THE OFFICIAL MAGAZINE OF **AEROSPACE TESTING EXPO, HAMBURG, EUROPE 2013**

JULY 2011

AEROSPACE TESTING INTERNATIONAL

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Jetman gets grand
Yves Rossy, aka Jetman, tests his new wings, stunt flying over the Grand Canyon

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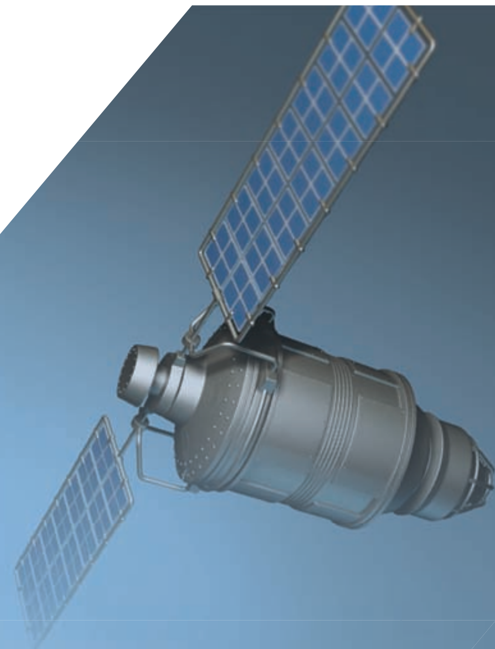

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Embedded Success dSPACE

Space Shuttle Columbia was first launched as the STS-1 mission, the beginning of the entire space shuttle program. Columbia successfully left Earth's gravitational pull on April 12, 1981, the 20th anniversary of the first ever human spaceflight (Vostok 1).

I was 15 at the time, and on holiday in Florida. My father was a pilot, so Cape Canaveral was a must-visit. We pulled in to the Kennedy Space Center. The Saturn V rocket was a big wow! The Vehicle Assembly Building (the largest single-story building in the world) – really wow! But in the far distance, toward the coast, was a large, white, ungainly aircraft standing upright, and strapped to a bunch of rockets. It was Columbia, five days before the inaugural launch. I wish I had taken in the massive significance more than I did. It seemed strange at the time to envisage a spacecraft that would actually land back on our planet in a controlled manner, and go up again!

At the time of going to press (one week ahead of the final launch), technicians at Launch Pad 39A concluded all tests and all x-ray scans of the stringers – the 21ft support beams on Space Shuttle Atlantis's external fuel tank. According to NASA, the scans were finished well ahead of schedule, and engineers found no problems as they continued to analyze the results. Teams at the pad are also installing the heat shield for the shuttle's main engine No. 3, and will have conducted a full retest of the engine's main fuel valve. The valve was replaced earlier in the week due to a suspected leak detected during a tanking test on June 15.

The STS-135 astronauts are back at NASA's Johnson Space Center in Houston following completion of their countdown dress rehearsal and training activities at Kennedy this week. They have also now conducted a final review of the flight data file in preparation for their mission to the International Space Station (ISS), and will conduct one final check, the Flight Readiness Review (FRR), to assess whether Atlantis, its four-astronaut crew, and the ISS are adequately prepared for the orbiter's launch. The targeted launch date for the space shuttle program's final mission is July 8, 2011, so it should have already happened as you read this.

Despite rigorous testing, the Space Shuttle Columbia I stared at 30 years ago ended its days on February 1, 2003, when, shortly before it was scheduled to conclude its 28th mission, STS-107 disintegrated over Texas during re-entry into the earth's atmosphere. It grounded the program for more than two years.

Interestingly, there is a test pilot called Joe Kittinger who, in 2003, was convinced that if Columbia had had an escape hatch, the crew could have survived. In 1960, Kittinger was sent into space, in a capsule attached to a helium balloon. He'd reached an altitude of 102,000ft (20 miles) straight up – some 40,000ft higher than Columbia was when it broke apart – when he jumped out of the capsule. It is not clear whether he hit the sound barrier, but it is known that he exceeded way over 600mph in freefall. He pulled his parachute at 18,000ft, was slowed by the thickening atmosphere, landed gently in the New Mexico desert, lit a cigarette, and went home for dinner. Of course, the Columbia was traveling at way past 1,500mph when it broke apart, but the cockpit section did slow greatly.

The shuttle has made huge advances in the space program, and is arguably the most complex machine ever built by mankind. It has never landed on the moon, though; really, it has just serviced the ISS over the last three decades and proved that frogs and insects can live in space. But it should not be forgotten that this machine generates 37,000,000hp on take-off. When Atlantis goes up, it is doing more than 120mph by the time its tail clears the tower. On take-off, it weighs 2,040,000kg, of which 81% is fuel, and each solid rocket booster generates 1,194,020 kg of thrust. As it re-enters the atmosphere, the temperature on its nose is hotter than the surface of the sun.

Just days after the Columbia disaster, at a service in memorial to the seven astronauts who died on board, then-President George W. Bush said, "Each [of the Columbia astronauts] knew that great endeavors are inseparable from great risks, and each of them accepted those risks willingly, even joyfully, in the cause of discovery." Wise words.

Hopefully the end of the shuttle program will not mark the end of space exploration, but a new international dawn, and a move ahead using the technology learned from the program.

Christopher Hounsfield, editor

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COVER IMAGE: Space Shuttle Atlantis launch (picture courtesy of NASA)

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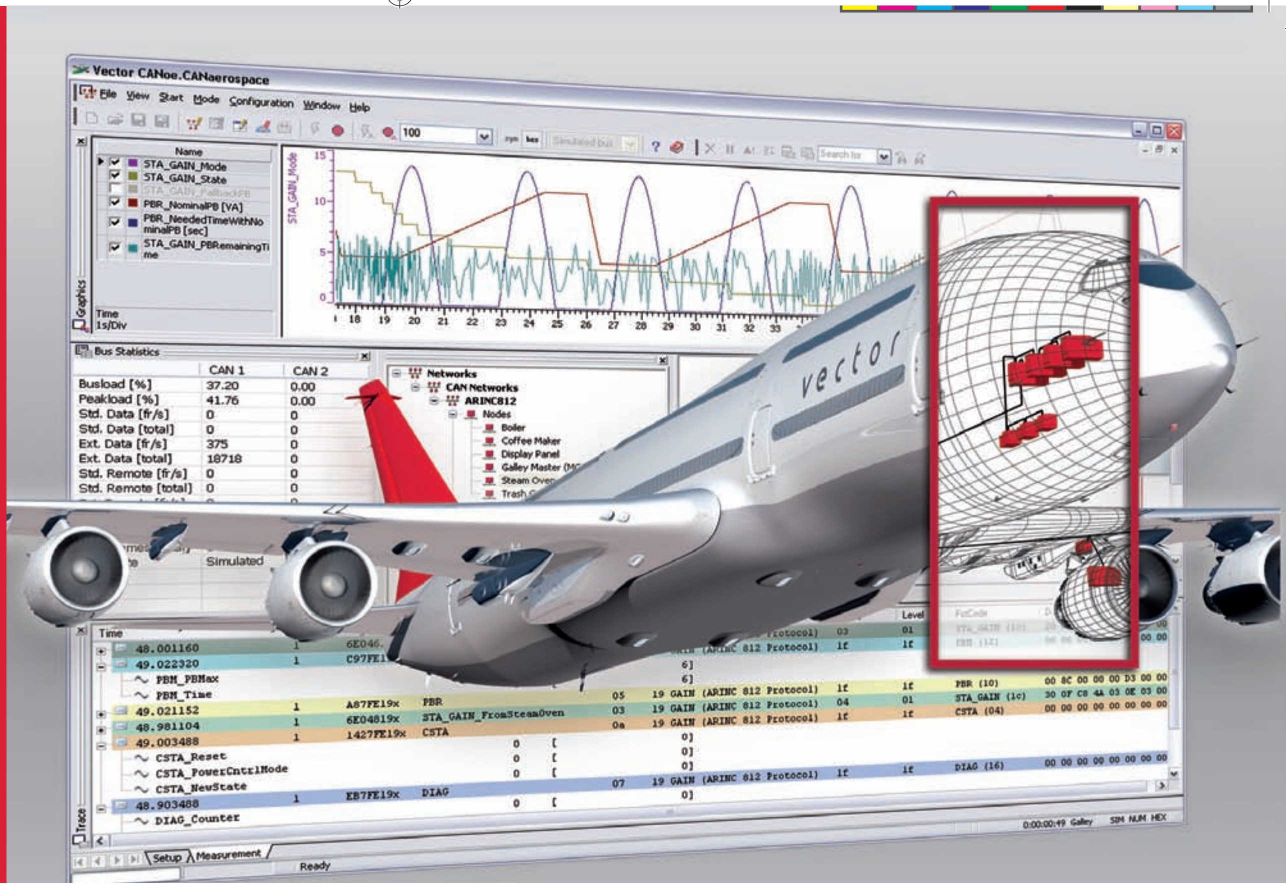

