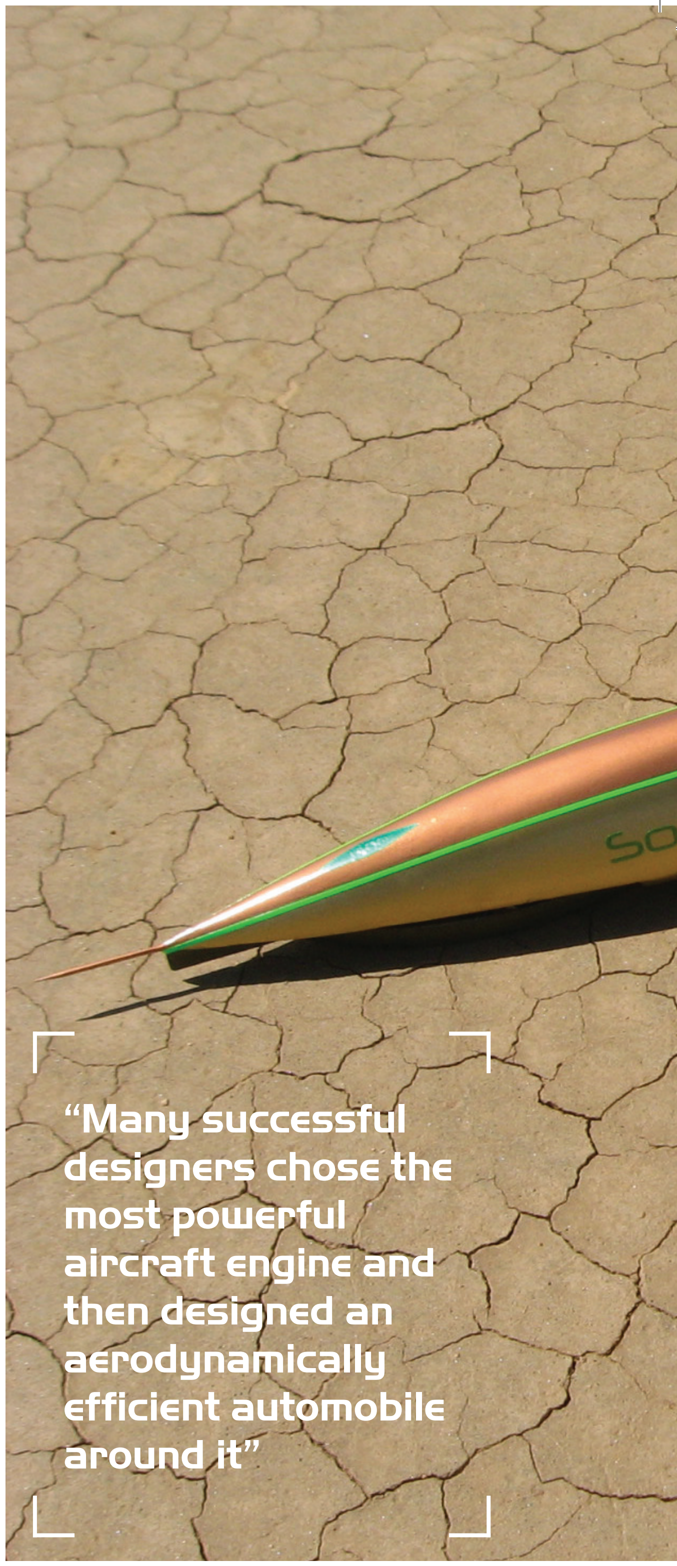
Aircraft rocket engine

The XLR-99 rocket engine was known by its creators as the 'million horsepower engine' because in theory it could generate that amount of power. Its maximum thrust is 57,000-61,000 lb at sea level but it was designed to reach peak performance at the edge of space or an altitude of 330,000ft. The engine will initially be used in a slightly detuned mode, developing 26,000-34,000 lb of thrust. When tested (the current testing venue of choice is the Bonneville Salt Flats in Utah) it should push the Sonic Wind LSRV rocket car to well over 1,000mph.

The XLR-99 was originally designed to run on a combination of anhydrous ammonia and liquid oxygen (LOX). The team is now running it on methanol alcohol and LOX, which will make the engine slightly more reliable and safer by eliminating the toxicity and hard starting characteristics of ammonia. Methanol is much less corrosive and easier to handle and its use will also give the engine better overall performance and ease of starting. Plus, methanol combusts better than ammonia, which will help to keep the engine lit.

Composite chamber

The XLR-99 engine has been modified and tested by removing the injector assembly and mounting it to a (new technology) Compositex ablative composite one-piece combustion chamber/nozzle combination of modern design. This ablative nozzle/combustion chamber combination is built specifically to dimensions



"Many successful designers chose the most powerful aircraft engine and then designed an aerodynamically efficient automobile around it"

Currently being built in southern California, Sonic Wind LSRV is 85% complete

Non-aerospace systems

Two three-stage reefed 17ft diameter supersonic parachutes will be used to slow down the vehicle – one for deployment and the other as backup. A ground drag type of brake will bring the vehicle to a complete stop. This is done by collapsing the rear suspension by relieving air pressure in the rear shock absorbers at the end of a run and dropping the rear of the vehicle onto the ground. There is a rough drag plate mounted to the underside rear of the vehicle and the friction created by it dragging on the ground will slow and stop the vehicle while adding low-speed directional stability.

Another novel feature on this vehicle is the use of a high-energy 250W green diode laser firing forward from the nose of the vehicle. It is used by the driver as a guide to aim the vehicle at the horizon, which helps with directional control and steering precision in the same way a laser sight is used on a weapon.

The driver is encased in a cylindrical safety capsule built of maraging steel and wrapped with layers of composites that make it virtually blast-proof. In the event of a mishap the capsule is separated from the vehicle and has its own supersonic parachute to bring it to a stop. The driver is suspended in the capsule in a Kevlar and nylon webbing or hammock to isolate him from shock and vibration.

for peak exhaust gas expansion ratios at the altitudes of the venues planned to run the car. This ensures peak engine performance at all times during the burn. Maximum engine burn duration is 22 seconds at maximum thrust with the current propellant loads.

The Compositex ablative carbon composite combustion chamber eliminates the need for the high pressures of the original stock regeneratively cooled nozzle and combustion chamber. This enables the team to run the engine, propellant, and pressure vessels at much lower pressures.

The original XLR-99 turbo pumps were eliminated and replaced with a simple blow-down fuel and oxidizer system using helium gas as the pressurant for the LOX or oxidizer system and nitrogen gas to pressurize the methanol system. The helium and nitrogen gases are stored on board in high-pressure titanium spheres of various diameters. Twin regulators and separate complete feed systems enable the best fuel-to-oxidizer ratios for peak engine performance.

Aerodynamics

In the history of land speed record racing, many of the most successful automobile designers chose the most powerful aircraft engine of the day and then designed an aerodynamically efficient automobile around that engine. Sonic Wind LSRV follows that very same concept. The X-15 is still unmatched in performance and that is why its XLR-99 engine was chosen as the powerplant for the Sonic Wind LSRV.

Aerodynamically, though, the Sonic Wind LSRV vehicle is unique to land speed record designs. In frontal view the vehicle has a bell shape that diverts most of the air that strikes the vehicle onto the top of the vehicle. With a bell plan form even the sides of the vehicle are considered the top of the vehicle because of the slope incorporated in the bell shape.

Sonic Wind LSRV's body was originally designed with a hollow area at the top of the center of the vehicle and a wasp waist contour. CFD analysis showed that there were shock anomalies created by this design that could possibly generate excessive lift and create drag, so the entire design was shortened and simplified into its current single slope shape. This results in better control of shockwaves by anchoring them over the top of the car to aid in negative lift.

There is a progressively expanding rectangular tunnel running the length of the underside of the vehicle that enables underside air to be vacuumed into the plume of the rocket engine and evacuated from the underside of the car. This generates a negative lift throughout the entire length of the vehicle.

It also incorporates an expanding vertical supersonic ogive-shaped air dam under the nose of the vehicle that wraps around the front wheels and expands automatically as necessary if a lifting moment is detected. In expanding it creates a turbulent air wake at the underside and base of the vehicle. This wake creates high drag at the base of the car, which gets aerodynamically heavier without changing the flow over the vehicle. This new device eliminates the drag wakes caused by the adjustable canards of earlier LSR vehicles.