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Strike aircraft weapons upgrade

UK Panavia Tornado GR4 strike aircraft are now flying combat missions over Libya equipped with the MBDA Advanced Short Range Air-to-Air Missile (ASRAAM), after the weapons clearance on the aircraft was accelerated. The move is the first time new equipment has been installed on RAF aircraft as a result of the Libyan conflict and required intense effort by the UK's test and evaluation community.

It had been planned that the clearance of the UK-made ASRAAM would take place in July, but the outbreak of hostilities in Libya in March prompted the rapid fielding of the new weapon, according to an announcement by the UK Defence Equipment & Support (DE&S) organization in May 2011.

> "The ASRAAM replaces the Raytheon AIM-9 Sidewinder, the standard weapon of the RAF bomber force for more than 20 years"

The ASRAAM replaces the Raytheon AIM-9 Sidewinder, which had been the standard close-in protection weapon of the RAF Tornado bomber force for more than 20 years. AIM-9Ls were the most current version in use on RAF Tornado GR4s. The new weapon provides a 'greater self-defense capability against four generation threats'.

The accelerated introduction to service involved personnel from a variety of organizations, including the DE&S Fast Air Support and Short Range Air Defence project teams; BAE Systems, which is the GR4 design authority; MBDA, the missile's design authority; test experts from QinetiQ; and the RAF's fast jet test and evaluation unit, 41 Squadron.

"Personnel from the stakeholder organizations worked extended hours to bring the in-service date for the operational missile forward to support Operation Ellamy [the codename for the UK mission in Libya]," said a DE&S spokesperson.

The DE&S also hinted that the UK has been considering using its Tornado GR4s for suppress enemy air defence (SEAD) missions over Libya. The GR4s are equipped with the 1980s vintage British Aerospace Dynamics Air Launched Anti-Radiation Missiles (ALARM).

The DE&S said that QinetiQ had provided "release-to-service recommendations on the employment of ASRAAM and ALARM anti-radar missiles on a limited number of Operation Herrick (Tornado GR4) weapon configurations, which further enhances the aircraft capabilities".

These clearances are necessary because the RAF Tornado GR4s, modified under urgent operational requirement (UOR) funding for missions in Afghanistan, and also used in Libya, had not used the ALARM missile. Previously only the Tornado GR1 variant had fired the weapon in the 1991 Gulf War and 1999 Kosovo war. Work had been done to equip Tornado F3s with ALARM for use in the 2003 Iraq war but no weapons were employed.

At the time of writing, the UK Ministry of Defence has not confirmed the employment of ALARMs in the Libyan conflict.

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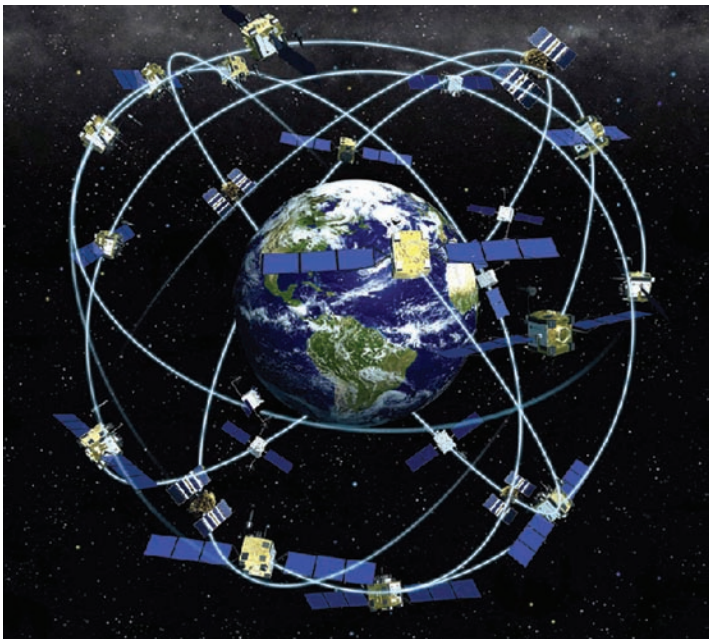
Tests show 4G interferes with GPS

The ubiquitous Global Positioning System (GPS) navigation and timing signals, widely used by civilian and military sectors, are under threat from a new commercial wireless broadband 4th Generation (4G) network being set up across the USA, according to the USAF General William Shelton, who heads the service's Space Command. In May 2011, Shelton said data from testing actual hardware appears to confirm initial concerns that a new 4G network would interfere with the GPS signal. His opinion is in line with several leading manufacturers of GPS equipment who have concluded that the towers on the proposed system actually jam GPS signals within 12 miles of them.

"If we allow the system to be fielded, and it does indeed jam GPS, imagine the impact," said Shelton, speaking to the US Senate's Armed Services Committee's strategic forces panel. "Although the data is still being analyzed, I would tell you that the empirical data appears to be consistent with the analytical data. We have concerns for civil, commercial, and military applications involving GPS."

The Virginia-based company LightSquared is proposing to set up a network of more than 40,000 towers mostly in US urban centers for its new 4G broadband network.

The full technical analysis by the USAF is due for delivery to the Federal Communications Commission – which is considering whether to grant the LightSquared an operating license by the deadline.



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SIGINT at center of Reaper enhancements

The USAF wants to incorporate two signals intelligence-gathering (SIGINT) sensors on its General Atomics MQ-9 Reaper unmanned aerial vehicles (UAVs) from 2012. This is part of a US$3.7 billion package of enhancements to its MQ-9 and MQ-1 Predator fleets. Projected spending on enhancements to the fleet of more than 58 MQ-9s and 163 MQ-1s is set to jump more than US$600 million, if Congress approves the latest USAF budget request. `

According to its FY2012 budget request, the USAF wants to start fitting the Northrop Grumman ASIP-2C SIGINT package to new-build MQ-9s from 2012. A low-rate initial production buy of four of the miniature sensor packages are to be purchased in 2012 and then serial production will ramp up to 36 a year by 2014. By 2016, some 127 ASIP-2C packages will have been delivered at a cost of US$29.48 million. Since the USAF wants to ramp up MQ-9 production to some 48 air vehicles a year from 2011, it is unlikely that its entire fleet will be equipped with the sensor. The USAF has been eyeing a SIGINT capability on its UAV fleet for several years and sees it as important to find insurgent targets in mountainous Afghanistan. To bring a limited SIGINT capability into service ahead of full deployment of the ASIP-2C, the USAF has requested US$6 million to field six Blue Moon sensor packages during 2012. This classified program is being executed under a quick-reaction modification project, run by the USAF Air Material Command's Airborne SIGINT Enterprise project office, involving accelerated integration and fielding.

The launching of the SIGINT projects is part of a US$2.6 billion package of enhancements for the USAF Reaper fleet. This includes continued funding of US$631 million until 2016 for the controversial Gorgon Stare wide area-surveillance video system, despite recent critical test-and-evaluation reports.

Under a US$658 million effort, the USAF wants to progressively migrate its Reaper fleet to Block 5 standard, which incorporates sensor, communications and avionics improvements. Some US$680 million is to be spent on upgrades to the MQ-9s MTS-B

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Shelton remarked that the company had shifted its business model from a largely space-based effort with terrestrial augmentation to a terrestrial-based network with space augmentation.

US deputy defense secretary Bill Lynn wrote to the US Federal Communications Commission chairman saying that he ‘strongly’ recommended that the commission defer final action until the analysis is completed. “We believe from what we have seen thus far is that virtually every GPS receiver out there would be affected,” said Shelton.

The controversy highlights growing concern around the world about the resilience of the GPS network. The European Commission has estimated that 6-7% of GDP in Western countries, amounting to €800 billion in the EU, is already dependent on the satellite radio navigation market.

In March 2011, the UK Royal Academy of Engineering published a report saying that western societies may already be dangerously over-reliant on satellite radio navigation systems such as GPS, given that the range of applications using the technology is now so broad that, without adequate independent backup, signal failure or interference could potentially affect safety systems and other critical parts of the country’s economy.

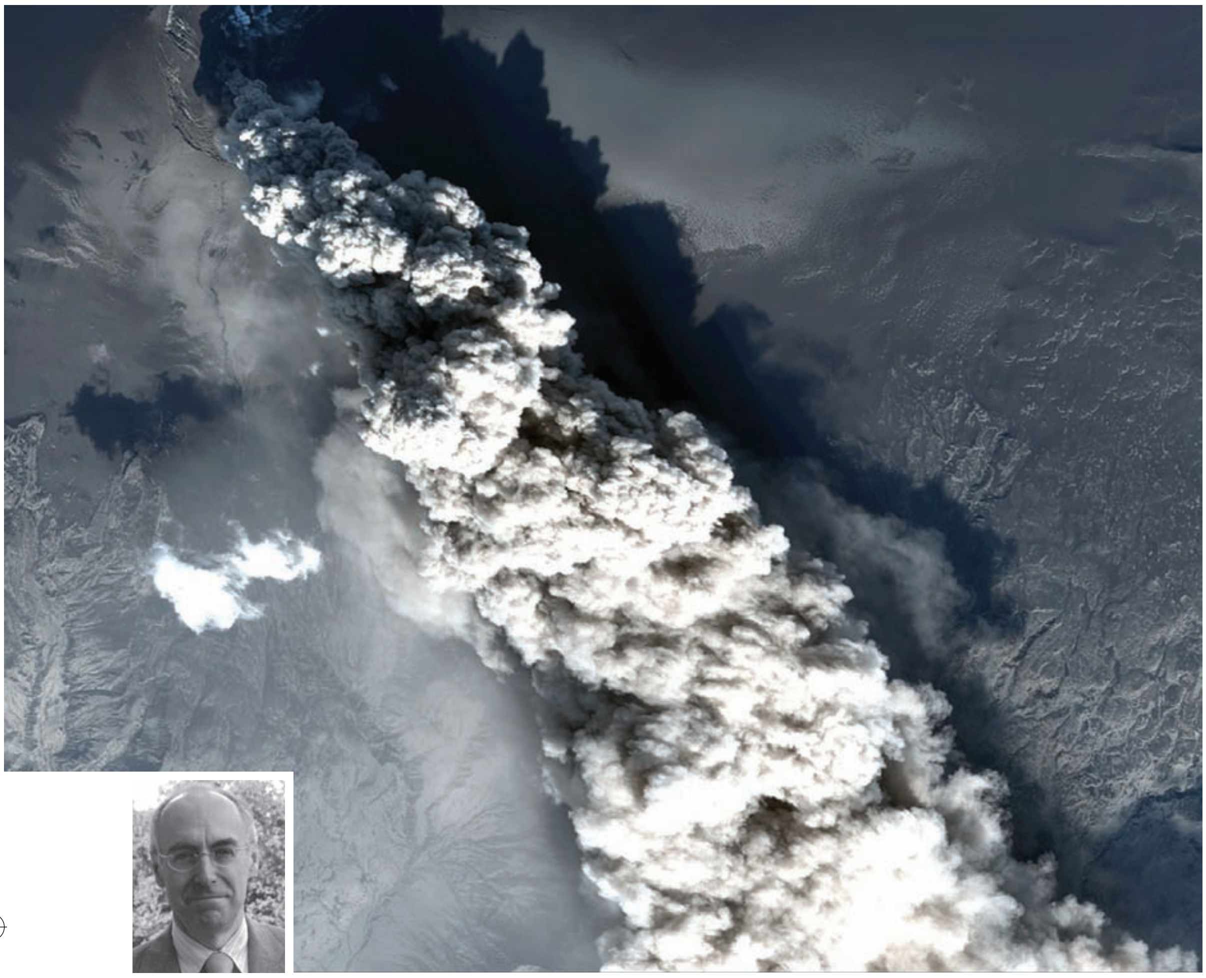
The Royal Academy report highlighted the ease and simplicity at which GPS signals could be deliberately disrupted by terrorists or criminals and by interference from existing radio emitters, such as CB radios, used by truck drivers.

It outlined a number of recommendations to counter the threat to the GPS network. These ranged from increasing awareness of global navigation satellite-systems’ vulnerabilities to stimulating manufacturers (and the users of the technology) to think more about increasing the resilience of Global Navigation Systems themselves, as well as developing back-up systems. It also suggested the building of additional satellites to make the GPS constellation more robust and even improve its signal coverage.

electro-optical sensor, and US$100 million on Lynx synthetic aperture radar. A further US$333.5 million is to be spent on ground control station modifications and US$94 million on migration to military Ka-band satellite networks. Around US$116.8 million is to be spent on airframe reliability and maintenance enhancements.

The USAF is now committed to keeping its MQ-1 Predator fleet in service beyond 2016 and wants to spend US$1.12 billion on enhancements over the next five years, up by just over US$120 million on last year’s projected budget.

The requested enhancements include high-definition video, secure datalinks, VORTEX video exchange of information systems, ground control station improvement system and ergonomic enhancements, payload upgrades, and aircraft modifications.



Dark clouds ahead

In reaction to the recent eruptions of another Icelandic volcano, Grimsvötn, the director of engineering at the UK's prestigious Institution of Mechanical Engineers in London, Dr Colin Brown, has called for more research into the ash cloud threat. He wants to improve understanding of the effects of ash on aircraft and improve management of future ash-cloud situations.

"Airlines and the Civil Aviation Authority should be using the Grimsvötn ash cloud to launch test flights to verify the theoretical modeling of how ash clouds disperse," argued Brown.

"More test flights should be taking place," he urged. "It's only by flying up to these areas and measuring the amount of ash in the atmosphere and the way it accumulates in engines, that work can be done to prevent disruption to air travel due to volcanic ash in the future. The difficulty for regulators is in trying to predict what an exact safe level of ash concentration is for airplanes to fly through. One hundred percent safety does not exist, so past experience and the gathering of ever more data are our only guides when trying to make an informed decision in the future."