The vertical supersonic ogive air dam is controlled by a balance sensor and powered by a pneumatic ram for quick and sure deployment and retraction. It will also be used as an air brake, as it can be deployed so wide that it extends past the body sides and makes all the air on the lower part of the body turbulent, increasing overall vehicle drag. ∎

Waldo E. Stakes is a land speed racer and the designer and engineer for the LSRV

Sensing change

OPTICAL FIBER SENSOR TECHNOLOGY IS BEING TRIALLED TO ASSESS ITS SUITABILITY FOR MONITORING AIRCRAFT STRUCTURES

BY DR CRISPIN DOYLE

Structural health monitoring (SHM) is the process of detecting damage in a structure, with a view to evaluating its ability to carry the loads required of it. It is an important part of a generic health and usage monitoring system (HUMS) and as such can help to ensure the safety, reliability, and availability of vehicles.

The two largest commercial aircraft manufacturers, Airbus and Boeing, have both investigated SHM. Boeing has considered the potential benefits in terms of reducing structural inspections and evaluating hard landings, and has also made an experimental installation of an SHM system focused on corrosion detection in the cargo bay of an in-service 767-300ER.

Airbus has examined the possibility of using SHM, not only to enhance the availability and inspection of existing aircraft, but to take advantage of the extra information that a comprehensive system could provide in order to reduce the weight of future aircraft structures. The same benefits could accrue to military aircraft, perhaps to an even greater degree as the loads they are subject to are much less predictable than those supported by civil aircraft.

The obstacles to the implementation of aircraft SHM are numerous. They include: the integration of sensors into structures; understanding of their outputs; correlation with existing damage detection techniques; overcoming regulatory barriers to changing maintenance philosophies; and last but not least, the availability of flight-worthy monitoring equipment. There has been progress in this latter area, particularly with regard to load monitoring.

For flight trials, new aircraft may be fitted out with extensive load instrumentation in the form of electrical strain gauges. While these gauges can provide accurate information on structural performance in flight, they have certain characteristics that mean they are not suitable for permanent installation and prolonged in-service use, namely short lifespan (relative to the airframe), susceptibility to electromagnetic interference, and the excessive weight of both copper cables and data acquisition systems.

Fiber sensors

Optical fiber sensors (OFS) offer potential solutions to all these problems, but the technology is relatively new and undeveloped. Nonetheless, the benefits are clear enough that a significant body of work has been done to advance their maturity, with particular emphasis on developing, testing, and demonstrating rugged lightweight instrumentation for flight trials of SHM.

Some flight trials have been performed with the instrumentation located in a pressurized cabin. For example, BAE (under the MONITOR program), CIRA (Italian Aerospace Research Center), and Technobis have all flown OFS systems. The environmental requirements for such a system are not much more severe than for laboratory use, so although such demonstrations can be useful to show the potential of a technology, they do not address issues of ruggedness and reliability under representative operating conditions.

An important and ambitious study of the issues involved in designing and implementing aircraft SHM was carried out by NASA Dryden in the late 1990s. The flight research center designed an integrated vehicle health monitoring (VHM) system for the X-33 reusable launcher, consisting of central storage and processing units located in an avionics

NEAR LEFT: The BAe Hawk T1A XX324 19 Squadron used for AHMOS II trials

FAR LEFT: An artist's impression of the NASA/Lockheed Martin Single-Stage-To-Orbit (SSTO) Reusable Launch Vehicle (RLV) in orbit high above the earth. NASA's Dryden Flight Research Center, Edwards, California, expected to play a key role in the development and flight testing of the X-33, which was a technology demonstrator vehicle for a possible RLV

"If sensors fitted deep inside the aircraft structure can reliably detect the onset of damage......this could save many millions of pounds over the lifetime of a fleet"

bay, linked to remote sensor nodes in different parts of the airframe. The sensor modes operated different types of sensor such as accelerometers, strain gauges and temperature probes. A fiber-optic interrogator for distributed strain sensing was also included. Flight tests on an F/A-18 research aircraft were largely successful, resulting in the collection of 25GB of data. However, the OFS system was found to need further development before it could be described as fully flightworthy.

AHMOS

A later project was undertaken by a European consortium. Called AHMOS (Advanced Structural Health Monitoring System), its goal was to demonstrate an inflight damage-detection capability with a view to supplementing and eventually replacing ground inspections. This was to be done with the understanding that no single damage-detection method is the best one to use in all circumstances; rather, the fusion of different techniques can provide better sensitivity, robustness and reliability.

Therefore, the basic outputs of several instruments were combined in a central processor ready for presentation to the aircraft maintenance crew after landing. The first phase consisted of ground trials of candidate technologies, which resulted in a number of methods being selected for further development. In the second phase, rugged instrumentation was developed for inflight use by Smart Fibres. A complete experimental system was housed in an underwing pod on a BAE Systems Hawk. It was largely self-contained, requiring only power from the aircraft, and consisted of a central computer linked to systems for acoustic emission detection, ultrasonic guided wave propagation, fiber-optic strain sensing, and conventional electrical strain gauges, along with a pair of test coupons on which all the sensors were mounted.

Finally, a series of flight trials, including simulated air combat maneuvers, was conducted in which data from all the systems was acquired, synchronized, stored, and later analyzed to show the progression of cracks and disbonds in the coupons. All of the equipment worked without interruption during the seven flights – each one hour long.

According to BAE Systems: "If sensors fitted deep inside the aircraft structure can reliably detect the onset of damage, the need to dismantle sections of the airframe will be considerably reduced. The new detection process can be performed remotely – at the press of a button or even automatically online. It is estimated that this could save many millions of pounds over the lifetime of a fleet." The key point here is that the system must be reliable. Much work will be needed over many years before an automated system can be permitted to replace current inspection procedures, but the goal is worth pursuing.

Major aircraft manufacturers and users are becoming convinced of the benefits of SHM and are undertaking research programs in this area. The recent availability of off-the-shelf flight-worthy instrumentation will facilitate further trials and enable new technologies to gain acceptance by the aerospace community. ∎

Dr Doyle is the chief scientist within Smart Fibres based in the UK

UAV flight trials

A recent demonstration of inflight SHM has been the flight trials of the Indian Nishant UAV, which flew with a Smart Fibres fiber-optic strain measurement system on board. The requirement for SHM on a UAV is perhaps stronger than on a manned aircraft, as the former has no means of getting feedback from the pilot about the state of the airframe. Indeed, onboard SHM is viewed as a critical requirement before UAVs are allowed to operate autonomously in civil airspace.

It is a dubious accolade to have been shot down by one's own missile, but as Pete Purvis discovered, some things are just going to happen

The day I shot myself down

TRAILBLAZERS

Name: Purvis, Peter
(US AIR FORCE, RETIRED)

Pete Purvis

My friends have often introduced me with the unforgiving phrase, 'Hey, I'd like you to meet the guy who shot himself down.' This honor belongs to myself and another Grumman test pilot, Tommy Attridge, who managed to fly his F-11F-1 fighter into a hail of 20mm rounds he had just fired during supersonic gunnery testing. Several years later, as a test pilot for Grumman Aerospace flying out of Point Mugu, California, I found a more modern way to do this using a Sparrow missile and the F-14A Tomcat, which, at the time, was the Navy's fighter of the future.

More than three decades later, that day – June 20, 1973 – remains extremely sharp in my memory. And with good reason. It wasn't a dark, stormy night. The midday sun was bright in the clear southern sky. The Californian Channel Islands off Point Mugu stood out against the glistening ocean below as Bill 'Tank' Sherman and I flew west toward the test area in the Pacific Missile Test Range. Tank and I had known each other since we were in the same class in the US Navy's F-4 replacement air group training. He already had a combat tour under his belt as a Navy Radar Intercept Officer (RIO) and was good at his business. Analytical, competent and cool, he was the kind of pilot you wanted to have along when things got hectic. I learned the real value of a good RIO over North Vietnam while flying combat missions in the F-4B Phantom from the USS Coral Sea.

One of the myriad development tests of a tactical airplane is weapons separation, whether those weapons are bombs or missiles. That day, we were testing a critical point in the Sparrow missile launch envelope. We weren't testing the missile's ability to kill airplanes, only its ability to clear our airplane safely when fired. The crucial test point took place at Mach 0.95, 5,000ft altitude and zero *g*, and it consisted of firing Raytheon AIM-7 Sparrow missiles from the farthest aft station (Number 4) in the 'tunnel' that is under the F-14 between the two engines where most missiles are mounted in semi-submerged launches in the tunnel with two of its eight cruciform wings (four forward, four aft) inserted into the slots in each launcher. These triangular fins are 16in wide and, when the missile is attached to the launcher, stick into the bottom of the fuselage.

The test point for that day was in the heart of the low-altitude transonic range where the high-dynamic pressure flow fields close to the fuselage are mysterious. The zero *g* launch parameter meant the missile would not get any help from gravity as it was pushed away from the airplane by the two semicircular feet embedded in the launcher mechanism. Each of these feet was attached to a cylinder that contained a small explosive charge that was set off by pulling the trigger on the stick.

This particular launch was not thought to be risky from a pure separation standpoint because preceding Sparrow launches from the F-14 wing pylon, forward and mid-fuselage positions in inflight flight conditions had demonstrated favorable release dynamics, and good clearance between the missile and the aircraft throughout the entire launch sequence. In fact, the missile company Raytheon, on the basis of its own aerodynamic analysis, was concerned that the missile would severely pitch nose down as it had on two of the three prior launches at this condition, and possibly be so far below the aircraft as it passed the F-14's nose radar that it could, in the real world for which it was designed,

The F-14 was the United States Navy's primary maritime air superiority fighter

lose the rear antenna radar signal and compromise the target acquisition portion of the missile trajectory.

Raytheon engineers had predicted a 2ft clearance. Independent Grumman wind tunnel tests confirmed the Raytheon analysis. However, this was not to be the case for this launch.

During the preflight briefing, the engineers once again displayed graphs that showed the predicted missile-to-fuselage clearance as a function of the time after trigger pull. As expected, clearance was seen to be tight. But we had the utmost confidence in Grumman's separation engineer, Tom Reilly, and his data. All previous launch data used during build-ups had come out on the money. We were good to go.

The test missile was a dummy AIM-7E-2, an obsolescent model of the Sparrow with the same form, and function as the AIM 7-F, the missile scheduled for the fleet. The 7E2's casing, however, was slightly thinner than the 7F's.

The rest of the briefing was routine. After the routine ground checks, we took off and flew directly to our test location about 80 miles offshore between Santa Rosa and San Nicolas Islands, directly west of Los Angeles. The test crew has two primary jobs: to hit a specific data point (aircraft attitude, altitude, airspeed, *g* loading) in the most efficient manner; and to relate unusual phenomena and analysis to the folks back on the ground. On this day, the second part was covered by several million dollars' worth of test instrumentation. This was very fortunate, because things were about to get exciting.

We hit our point in the sky (567 KIAS, 5,000ft, zero *g*) and I pulled the trigger: 'Ka-whumpf'!! A much louder 'ka-whumpf' than we had ever experienced before. The missile appeared in my peripheral vision as it passed from beneath the left nacelle. It was tumbling end over end, spewing fire. 'That's weird', I thought. My first real thought was, 'I'll bet stray foreign debris pieces enter the left engine'. My instant analysis seemed to be confirmed a few seconds later when the master caution light flashed in front of me. My eyes jumped to the caution panel, which had begun to light up like a pinball machine!

'HORIZONTAL TAIL' and 'RUDDER AUTHORITY', numerous lesser lights, and 'BLEED DUCT' (that's the one that usually came on before fire warning lights) blinked at me. I disregarded all but the 'bleed duct' light and tried to punch it out by turning off the bleed air source. That didn't work! Now the chase told me I was venting fuel, and had 'a pretty good fire going'.

"How good is that?" I asked in my cool-guy, smart-ass best. "There's the left fire warning light!" I shut down the left engine, which didn't work either. As I reached for the left fuel shut-off handle, the nose pitched up violently, so sharply in fact that the force of more than 10g curled me into fetal position. I couldn't reach either the face curtain or the alternate handle between my legs. It didn't take long for me to figure out that I was no longer in control of the situation.

'Eject, Tank, eject', were my thoughts, and as the high g force (data said it peaked at 1.3 seconds) bled off to a point at which one of us could reach the face curtain, either Tank or I initiated the ejection sequence, and in just one second we went from raucous noise and confusion to almost complete peace and quiet.

The ejection was smooth and, after my body completed about four somersaults, my chute opened. The opening shock was gentler than I had expected. In fact, I hardly noticed it. All the action from missile launch to our ejection took only 39 seconds. It seemed much longer. We had ejected at an estimated 350kts, having bled off 150-200kts in the pitch up, and at 7,000ft we were 2,000ft higher than we started. Post-accident analysis of the instrumentation showed the violent nose-up maneuver was caused by a full nose-up stabilator command, the result of a probable burn-through of the control rod that actuated nose-down commands. Had the stabilator command gone full nose-down, these words would not be written.

As I stopped swinging in the chute, I saw Tank about 225ft away and 100ft below me. We waved at each other to indicate we were in good shape. We'd hoped to wave at a helicopter, which had launched a few minutes after we'd ejected, but to travel 80 miles in a helo flying at 120kts takes a long time. Our airplane descended in a slow, shallow left spiral, burning fiercely in a long plume reaching from the trailing edge of the wing to well beyond the tail. On impact, it broke up and scattered pieces across a 100ft radius. The largest chunk was the left portion of the tail section, which floated in a pool of pink hydraulic fluid.

The parachute ride was calm, serene, and long. The only noise was the chase plane roaring by several times. As I hung in the chute, my thoughts turned to the next phase: water survival. The sea below was calm. I wondered whether the crash sound had alerted the sharks, which must be lurking hungrily below awaiting their next meal? Oddly, that was the last time I thought of sharks for the rest of the day because my mind soon became otherwise engaged. Sharks weren't something I could control, but water entry was, so I began to go through my water survival tactics. I pulled the right handle of the seat pan to release my life raft, which was supposed to remain attached to the pan on the end of a long yellow lanyard, or so I'd been told. I peered carefully below, but saw no raft or shadow on the water. Pulled the left one. Still no sign.

Bear in mind that the last time I had hung in a parachute harness was in preflight some 16 years before. I wasn't about to perform a creative search for my life raft using chute steering or other acrobatics best left to the 82nd Airborne. Nor did I care to enter the water in other than the prescribed manner, so I gingerly walked my fingers up the risers and found the parachute's quick-release fittings, so I could actuate them when I hit the water to avoid becoming tangled in shrouds, yet another way to die.

After what seemed like a very long time hanging below the chute, the water suddenly rushed up at me, an event that according to survival school anecdotes signaled impending water entry. I plummeted about 10ft under, then bobbed to the top while trying to actuate my life vest all the way. In my state of diminished IQ, I had forgotten that very basic step on the way down. I flailed about the surface, kicking, treading water with one hand and searching for the life-vest toggle with the other, then treading water with both. My addled brain realized that this maneuver wasn't going to be a long-term survival technique. It is better to submerge if you must, open your eyes and find the damned toggles, or you're going to die. Doing so, I found the right one, pulled it, and once again ascended to the surface, this time from about 8ft down. Next, find the left toggle. Now that I was floating, I figured I didn't need to perform my immersion act again, so I somewhat calmly found the left toggle and inflated the r est of the life vest that contained most of the neck collar and therefore, lots more comfort.

Now, where was the raft? Because I hadn't seen either the raft or its shadow on the way down, I assumed it hadn't inflated but it must be on the water nearby. I couldn't turn around very well because of my stiff neck. I soon saw the raft about 15ft away out of the corner of my eye. I remembered rafts being yellow, but this

Purvis's story

Pete Purvis was born on December 1, 1934 in Cleveland, Ohio, where his first exposure to aviation came while sitting atop the family's 1937 Ford watching the Cleveland Air Races. After leaving high school he spent four years at the US Naval Academy, where he encountered his first Grumman aircraft.

Purvis flew his first Grumman aircraft, an S2F-1 Tracker, while assigned to VS-32 at NAS Quonset Point, Rhode Island. He soon decided that there was more to flying than chugging along at 100ft, and was eventually selected to attend the US Navy Test Pilot School where he was assigned to the Service Test Division.One of his most interesting projects was the Skyhook Covert Aerial Retriever System invented by Robert Fulton, who was a direct descendant of the steamboat inventor. He achieved several firsts for Skyhook, including the first live pick-up at night, and the first snatch of two people simultaneously. After three years at NATC, Purvis resigned his commission in 1968 to join Westinghouse in Baltimore as an engineering test pilot. Grumman called in 1971 and offered him the opportunity to become an F-14 experimental test pilot. By early 1975, flight test activity at Point Mugu had waned, so Purvis joined Grumman International as director of Washington operations, and in 1981 he became affiliated with Tracor Aerospace.