Volcanic ash: genuine threat to aircraft safety

An independent investigation by scientists in Denmark and Iceland into the volcanic ash cloud that caused travel chaos across Europe last year, has vindicated the European aviation authorities' decision to ground thousands of flights until the danger had passed. Detailed tests on particles collected from the ash cloud found that two weeks after the violent eruption of Iceland's Eyjafjallajökull volcano, the volcanic debris contained particles still sufficiently sharp to damage an aircraft.

In April 2010, the ash cloud grounded aircraft over much of Europe for nearly a week. Some 100,000 flights were cancelled, leaving an estimated 10 million travellers stranded or delayed. The decision to close airspace cost European airlines and tour operators between €1.5 billion and €2.5 billion, according to estimates by EU transport officials. The flight ban led to criticisms from the airline industry, with some carriers accusing the UK Civil Aviation Authority (CAA) of overreacting.

> "If the fine particles were to melt inside the jet engines and clog up cooling ducts, this could have caused a catastrophic engine failure"

"One of the important findings of our research was that the air traffic authorities' decision to close airspace was absolutely the correct one," said Professor Susan Stipp from the Nano-Science Centre of the University of Copenhagen. "In the Nano-Science Centre at the University of Copenhagen, we have analytical facilities and a research team that is unique in the world for characterizing natural nanoparticles and their reaction with air, water and oil."

Stipp, and Professor Sigurdur Gislason from the University of Iceland, revealed their findings in an academic article that concluded that the fine particles, in the drifting plume of ash, were hard and sharp enough to put aircraft at risk from abrasion on windows and airframes. More catastrophically, if the fine particles were to melt inside the jet engines and clog up cooling ducts, this could have caused a catastrophic engine failure.

The scientists reported they have drawn up emergency procedures to be used in future incidents when ash clouds threaten to close airspace. They maintain their tests can reveal in one hour whether the particles are toxic to people and animals, and in six hours, aviation officials would know whether the ash cloud posed a danger to aircraft. In 24 hours, there would be enough information to predict the size and density of the ash cloud and how it carried on the winds.

'I was surprised to find nothing in the scientific literature or on the web about characterizing ash to provide information for aviation authorities. So we decided to do something about it', wrote Stipp.

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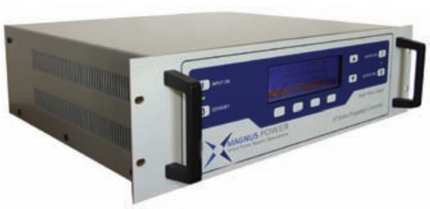

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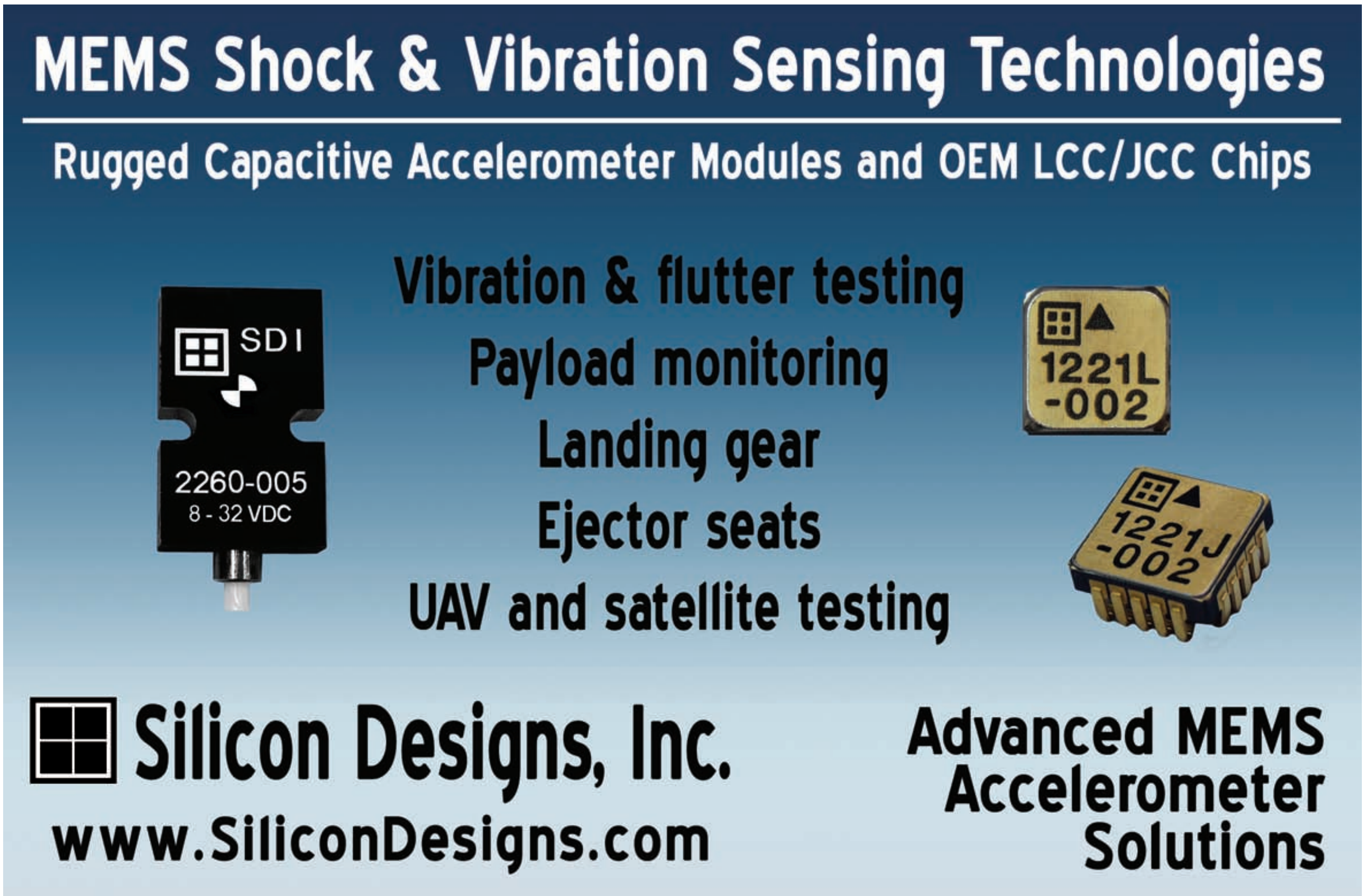
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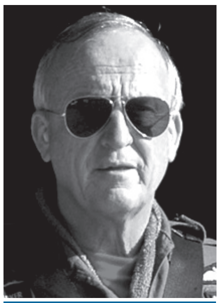


Put on a display

ADDRESSING THE DANGERS FACING TEST PILOTS IN LOW-LEVEL DISPLAY DEMONSTRATIONS, THE 5TH EUROPEAN FLIGHT TEST SAFETY WORKSHOP PROMISES TO BE A MAJOR EVENT FOR THE FLIGHT TEST COMMUNITY

BY DES BARKER

Product demonstration flying is actually only different from airshow display flying in terms of the objectives of the display. Essentially, the cardinal difference between product demonstration flying and airshow display flying is that the commercially orientated flight test product demonstration focuses on exhibiting the aircraft's performance and handling qualities to the prospective customer, while in classical airshow display flying the emphasis is on the skills of the pilot in providing entertainment to fee-paying spectators.