The F-14 entered service in 1974 with the US Navy, replacing the F-4 Phantom II. It was retired in 2006

one was black and at first glance seemed partially inflated. Both illusions were caused by the protective cover draped over the raft's side. I pulled on the lanyard and pulled the vessel to me.

Now the fun began. The time had come to board the raft, I remembered the 'method' from earlier days in water survival training: "Face the low end of the raft, grab the sides, pull it toward you, do a snap roll, and you'll be in a nice, comfortable position on your back." Right. But this approach didn't consider that the person boarding the raft still had his seat pan strapped to his butt. The outcome of this trick was an inverted raft parked on top of my head. I flipped the raft and rested.

Soon I hoisted myself into the raft on my stomach, rested, then tried to complete a sneaky slow-roll. After about 45° of roll, I became hung up on something. My oxygen hose was still connected to the seat pan. I fumbled around and eventually freed the hose, disconnected the pan, and very carefully pushed it to the foot of the raft – I certainly didn't need to puncture it now. About now, my tired and befuddled mind decided to take stock of the situation and sort out priorities.

Where's Tank? I figured he was behind me because he yelled from that direction a few minutes ago. I had replied by waving my arms, I was too weak to do much else after flailing about, and I was nauseous from swallowing sea water.

I turned on my Guard channel beeper, mainly to see if it would work. Half the world knew where we were, probably including the Soviets who regularly shadowed Pacific Missile Range operations with trawlers offshore. Planes had been flying around us when we ejected: two F-4s (Bloodhound 21, an S-2 used by PMR for range clearance. We also carried a PRC-90 survival radio, so I stowed the Guard beeper and pulled out the PRC, connected the earphone plug to the plug on my hard hat (this was probably the most coherent thing I'd done since leaving the airplane), turned to Guard transmit/receive, and held a short confab with Tank. We were both fine. We were the only people talking on Guard, so I attempted to raise someone on Plead Control, PMR's main range-control frequency. Success. Bloodhound 21 flew low overhead, and we began conversing. Where was the cavalry? It was about 10 minutes away, in two helicopters.

Relieved, I tried to get comfortable. I first sighted the helo as he passed the foot of my raft several hundred yards away, and headed for the wreckage. Almost in unison, both Bloodhound 21 and I let him know neither Tank nor I were at the wreckage. "I'm at your nine o'clock," I vectored him to me over the radio. (I was really at his three – another good argument for giving direction first, then clock code.)

He quickly locked on. "You don't need a smoke." I was happy to hear that. If lighting a flare followed the trend of my misadventures of the past hour, I probably would have doused myself in orange smoke, or opened the wrong end and burned myself.

"Do you have any difficulty?" asked the helo pilot.

"I'm hung up on something in the raft," I said.

"I'll drop a swimmer," he yelled.

After about 30 seconds, the swimmer splashed down about five yards away, disconnected me from whatever had me hung up, then guided me toward the horse collar being lowered by the second crewman. Using sign language, he told me to get out of the raft. Hesitant to leave the security of my new-found home, I somewhat reluctantly obeyed. Strange thoughts race through the mind at times. I got into the horse collar the right way on the first attempt (getting in the wrong way is probably the most common mistake in rescues). As I came abreast of the helo's door, the crewman grabbed me and pulled me in. I let him do everything his way. At this point, I wasn't about to insert my own inputs, the wisdom of which I had begun to suspect not long after entering the water nearly an hour earlier.

I saw the other helo getting close to Tank, who had a flare in his hand that was billowing immense clouds of orange smoke. I walked forward in the aircraft and watched as the crewman hoisted the swimmer aboard. Both helped me out of my flight gear, then I strapped myself onto the canvas bench, looked out of the open door at the sight of the ocean below me, and smoked one of several cigarettes offered by the crew as we flew off.

One tenet of the fighter pilot's creed is: 'I would rather die than look bad.' You have to look cool as you dismount, just as though nothing had happened, kind of John Wayne-like. Yeah, right! As I stepped down from the helicopter and my feet hit the ground, I began to shiver uncontrollably, and I had great difficulty talking. The thermal shock from flailing around in the 60° ocean for almost an hour had hit. This embarrassing state didn't wear off until later in sick bay, after I had belted down four large, raw brandies.

That evening, Tank and I had our Grumman bowling league scheduled. We went. Luckily, neither of us dropped a ball. ■

"As I reached for the left fuel shut-off handle, the nose pitched up so sharply that the force of more than 10g curled me into fetal position"

Turbulence monitoring

IT IS NOW POSSIBLE TO GET A BETTER UNDERSTANDING OF HOW SMALL PRESSURE FLUCTUATIONS AFFECT THE ACOUSTIC EFFECTS IN A HYPERSONIC WIND TUNNEL

BY BOB METZ

Hypersonic boundary layer transition on re-entry vehicles and lifting bodies is a phenomenon that is not well understood. During the study of test models in a hypersonic wind tunnel, the presence of small pressure fluctuations can complicate the understanding of the boundary layer transition phenomenon. These small, acoustic pressure oscillations that occur in the transition region tend to create heating and skin friction. As a result, the heat build-up can more than double. Transition can also affect other boundary layer properties such as flow separation on nearby control surfaces. Therefore, boundary layer transition is important to structural and thermal protection system design engineers. Increased heat transfer requires a more robust thermal protection system.

A better understanding of boundary layer transition will allow design engineers to improve the design of thermal protection systems by reducing the weight of the vehicle, decreasing fuel burn and increasing the payload-carrying capability for the mission.

Pressure sensors

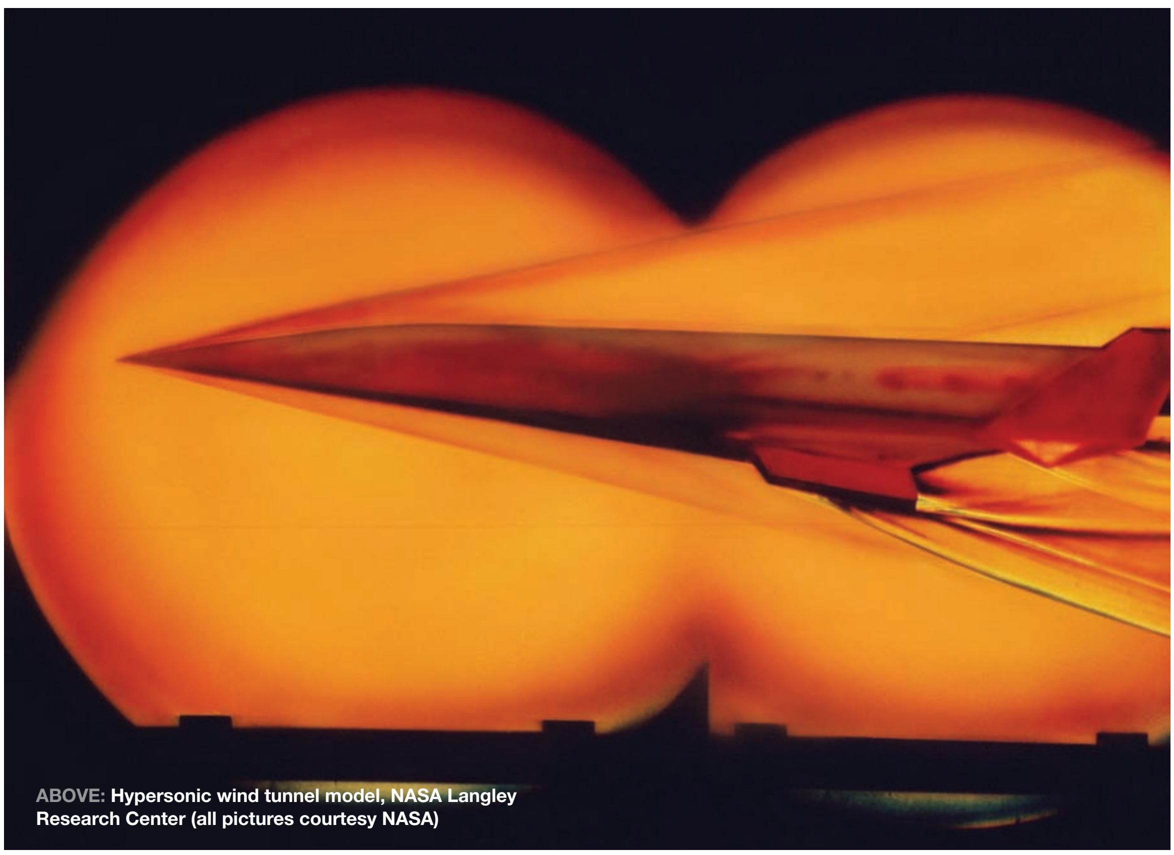
Second mode frequencies on experimental tunnel models have been estimated as high as several hundreds of kilohertz (kHz), therefore it is required that pressure sensors have a resonant frequency greater than 1,000kHz.