Test pilots that are not in the full-time business of airshow display flying are at a disadvantage as they must incorporate the additional nuances of low-level display flying into their flight test demonstration skills. That test pilots have historically been very successful product demonstrators is without a doubt. However, there are several examples of flight test demonstration accidents that resulted in the loss of lives and prototypes, bringing delays and cost overruns to programs.

"Product demonstrations push the outer edges of the flight envelope in ways that formation teams and barnstormers rarely do"

The earliest accident dates as far back as 1908 when Orville Wright crashed during army performance demonstration tests at Fort Myer, Virginia; his observer passenger was killed. So as well as achieving the world's first powered flight, the Wright Brothers were also involved in the first ever flight test demonstration accident. In more modern times in Europe, the loss in 2005 of the second prototype Pilatus PC-21 while practicing for an upcoming sales tour to the Middle East, and the loss of the Grob SPn in 2006 during a demonstration to invited company guests cost the lives of both companies' chief test pilots. There's no doubt that test pilots understand that the primary aim of a flight demonstration must be to promote the particular aircraft in support of a company's marketing strategy, with the complementary aims being to enhance the reputation of a manufacturer by the presentation of a safe, imaginative, sensible, competitive, and professionally impressive display. Transferring the positive and enhancing features of the aircraft to the prospective customers while minimizing any shortcomings in the aircraft will be high on the list of priorities.

New product demonstration flights at domestic and international airshows are an essential component of the marketing campaign of an aircraft. However, the test pilot will be faced with having to perform a convincing routine and display of the aircraft's capabilities within the confined volume of the low-level airshow box and, in most cases, under the interrogation and assessment by a very critical peer group.

Precision formation teams will demonstrate pilot training and formation air-work skills and the focus of these displays are extreme discipline and pilot skills while barnstormers seek to thrill the crowd in ways that are uncharacteristic of a product demonstration. For example, extremely low-altitude inverted flight to cut ribbons being held between two pylons on the ground and record-breaking consecutive snap rolls are designed to impress the thrill-seeking public who are looking for a performance that keeps them on the edge of their seats. While these types of displays are intended to thrill and demonstrate the daring nature of flight, many of the maneuvers are dependent upon pilot skill level and the pilot's willingness to accept risks based on his/her abilities and not so much the performance attributes of the aircraft.

In contrast, product demonstrations are flown for the sole purpose of displaying to a discerning observer the aircraft's performance attributes and not merely the pilot's skill level. The bottom line is that to be effective, product demonstrations require the aircraft's unique performance traits to be displayed at low altitude before a discriminating and critical potential customer. As a result, product demonstrations push the outer edges of the flight envelope in ways that formation teams and barnstormers rarely do. Pilot skill is obviously a factor in these displays; however, it is the aircraft's capabilities that are pushed to the limits and not necessarily the pilot's.

Flight test demonstrations alone do not sell an aircraft, but they certainly serve as an invaluable adjunct, enabling prospective customers to get a first look at the capability of an aircraft. Important as it is from the commercial viewpoint of making the sale, flight test demonstration is, as in all cases of exhibition flying, a hazardous activity.

The range of locations at which flight demonstrations could be presented may range from the international exhibitions such as Farnborough International (UK), ILA (Berlin, Germany) or Le Bourget (Paris Airshow, France), the manufacturer's airfield, or even at military bases. Demonstrating an aircraft at the customer's premises is somewhat different from doing so at home base, and in most cases, more analogous to a public airshow. The main difference is that more time is generally available and safety regulations may be less restrictive as there are no large crowds of spectators.

So, what guidelines should the commercial demonstration pilot consider in best exhibiting the air vehicle to a prospective customer? What are the requirements for the selection of demonstration pilots? What are the guidelines regarding the target audience? What are the demonstration pilot's responsibilities toward the company? What are the responsibilities of management? What are the demonstration pilot's responsibilities to the prospective buyer's team and pilots, briefings, and reporting? These are typically the focus areas for aircraft manufacturers when developing their marketing strategies through product demonstrations. Ideally, test pilots involved in product demonstration flights need to regularly revisit the safety elements governing the objectives, routine design and risk management involved. ∎

The 5th European Flight Test Safety Workshop takes place in Salzburg, Austria, from November 8-10, 2011

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

New light through old windows

A NEW ERA IN MANNED SPACE FLIGHT BECKONS AS THE USA MOVES ITS PROGRAM FROM THE PUBLIC SECTOR TO THE PRIVATE

BY TIM RIPLEY

When the US Space Shuttle Endeavour lifted off from Florida's Kennedy Space Center for the last time on May 16, 2011, the countdown to the end of NASA's manned space flight program accelerated. In July (at the time of going to print), Endeavour's sister craft Atlantis will be on the verge of being launched on the last ever shuttle mission, bringing an end to the 30-year program.

The shuttle took over as NASA's only manned spacecraft after the end of the Apollo moon landing effort in the mid-1970s. It clocked up some notable firsts. In particular, it proved that reusable spacecraft were viable. With the shuttle project now rapidly winding down, the question being asked is how the USA will retain the expertise to resurrect manned space flight later in the coming decade.

The technology employed on the shuttle evolved considerably over its 30-year life, but after the spacecraft suffered two dramatic and fatal accidents in 1986 (Challenger) and 2003 (Columbia), the focus of NASA's efforts turned increasingly to ensuring the reliability and safety of the system.

This became a recurring headache for NASA engineers and scientists as the pre-launch checks became evermore intense and sophisticated to avoid a repeat of the Challenger and Columbia disasters. Endeavour's launch was delayed for several days after a faulty auxiliary power was discovered only four hours from launch on May 3, 2011. A more serious repair exercise had to be undertaken to Shuttle Discovery at the turn of the year, when cracks were found in its external fuel tanks. Stress loading of the tanks was blamed and an emergency fix made to strengthen the stringers or supports that attach the tanks to the shuttle vehicle.

Although NASA sorted out the problem and safely launched Discovery on its final flight in February 2011, the incident highlighted a major contributing factor in President Obama's decision to cut funding for the shuttle program after July 2010. The soaring cost of sending men safely into space was no longer affordable in an era of out-of-control national debt.

The next stage

For the US space industry the ending of the shuttle program is a major blow. In April, the industry team, the United Space Alliance, which provided many of the support services for NASA, announced thousands of job losses from its current workforce of 5,600 employees at its Florida, Texas, and Alabama sites. The reductions will affect multiple disciplines and multiple organizations across the company it announced.

The reduction is expected to impact 2,600-2,800 employees company-wide, including 1,850-1,950 in Florida, 750-800 in Texas, and 30-40 in Alabama. These job losses are expected to be followed by more from industry, and from within NASA itself, possibly rising to some 9,000 people who have an unprecedented degree of expertise and experience of manned space flight. The termination of the shuttle program will save NASA some US$1.8 billion each year but it is very clear that NASA and the US space industry has little idea how to manage the staff drawdown to protect key skills and expertise.