In addition to high frequency response, the pressure sensors must be able to detect miniscule pressure changes in a low-pressure wind tunnel environment, often of the order of a few hundred Pascal (Pa). Absolute pressure transducers using strain gauge and piezoresistive technologies have been frequency limited due to the use of various screens in front of their diaphragms, which protect the transducer sensing element from potential particulate impacts. However, according to manufacturer specifications, such screens limit the frequency response of the transducer to nearly 25kHz.

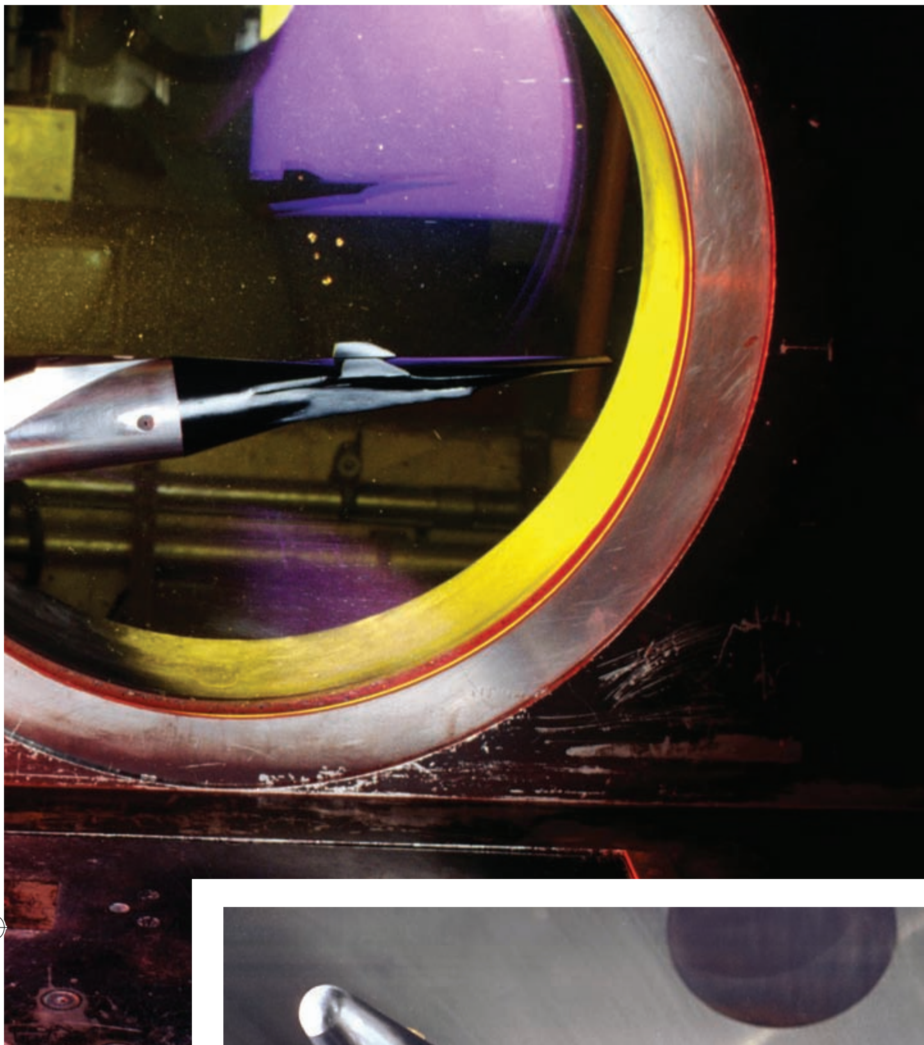
Hot wire airflow sensors have been employed as anemometers for more than 40 years and measure airflow through heat transfer. As heating occurs during airflow in a boundary layer transition, a corresponding increase in resistance of the wire restricts the current flow in the wire. An integrated electronic circuit in such a sensor converts the current change into a corresponding voltage output. But hot wire sensors have proved too fragile for the environment. They are also affected by density and humidity and require compensation. Hot wire sensors also lack the fast response time required for a second mode frequency analysis.

Wind tunnel experiments

A new acoustic pressure microsensing technology is now available that has allowed research of the hypersonic boundary layer transition. Over the past five years, piezo-electric microsensor model 132A31 manufactured by PCB Piezotronics has been used in hypersonic wind tunnel experiments because the pressure sensing technology has a resonant frequency greater than 1MHz and an acoustic pressure resolution of 7Pa.



ABOVE: Hypersonic wind tunnel model, NASA Langley Research Center (all pictures courtesy NASA)



> "Hot wire sensors have proved too fragile for the environment"

LEFT: **Hyper-X wind tunnel tests, NASA Langley Research Center**

BELOW: **Piezoelectric microsensors are small enough to allow multiple installation flush with the surface of the model**

The sensor was originally designed for use as a shockwave sensor for use in wave front time of arrival and target scoring of projectiles, with resolution fine enough to detect the bow and stern shockwaves. The sensor features a small size of 0.125in (3mm) diameter and 0.3in (7mm) length, so it is very easy to mount in small models typical of a hypersonic wind tunnel.

The piezoelectric microsensor uses a very small pressure-sensing crystal that is less than 1mm in diameter. The small size of the sensing element, and lack of mass in front of it in the form of a diaphragm, imparts extremely fast response time to the microsensor. The charge generated from the piezoelectric element when subjected to shock pressure creates a voltage on the input capacitance at the gate of the Integrated Circuit Piezoelectric (ICP) amplifier.

The ICP amplifier, in conjunction with the source element, transforms the input into a low-impedance output signal of equal amplitude. A DC bias voltage that exists on the signal lead wire is removed from the output signal by a decoupling capacitor in the ICP power supply signal conditioner. Resistors in the internal ICP amplifier of the microsensor set the internal discharge time constant, which determines the high pass characteristic (low-frequency response) of the microsensor. In the case of the subject sensor model 132A31, the high pass frequency is 11kHz.

Microsensors

The microsensor allows for flush mounting on the model surface, and the incident rise time mounted in this manner is less than three microseconds. Alternatively, it can be mounted in a pitot configuration to monitor overall tunnel noise. In this configuration, the rise time is less than 0.5 microseconds. Such response characteristics are possible from the close proximity of the ceramic sensing element to the shockwave. The sensor is not inhibited with a diaphragm or screen; rather, the rigid crystal structure directly bears the surface loading during shockwave propagation.

This novel microsensor offers another tool for investigating second mode shockwave frequencies in hypersonic wind tunnels. It is now possible to get a better understanding of how small pressure fluctuations affect the boundary layer transition region of a hypersonic wind tunnel model. ∎

Bob Metz is product manager for PCB Piezotronics Inc based in Depew, New York, USA

Support network

THERE ARE MANY CHALLENGES FACING AUTOMATED AND INTEGRATED SOLUTIONS FOR THE SUPPORT OF SAE TEST PLANS FOR MIL-STD-1553B COMPATIBLE DEVICES

BY JOACHIM SCHULER

For more than three decades, MIL-STD-1553 has been widely used as the defense industry's standard for data communications for various applications within aerospace and defense. Core systems deploying it typically have to operate over the lifetime of the program. Therefore the test systems at some future point in time need to be retrofitted with updated equipment to support new designs. Many new programs still use MIL-STD-1553 and the new equipment must support this standard.

Due to natural progression of the test equipment, equipment manufacturers also need to keep pace with the latest technologies to support efficient and effective testing of the MIL-STD-1553 equipment. Testing is typically executed in accordance with the MIL-STD-1553 test plans such as the industry standard SAE AS4111 to AS4114 for remote terminals and bus controller. These have been stable and have not changed the central testing procedures.

The plan

The test plans are in the public domain because of the SAE organization. It is natural for test equipment suppliers to offer integrated solutions in support of these test plans because the work to define such rigorous tests has already been done by leading industry experts.