Space industry sources also point out that the shuttle program played a major part in training large numbers of people in manned space operations, ranging from assembling spacecraft, overhaul, launch procedures, and mission control aspects. Without the constant churn of personnel joining the shuttle program, the source of future US space expertise must be in doubt, particularly in the manned operations aspect. The new build sector of the US space industry is less affected by the demise of the

STS-135

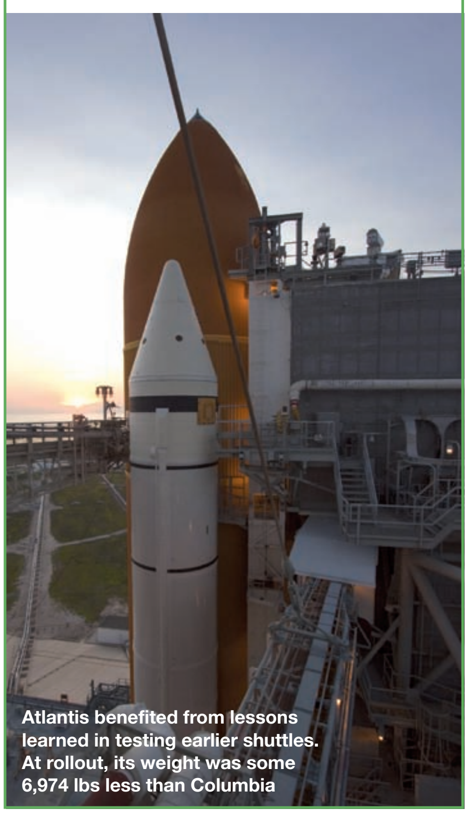
The rotating service structure (RSS) was rotated to the ‘park’ position in early June. However, the protection of the RSS and associated weather protection did not occur in time to stop Atlantis receiving a soaking during a localized thunderstorm, resulting in a small water intrusion, through a leak in the White Room hatch, located on the end of the orbiter access arm (OAA).

‘Due to the weather, a leak around the White Room-hatch seal allowed a small amount of water intrusion inside the forward of the orbiter’, according to the NTD report. ‘The water was isolated to just inside the hatch near the waste containment system (WCS) and was cleaned up.

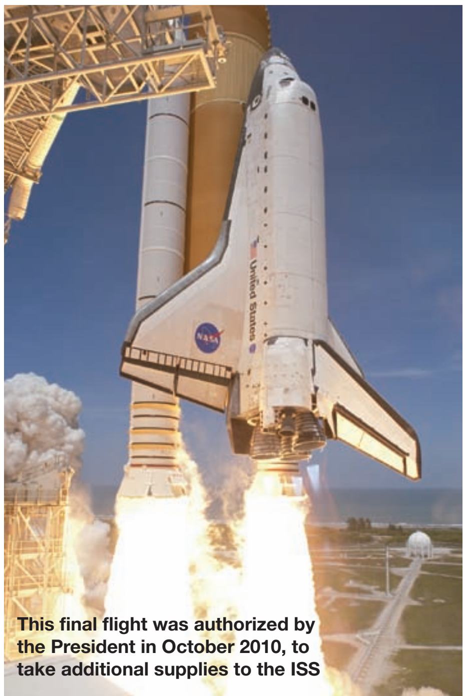
‘Adverse weather rolled through the area early Wednesday. A lightning strike was detected within 0.32nm of Pad A by CGLSS (Cloud to Ground Lightning Surveillance System); StrikeNet measured it at 0.87nm.

‘Initial analysis indicates very limited concern but engineering will continue the evaluation’, the NTD confirmed.

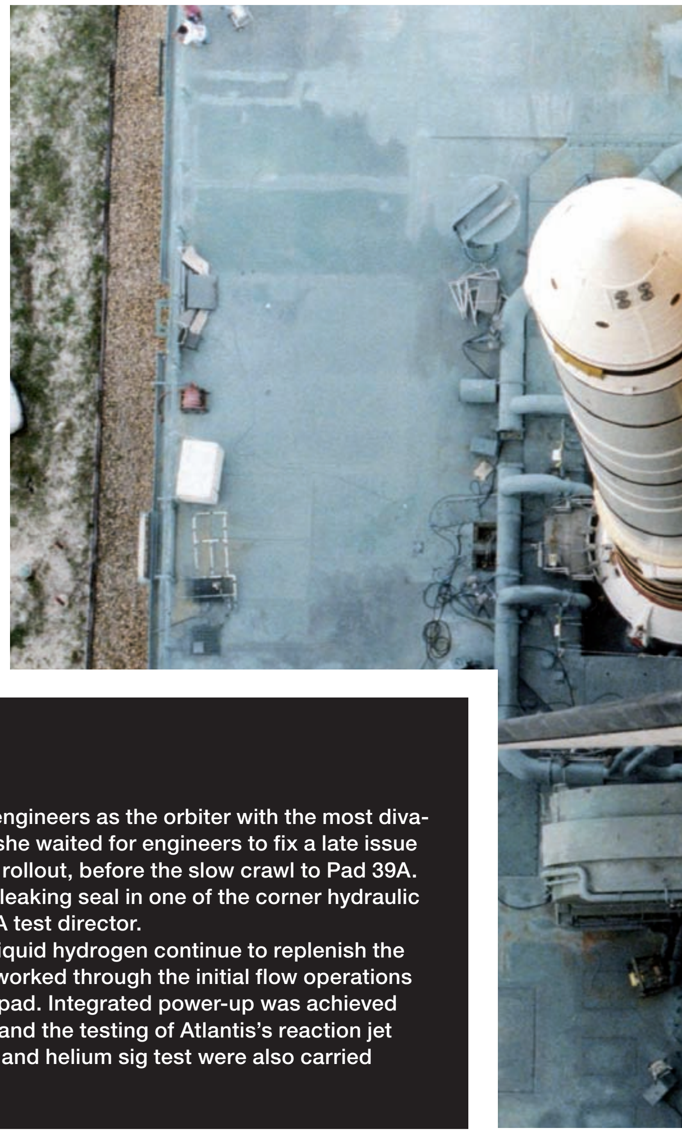
The ability to monitor the pads for lightning strikes is often-underestimated – four main systems are used to monitor, register, and observe lightning strikes, namely the catenary wire lightning instrumentation system (CWLIS), the lightning induced voltage instrumentation system (LIVIS), the aforementioned CGLSS, and the operational television (OTV) cameras.



Atlantis benefited from lessons learned in testing earlier shuttles. At rollout, its weight was some 6,974 lbs less than Columbia



This final flight was authorized by the President in October 2010, to take additional supplies to the ISS



Last of the last

According to NASA, Atlantis, known to some engineers as the orbiter with the most diva-like tendencies, lived up to her reputation, as she waited for engineers to fix a late issue with a crawler transport (CT) system ahead of rollout, before the slow crawl to Pad 39A.

“First motion was delayed slightly due to a leaking seal in one of the corner hydraulic valves of the C-T JEL system,” noted the NASA test director.

Waves of tankers full of liquid oxygen and liquid hydrogen continue to replenish the spheres at the pad complex, while engineers worked through the initial flow operations to hook up the STS-135 stack with the launch pad. Integrated power-up was achieved enabling an auxiliary power unit (APU) hotfire and the testing of Atlantis’s reaction jet drivers. The engine firing readiness test (FRT) and helium sig test were also carried out in June.

shuttle because of continued US military work and the global commercial market for new satellites and launchers.

NASA’s ambitions to send Americans again to the moon and to Mars over the next two decades have been progressively scaled back by Obama. Now the US government has ordered its space agency to look to the private sector or international partners to provide the spacecraft to take Americans beyond the earth’s atmosphere in the near term.

In terms of manned space flight, NASA is now looking to ‘buy seats’ on a number of private sector spacecraft that are under development. Richard Branson’s Virgin Galactic ‘space plane’ is an option for sub-orbital missions into the lower atmosphere using advanced technology derived from high-altitude aircraft, such as the famous U-2 spy plane. The Virgin concept involved a mother craft launching the orbital spacecraft up to the fringes of the earth’s atmosphere.