The challenges start with the capabilities that support the required MIL-STD-1553 interfaces (the 'tester' interface), which must address the required error injection/detection and analysis capabilities supporting the protocol testing chapters of the SAE test plans, which are in fact quite different from the basic interfaces required for operational MIL-STD-1553 equipment.

Part of the test plan also looks at the electrical behavior of the Unit Under Test (UUT). Today it is possible and highly desirable to have an integrated solution for both the protocol and electrical testing in order to simplify and minimize the required test and measurement equipment.

It should be noted that even with integrated approaches, such as including a 'digital scope functionality', there are limits when it comes to some specific tests such as the 'Common Mode Rejection' and 'Input Impedance' tests that require an additional 'function generator' device and impedance measurement.

Having provisions in a system concept for the integration of additional equipment via standard peripheral connections such as Ethernet, GPIB or serial ports, offers a huge advantage to perform this type of testing.

It has become apparent that the use of a UUT's maintenance port is 'typically' required to support the execution of the test plan, that is, for uploading test software or further control of the UUT during the tests, such as setting the 'Service Request' element or other 'Status Word' modifications, which form a key part of the various test steps.

In particular for MIL-STD-1553 Bus Controller (BC) related test plans (the AS4113 and AS4114), extensive commanding of the UUT is required since the 'tester' device typically mainly acts as a MIL-STD-1553 remote terminal that is not able to initiate any bus activity. In the same way for the integration of external equipment, the provisions for handling the UUT's maintenance port through standard peripheral connections increases the efficiency of an integrated solution moving toward a higher degree of test automation and reproducibility of test results by minimizing user interactions.

Hardware requirements

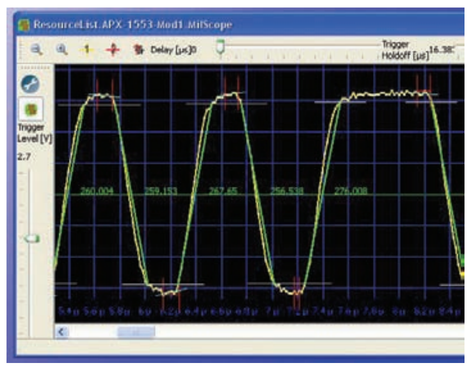
The hardware requirements for an integrated solution show that today's PC platforms offer an excellent baseline with PCI (-X) or PCIe backplanes and standard peripherals interfaces such as RS232 and at least one Ethernet port. Compact PCI platforms either as real PXI or standard 3U/6U-cPCI or PXIe/cPCIExpress offer a solid baseline with a wide choice of platform components.

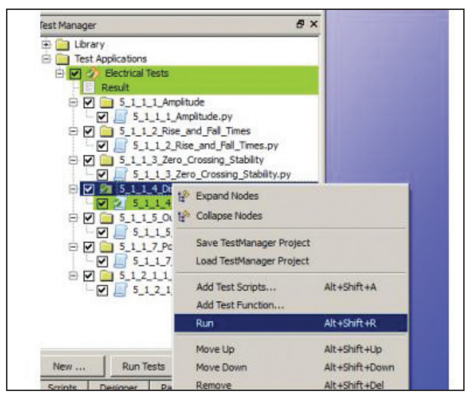
It is obvious that hardware interfaces and their integrated 'tester' features and selected platform play an important role for support of the SAE test plans. Another important item is the software support for this.

Driver software for the most popular operating systems (Windows and Linux) for integration of such 'tester' interfaces in customer-specific test systems is mandatory and the industry standard today. Built-in measurement and waveform analysis for captured MIL-STD-1553 waveforms through 'tester' interfaces with digital scope capability against the test plan is another mandatory function to be supported by the software.

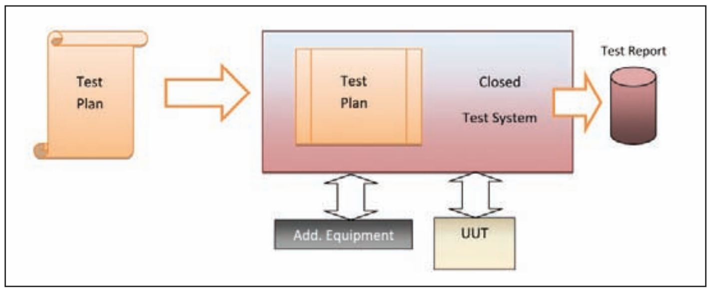
BELOW: Built-in waveform analysis based on a digital scope capable MIL-STD-1553 interface

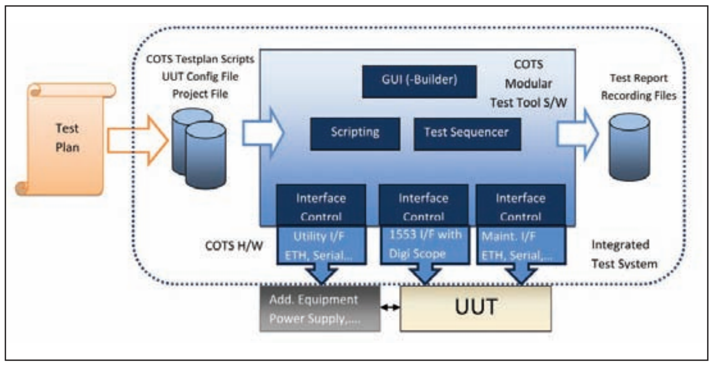
BOTTOM: Grouping and structuring of test cases in test sequencer





> **"UUT-specific behavior may be part of the design that is not fully compliant with the test plan"**





LEFT AND BELOW RIGHT: **COTS 1553 interface modules with scope capability and a portable system platform example based on 3U CompactPCI**

ABOVE RIGHT: **Proprietary test system with incorporated test plan**

RIGHT: **Schematic of integrated system based on COTS components**

Therefore, an integrated solution offering dedicated support for the SAE test plans becomes an attractive proposition for equipment suppliers when provisions are made for efficient and flexible integration of standard peripheral interfaces.

Handling of these standard interfaces is the next challenge, and users must have the necessary flexibility to adapt an integrated solution to the UUT's specific design. This all starts with required configuration capabilities and needs to be defined by the expected UUT's MIL-STD-1553 configuration (valid/invalid sub-addresses, etc). It ends with the adaptation of the UUT's specific commands using the maintenance ports and integration of further peripherals such as external measurement equipment, switch matrixes, and power supply.

Test cases

UUT-specific behavior may be part of the design that is not fully compliant with the test plan. This in fact is the case in real life and can cause a very strictly programmed test system to fail, even if the behavior is okay from the equipment supplier's point of view. Hence the user needs a flexible way to adjust the test cases to ease the use of an integrated solution; in other words, make it possible for all users of the corresponding system. (The justification of any deviation to the test plans is typically given to the equipment supplier at this point, and is not a subject of this article.)

Solutions that offer a high degree of automation plus the flexibility to adjust and structure – for example, the test case sequence (group test cases, enable/disable test cases or entire groups) – would be beneficial for the integration phase of a UUT, for a successive approach of a UUT to the final execution of a full test plan.

The documentation of the test results and measured values is a very important element, since with all the automation and flexibility of an integrated solution, an automated test report generation plus an optional chronological time stamped MIL-STD-1553 bus recording of the test plan performance, is the final thing that makes the integrated test solution highly desirable for equipment suppliers.

Having the flexibility and configuration capabilities for various test report output formats such as ASCII, HTML, XML or PDF versus a hardcoded test report with fixed layout is the 'cream on top' of an integrated solution.

AIM GmbH has developed a second generation of integrated testing COTS solutions for RT production and validation test plans (SAE

AS4111 and AS4112) based on its industry standard PBA.pro test and analysis software. This fully scalable approach, based on scripting, is now hard at work supporting various projects and space and avionics customers. Useful experience has been gained and further designed into the current product line to reflect the equipment supplier's needs. ∎

Joachim Schuler, managing director AIM GmbH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Additional exhibitors confirmed for Spacecraft Technology Expo 2012

A globally renowned, independently operated, UK-based organizer of next-generation B2B conferences and exhibitions has announced a rapidly growing number of exhibitors for Spacecraft Technology Expo 2012.

Newly confirmed companies include ANSYS, A&R, Astrobooks, Collier Research, DNB Engineering, Dytran Instruments, Glenair, HyperSizer, Lansmont, NUTEC, Polytec, RDF, Siemens, Silicon Designs, SpaceX, Thermocoax, UDash, United Space Alliance, Willick Engineering, Witte America, and Wyle Laboratories, which join already confirmed ACRA Control, Martinez & Turek, Microflown Technologies, RAL Space at the Rutherford Appleton Laboratory (UK), AlphaStar, Flotron, and Cryoconnect.

Set for May 8, 9, and 10, 2012 at the Los Angeles Convention Center in Los Angeles, California, USA, Spacecraft Technology Expo will be the first and only exhibition of its kind bringing together global decision makers, supply chain experts, suppliers, and customers to identify present and future market growth opportunities for OEM, design, manufacturing, testing, and launch operations of spacecraft, satellites, and space-related technologies. With its planned technical programming, comprehensive hall offerings, and highly targeted networking opportunities, Spacecraft Technology Expo will offer both exhibitors and attendees the opportunity to share in a unique marketplace of ideas. From satellite systems to launch vehicles, spacecraft design engineering to components and subsystems, and all facets of the manufacturing supply chain, exhibiting companies will effectively reach a highly targeted audience with a pre-established growing need for relevant technology and service offerings.

For further information contact
To request information about attending, sponsoring, exhibiting or speaking at Spacecraft Technology Expo, call (toll-free in the USA) 1-877-842-6289, visit www.spacetechexpo.com

or go to online enquiry card 101

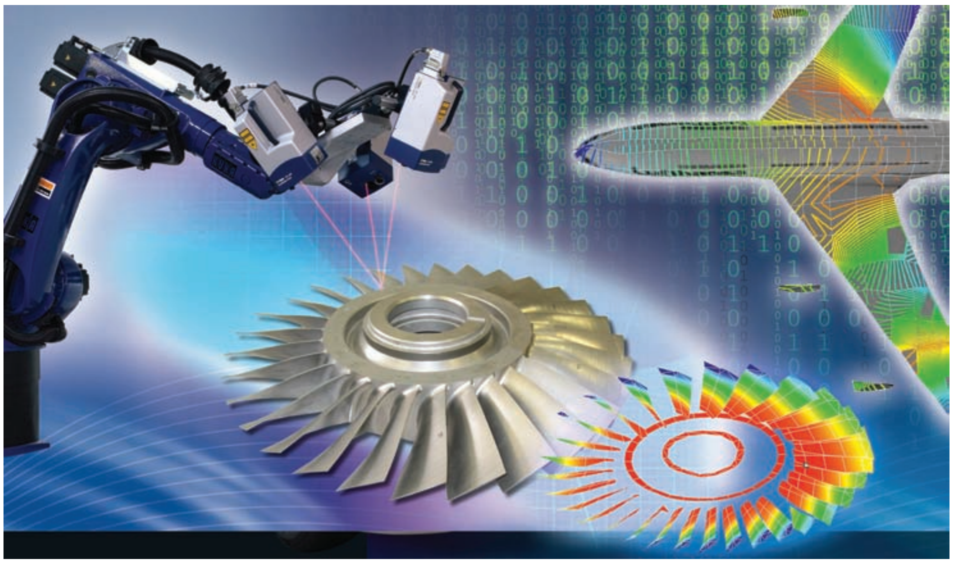
Updating the CAE simulation process

The development of commercial and military aircraft, unmanned aerial vehicles (UAVs), and space structures relies heavily on CAE simulation technologies to increase the efficiency of the product development cycle and to improve product reliability. Physical testing has long complemented the CAE simulation process to confirm the analytical predictions for systems, subsystems, and components through ground vibration testing, shock and vibe, qualification, acceptance, and other types of testing. So why is there such an investment in simulation?

Numerical models like those generated through the Finite Element (FE) method represent a simplified model of the real object based on assumptions, a company's knowledge-base, best practice, and assumed boundary conditions while creating the model. Consequently, proof of the product's design in the real world is required. Good test data used to update the model corrects for uncertainties like damping, stiffness in joints and bonds, material properties of composites, or geometric tolerances in the numerical model. The updated model will represent the real world much better and can therefore be used with a higher degree of certainty during development, or for future engineering changes. The better the test data, the better the FE update, which means fewer test iterations are necessary. This shortens the time to market for the product, while ensuring the design meets the functional performance specifications.

In addition, physical testing requires prototype hardware, which is very costly. So companies work to minimize time and cost of testing by only testing the required number of prototypes to validate the design or pass federal regulations. While automation is key in production, automation in structural testing is widely unknown and Experimental Modal Analysis is still a black art.

Is there a way to accelerate the testing phase of product development while improving the design validation process through automation? Polytec's answer to this question is a resounding 'yes', by combining its non-contact scanning laser technology with an industrial robot to create the Polytec RoboVib Automated Test Station. The RoboVib system applies the vibration sensors to the unit under test (UUT) through a scanning laser vibrometer. By importing the CAE or FE model into the RoboVib as the predefined geometry, coordinate system, and measurement points, the robot is programmed to optimize the position of the scanning laser sensors around the UUT automatically so the vibration measurements create a high-fidelity data set. This setup is saved and can be repeated for multiple test articles if necessary.



The system takes advantage of Polytec's unique non-contact scanning capability to measure structural response on the UUT and to eliminate the effects of mass-loading of traditional contact transducers like accelerometers. Once the data is acquired, the RoboVib system allows the user to visualize the deflection shapes with vivid animations of the high-fidelity geometry and export this frequency or time-based data into the FE software for model updating. This allows the RoboVib system to bridge the gap between CAE and Experimental Modal testing.

The sum of all this technology improves the accuracy of the measurement locations and acquired vibration data as related to the CAE or FE model, and increases the efficiency of the test through automation. In short: better data, faster, and more of it to help you revolutionize your product development cycle.

The concept of the RoboVib System was born out of the demands of short lifecycles in the automotive industry and is being further developed to its fullest potential in the aerospace industry with its increasing demand for more reliable data on complex structures. Product development with the Polytec RoboVib system is a paradigm shift and is a step toward the future of testing.

For further information contact
Polytec, 16400 Bake Parkway, Irvine, CA 92618, USA.
Tel: +1 949 943 3033

or go to online enquiry card 102

Uniting structural dynamics simulation and testing

Responding to the accelerating time-to-market that aircraft and vehicle manufacturers experience, Brüel & Kjær has further extended its structural testing solutions with advanced test-to-finite element analysis (FEA) correlation. The new capabilities are part of the PULSE 16 analysis software.

The increasing demands for lighter structures to achieve faster speeds and higher fuel economy places stringent demands on the mathematical Finite Element Models (FEM) to ensure that the calculated eigen-values (resonant frequencies) do not coincide with the excitation frequencies encountered by the structure.

Once the FEM has been approved, FEM prototypes are developed in accordance with them for carrying out experimental modal tests. The results from these modal tests (resonant frequencies and mode shapes) should then agree with the results achieved from the FEM analysis, thus validating the theoretical model.

Brüel and Kjær's PULSE Reflex Modal Analysis software, developed from the company's extensive experience in the field of modal testing, is now enhanced with a correlation module to compare the experimental and theoretical results achieved from FEM packages. Because of Brüel & Kjær's open data policy, data can be imported from various leading FEM programs such as Nastran, Ansys, or as UFF files.

Accurate correlation is quickly obtained by following an intuitive, yet flexible, workflow process that guides the user efficiently through geometry alignment, DOF mapping, comparison, vector comparison, mode pairing, and reporting.

For further information contact
Brüel & Kjær Tel +45 4580 0500 www.bksv.com

or go to online enquiry card 103

Successful demonstration of Lynx maritime mode on Aerostat

General Atomics Aeronautical Systems (GA-ASI), a manufacturer of unmanned aircraft systems (UAS), tactical reconnaissance radars, and electro-optic surveillance systems, has successfully participated in a US Air Force exercise designed to demonstrate the capability of an aerostat equipped with maritime radar and an Electro-optical/Infrared (EO/IR) sensor to provide situational awareness for littoral environments.

"Successful integration and operation of the Lynx Multi-mode Radar on an aerostat, which presented many navigation system challenges, is a testament to the radar's versatility," says Linden Blue, president, Reconnaissance Systems Group, GA-ASI.

"The exercise validated the robustness of the Lynx Maritime Wide Area Search [MWAS] mode and demonstrated that this capability is ready to transition to the military and border patrol users on various types of manned and unmanned aircraft," he says.