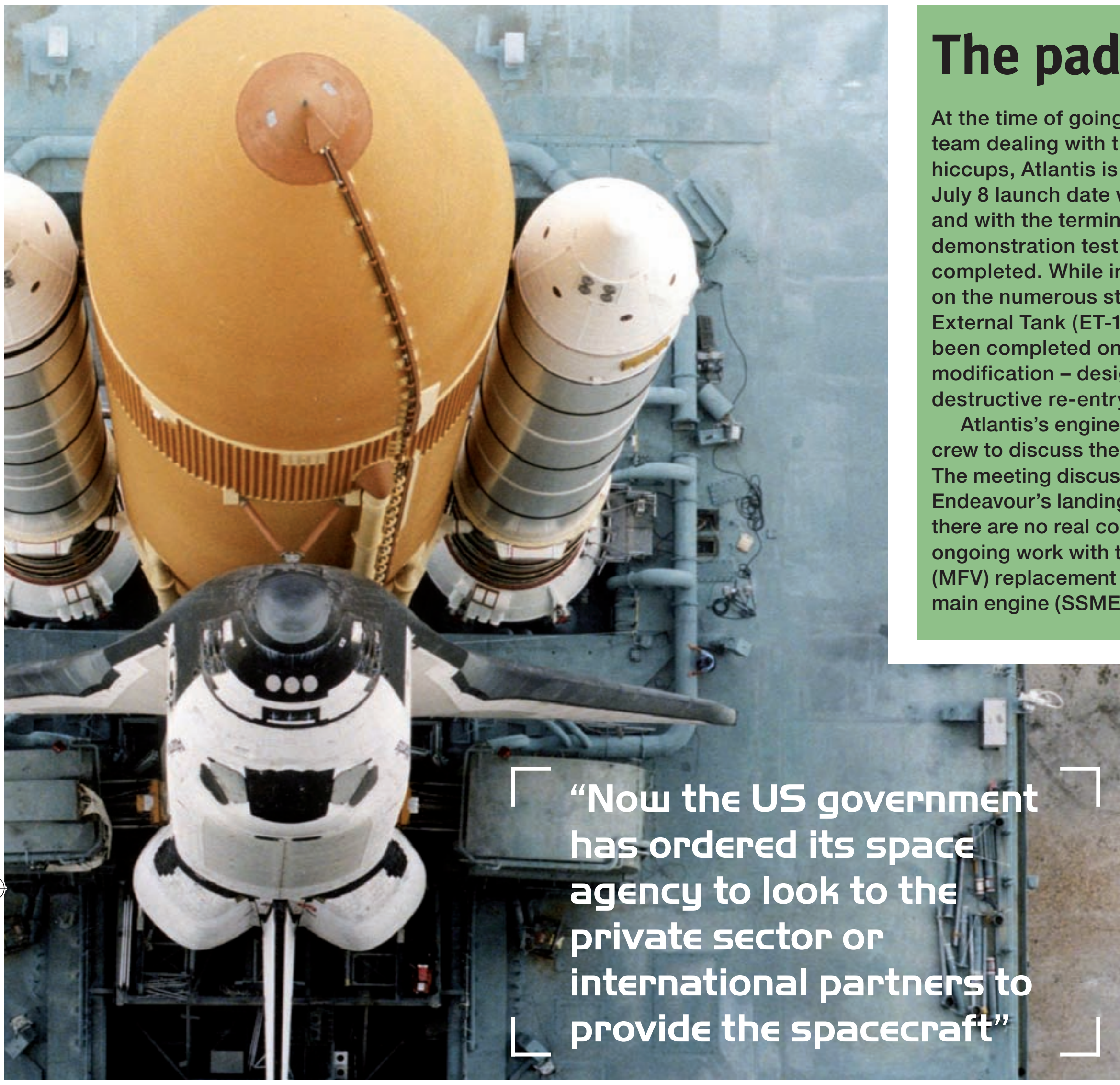
Virgin Galactic set up its ‘space port’ in New Mexico with help from US$200 million in funding from the state’s government, from where tests and fully operational flights will be made. The world’s first commercial spaceport, the Virgin Galactic site will require personnel with very different skills to those used on the shuttles in the past. The actual spaceship is essentially an air-launched glider with a rocket motor and a couple of extra systems for spaceflight.

One of the main technologies employed in the Virgin craft are scaled composites and the latest versions of the company’s design make it the largest all-composite aircraft ever built.

Power for the Virgin craft is provided by hybrid rocket motor technology. This is because a rocket has to operate in the very thin upper atmosphere, where oxygen for fuel combustion is scarce, and in space, where there really is not any, so it has to carry its own oxidizer. On the Virgin craft, the fuel is in solid form and the oxidizer is a liquid. Hybrid motors offer both simplicity and safety. The oxidizer is nitrous oxide and the fuel, a rubber compound. Both are benign, stable, and contain none of the toxins found in solid rocket motors, says Virgin Galactic.

International Space Station

The Virgin-based Space Adventures went into partnership with aerospace giant Boeing in 2010 to offer more traditional space flights, including the possibility of docking with the International Space Station. The Boeing CST-



The pad flow

At the time of going to press, with the team dealing with the usual pad-flow hiccups, Atlantis is heading toward its July 8 launch date with no major issues, and with the terminal countdown demonstration test (TCDT) now completed. While inspections continue on the numerous stringers on Atlantis's External Tank (ET-138), work has now been completed on the camera modification – designed to film the tank's destructive re-entry.

Atlantis's engineers have met with the crew to discuss the health of their orbiter. The meeting discussed the brake fire from Endeavour's landing on STS-134, of which there are no real concerns, through to ongoing work with the main fuel valve (MFV) replacement on the Space Shuttle main engine (SSME-3).

This view looking directly down onto the shuttle atop the Mobile Launcher Platform and crawler-transporter was taken from the VAB roof approximately 525ft (160m) above the ground (all pictures courtesy NASA)

100 craft is to be launched in a conventional manner and the company has also teamed up with Bigelow Aerospace to work on plans to build a new low-earth orbital space station by 2015. The Bigelow concept is for an expandable station that is built by attaching a series of modules.

Boeing is currently in the process of selecting launchers that will be used for the test flights and probably the first set of operational flights of the CST-100. In 2011, NASA awarded the Boeing and Bigelow team US$18 million to mature the capsule design under the agency's Commercial Crew Development

(CCDev) program. The CST-100 is intended to support crews of up to seven, as the result of greater habitable interior volume and the reduced weight of equipment needed to support an exclusively low-earth-orbit configuration. It is designed to be able to remain in orbit for up to seven months and for reusability for up to 10 missions.

The 13-metric-ton CST-100 is being designed to be launched into orbit atop a variety of rockets, including United Launch Alliance's Delta 4 and Atlas 5, Space Exploration Technologies' Falcon 9, the European Ariane 5 and the proposed Liberty rocket that would be built by Minneapolis-based ATK and Les Mureaux, the French Astrium Space Transportation.

Boeing expects to conduct a pad abort test of the CST-100 crew escape system in 2013, followed by two unmanned flight tests the following year. A final flight demo, slated for late 2014, would send two Boeing test pilots to low earth orbit.

The CST-100 is emerging as the central element of future US manned space missions in the near term. While Boeing and its partners will likely draw upon many of the personnel who currently work on sending the shuttle into space, uncertainty of the timelines of NASA funding streams make it difficult to predict when CST-100 activities will ramp up. In the meantime, the expertise built up in the shuttle program is in danger of wasting away.

Commercial future

These commercial ventures are all based on far more modern and cost-effective technology than that used on the soon-to-be-retired shuttle. They will use more advanced power storage and generation, communications, lightweight material, heat protection, and life-support systems. The timelines for the commercial projects of the companies involved are also ambitious, with the projects targeted to achieve operational status within five years. Central to these efforts is that they are all operating with private sector management procedures rather than being held back by NASA bureaucracy and the US Congress budget cycle.