The flight test was conducted in July during the US Air Force Airborne Combat Command Mobile Unified Communications exercise held at Naval Air Station Oceana, Dam Neck Annex in Virginia Beach, Virginia. The SkySentry Aerostat, operated on behalf of the US Army Space and Missile Defense Command and Battle Lab and tethered approximately 1,000ft above ground level, was equipped with the Lynx radar, an EO/IR camera, and a maritime automatic identification system (AIS). Lynx successfully detected and tracked maritime targets of various sizes and speeds off the Virginia Beach coastline. The radar detections and AIS data were correlated and displayed as a common operating picture overlay for improved operational situational awareness of maritime traffic flow and target identification. Lynx enabled operators to point the EO/IR camera automatically at targets of interest. The test demonstrated that the Lynx Multi-mode Radar is capable of providing situational awareness on relatively stationary airship/aerostat platforms, as well as on unmanned and manned fixed-wing aircraft.

Capable of a 30°-per-second scan rate with algorithms optimized for detecting small vessels, including self-propelled semi-submersible vessels, the Lynx radar's MWAS mode has also been demonstrated successfully on a King Air aircraft and a surrogate Predator B UAS. The MWAS mode, along with a three-fold increase in the ground-moving target indicator area coverage rate and a new SAR-aided alignment mode, has been incorporated into Lynx radars deployed by US customers over the past year, and is available now for airship/aerostat applications.

For further information contact
General Atomics Aeronautical Systems.
Web: www.ga-asi.com

or go to online enquiry card 104

Next generation Q-EM high-speed camera

With airborne applications and beyond, high-speed film cameras are being replaced due to a lack of film supply, plus the need for immediate availability of image data. Unlike with industrial high-speed camera applications, the airplane and the test routine should not be modified to accommodate the new digital camera. Installing extra data and control cables to an airplane or modifying the test routine itself often leads to a complete re-certification of the whole airplane and procedure, and this should be avoided.

The AOS Q-EM offers precisely the specifications customers need to replace the film-based high-speed cameras with digital ones.

An impressive image resolution of 3 Megapixel to visualize even the smallest details and fine textures, frame rates up to 100,000 frames/sec, built-in image memory of up to 10.4GByte, and a built-in rechargeable battery are just some of the key specifications.

The Q-EM's built-in PowerPC allows the camera to be configured so it behaves like film cameras, with the result that only minimal modifications are needed on the airplane, as well as on the test procedure. Existing handshake routines can be duplicated by a number of programmable status lines. Double data security is provided by a built-in CompactFlash memory card to safeguard the valuable image data.

Cameras designed for airborne applications like the AOS Q-EM are tested and certified to rigid standards such as MIL-STD 461 and MIL-STD 810.

For further information contact
AOS Technologies AG, Taefernstrasse 20, CH-5405 Baden-Daettwil
Tel. +41 56 483 34 88; info@aostechnologies.com; www.aostechnologies.com

or go to online enquiry card 105

Rotating machine conditioning

Precision Filters recently published an application brief entitled *Signal Conditioning for Gas Turbine Engine Testing*, which can be downloaded at www.pfinc.com. This brief describes the measurement challenges and Precision Filters' solutions for testing in this extreme environment.

Precision Filters offers a unique suite of signal conditioning cards designed for the demanding requirements for testing rotating machinery. The 28114 and 28144 Quad Conditioners offer both balanced constant voltage and balanced constant current excitation, allowing flexibility to the measurement team for measuring dynamic or static strain, pressure, or any bridge type transducer.

The 28454A Quad and 28458 Octal Conditioners provide balanced constant current excitation optimized for conditioning high-temperature dynamic strain gages.

For pressure and other bridge-type transducers, the 28104A Quad and 28108 Octal Conditioners provide a balanced constant voltage excitation up to 20 V.

For acceleration, velocity, and displacement, the 28302B Dual Vibration Amplifier card accepts inputs from single-ended or differential piezoelectric or also IEPE accelerometers.

For frequency measurements, the 28524 Quad Frequency-to-voltage Converter Module provides conditioning for pulse, flow rate, and tach signals.

Members of the Precision 28000 Signal Conditioning System family, these cards provide all the flexibility a client needs to manage the measurements.

For further information contact
Karen Moore, sales manager, Precision Filters,
Tel: +1 607 277 3550, Email: sales@pfinc.com

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A tale of two engines

BY FRANK MILLARD

Dr Gordon Lewis CBE (1924-2010) was one of the most innovative engineers of his generation. He was responsible for the Pegasus engine that powered the iconic Hawker Harrier jump-jet together with its vertical take-off technology, plus much of the development of the Olympus engine that powered the equally iconic Vulcan, TSR2, and Concorde. No mean achievement.

Lewis was born in Gloucestershire, the son of a Great Western Railway clerk. He was educated at Pate's Grammar School, Cheltenham, and the University of Oxford, joining the Bristol Aeroplane Company as a graduate engineer in 1944.

The Pegasus

In 1956, when Lewis was working at Bristol, he was introduced to Michel Wibaut, who had originated a basic design for a vertical take-off airplane (Gyroptère) powered by a Bristol Orion jet engine. Lewis took the Frenchman's idea and applied his practical know-how and experience to come up with an efficient workable design – a vector trust engine with swivelling nozzles. The Pegasus was a vectored-thrust turbofan with – according to the Rolls-Royce website – a two-shaft design featuring three low-pressure and eight high-pressure compressor stages driven by two low-pressure and two high-pressure turbine stages. "The combustor is annular and features vaporisers," the website states. The engine development was almost entirely paid for by Hawker, whose chief, the visionary Sir Sydney Cam, was keen on its development during a time of a lack of government support for piloted military aircraft.

The Olympus

Lewis said of the Olympus: "You should have heard it before I silenced it." In 1949, Bristol's chief engineer was Stanley Hooker, but the Olympus project was run by Charles Marchant, with Lewis as one of his assistants in the engine division of the Bristol Aeroplane Company. The engine adopted a split-compressor design during the watch of chief engineer Frank Owner, and eventually was configured with two axial stages each driven by a separate turbine.

The design was conceived in the late 1940s by Owner. However, the Owner concept was different from one put forward by Lewis.

"The TSR2 was the most advanced of its type in the world at that time, but was scrapped by an economising British government"

"Lewis proposed the twin-spool turbo jet that was subsequently adopted and was the feature that continued throughout all marks of the Olympus, although in reality they were completely different engines," states the Rolls-Royce Heritage Centre. Lewis not only worked on the development of the Olympus from the outset, he inherited it as principal engineer and moved with it as the company became Bristol-Siddley and was later subsumed into Rolls-Royce Engines.

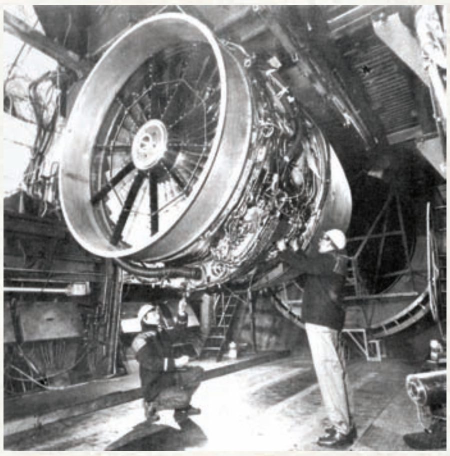
The Olympus 100, 200, and 300 series powered the Vulcan bomber and was the natural choice to be further developed into the engine (the Olympus R22) that powered the best airplane that the industry never had – the TSR2 tactical strike aircraft. The TSR2 was the most advanced of its type in the world at that time, but was scrapped by an economising British government as it was about to go into full production. The engine didn't rust, however, but was reborn in an adapted form (the Olympus 539) that powered the Concorde supersonic airliner – not dissimilar in look from its military predecessor. Nearly scrapped itself, the Concorde became the flying icon of its age.

From 1968, Lewis directed the Rolls-Royce team, which in collaboration with German and Italian engineers, built the engine for the Tornado and Typhoon Eurofighter. He retired in 1988 as technical director at Rolls-Royce.

The engineer – the man

This issue's small offering isn't about a great, well-known aircraft inventor. It concerns itself with an engineer at the top of his profession, an interpreter who could take a vague concept and turn it into a practical working reality. For the engineer is the greatest hero of industry; without him the wheel wouldn't turn, the bridge wouldn't span, and the aircraft would remain earthbound.

Lewis (in spite of a gross lack of investment in the aircraft industry by successive governments) took a Frenchman's dream of a vertical take-off jet aircraft and turned it into the Hawker Harrier, picked up on the development of the Olympus engine, and helped make three of the greatest aircraft in the world truly great. ∎



MAGNIFICENT MEN
and their flying machines