However, these projects, with the exception of the Virgin Galactic, rely on NASA being the main customer. Their business models envisage the US government making a long-term financial commitment to buy seats for NASA astronauts and space for NASA equipment on their spacecraft. Manned US space flight is not quite going totally private but NASA is looking to build a market for private suppliers of services. The final frontier has met the free market, so to speak.

Endeavour's commander on its final mission was Mark Kelly, whose wife is Gabrielle Giffords, the Arizona politician shot in the head by a gunman in January. He summed up the views of many Americans when he radioed launch controllers moments before lift-off. "It is in the DNA of our great country to reach for the stars and explore. We must not stop." ∎

Tim Ripley is an aerospace and defense commentator and analyst. He regularly talks to UK and international media about a variety of defense and aerospace issues. Tim is a prolific author of books and articles on military and aviation subjects

Space travel Inc

WITH NASA SET TO TAKE A GIANT LEAP INTO THE PRIVATE SECTOR, *AEROSPACE TESTING INTERNATIONAL* REVIEWS WHAT IS HAPPENING, HOW IT IS HAPPENING, AND THE US GOVERNMENT POLICY

> "Ford didn't invent the internal combustion engine but he found out how to make one at low cost, and that's the appropriate analogy here"

BY MICHAEL BELFIORE

The agency that put men on the moon will this year fly the last of its manned spaceships into retirement. The Space Shuttle, far from realizing the promise of its developers that it made travel to space truly routine, never progressed beyond temperamental experimental vehicle status. Since NASA's US$10 billion replacement, originally intended to send astronauts back to the moon, is nowhere near ready for flight, the agency now must rely on the Russian Federal Space Agency to send its astronauts to the International Space Station, at a cost of US$63 million a seat.

The era of big-budget moonshots may indeed be over, but as it turns out, there's more than one way to get people into space. And therein may lie NASA's salvation, along with a chance to again blaze new trails in human space flight.

President Barak Obama last year charted a new direction for NASA, responding to the report on the 'Review of US Human Space Flight Plans'. It declared that the back-to-the-moon program launched by his predecessor was prohibitively expensive. Obama moved to cancel the moon program and return NASA to its roots as a research and development agency. NASA would focus its resources on developing new technologies for exploring space, and for studying planet Earth. For the routine work of servicing the space station, including transporting crews, it would foster the development of homegrown companies to do what the Russians were already doing: providing space taxi services.

"By buying the services of space transportation rather than the vehicles themselves," President Obama told an audience of NASA employees at the Kennedy Space Center in April 2010, "we can continue to ensure rigorous safety standards are met, but we will also accelerate the pace of innovations as companies, from young startups to established leaders, compete to design and build and launch new means of carrying people and materials out of our atmosphere."

Obama's speech didn't quite have the ring of President Kennedy's "We choose to go to the moon" speech of 1962, but was just as radical, and it may, in fact, foster greater innovation. Instead of launching NASA on a go-for-broke single-purpose mission, it points the way toward sustainable human space flight, where the forces of competition and economies of scale may finally succeed where the Space Shuttle failed.

The new direction

Underscoring the potential of NASA's new direction, in December 2010 Space Exploration Technologies (SpaceX) of Hawthorne, California, became the first private entity to launch and recover an object from orbit. Even more significantly, this prototype space capsule was large enough to carry up to seven astronauts. This test flight was ultimately sponsored by NASA, but the capsule, called the Dragon, and its launch vehicle, the Falcon 9, was developed mostly with private investment.

Total outlay for design, build, and launch of an all-new booster and space capsule, starting from SpaceX propulsion chief Tom Mueller's garage and a nifty idea from CEO Elon Musk: US$800 million. That figure includes development of the Falcon 1 satellite launcher, which uses a single, designed-from-scratch Merlin engine in its first stage. The Falcon 9 has in its first stage a cluster of nine Merlins.

Contrast that with NASA's average per-launch cost for the Space Shuttle (also including development costs) of US$1.5 billion, and it's easy to see why President Obama has embraced the idea of commercial space flight. NASA has granted SpaceX a contract worth US$1.6 billion to deliver cargo to the International Space Station starting in 2011. Astronauts could follow by 2015. Musk says he can fly astronauts for US$20 million per seat.

SpaceX is not the only American company investing private funds in a new generation of safer, more affordable spaceships (the Dragon will feature integrated escape rockets that can boost it away from a launch gone awry). Test pilots at Mojave, California-based Scaled Composites made headlines by flying the very first privately built spaceship out of the atmosphere in 2004, and they are now nearing completion of a eight-seat passenger vehicle for Richard Branson's Virgin Group.

In addition to SpaceX, NASA has contracted with Orbital Sciences Corporation of Dulles, Virginia for ISS cargo flights. And in 2011, the agency awarded a total of US$269.3 million to four companies, including SpaceX, to aid further development of next-generation manned ships. Importantly, the money is not enough to fund complete development; the companies must contribute significant resources of their own. This will not only spread NASA's risk among the different competing companies; it also makes the companies less dependent on fickle political whim.

"It's a big deal for us," says Sierra Nevada Corporation president, Mark Sirangelo of his company's own investment in its NASA-fostered spaceship. "It's not just making the statement that we're co-investing. We want to get this thing moving and flying as soon as possible."

A flawless first for private enterprise

SpaceX made history on December 8, 2010 by becoming the first private company to launch and then recover an object from space. This was the inaugural flight of the company's Dragon space capsule, which is slated to begin delivering cargo for NASA to the International Space Station in 2011, and could fly astronauts by 2015. It was the second flight of the SpaceX Falcon 9 rocket. After a 24-hour delay, during which SpaceX technicians repaired a cracked engine nozzle in the second stage, the rocket lifted off from Cape Canaveral in Florida shortly before 11:00. First stage shutdown, second stage ignition, and capsule separation all went smoothly to insert the spacecraft into low-Earth orbit at an inclination of 34.53° as planned. The Dragon completed two orbits and then fired onboard thrusters to re-enter the atmosphere for a successful test of the craft's heat shield and precision landing capabilities. It splashed down in the Pacific Ocean off the California coast within a mile of the target location.

"If there had been people sitting in the Dragon capsule today," said SpaceX CEO Elon Musk afterwards, "they would have had a very nice ride."

Latest commercial technologies

These new efforts are marked by small teams of engineers and technicians working closely with managers to build a little and test a little toward increasingly robust flight hardware. Managers and engineers at SpaceX, including CEO Musk, work in open, low-walled cubicles in shared office space at the company's headquarters in a former Boeing 747 plant. The layout is designed to encourage collaboration. The SpaceX high bay is in the same building, just steps from the cubicles, inviting easy interaction with the technicians machining Merlin engine nozzles and friction stir welding Falcon 1 and Falcon 9 fuselages.

The Falcon architecture was designed from the beginning for scalability. With the same engine powering the entire family of rockets, engineers could first test and then fly the single-engine Falcon 1 rockets as precursors to Falcon 9 flights. The Falcon 1 itself produces revenue from companies seeking more affordable satellite launch services than the prevailing rate. This in turn has helped to fund the next generation Falcon 9 and the Dragon.

If all goes according to plan, SpaceX will soon become the world's largest producer of rocket engines. Mass production. Economies of scale. Streamlined assembly techniques, borrowed from the auto industry (Musk is also the CEO of electric car maker Tesla Motors). These are new to the space launch industry, but, as Musk is fond of pointing out, not at all new to generations of industrialists. Musk is not shy about proclaiming his ambition to become the Henry Ford of space. "Ford didn't invent the internal combustion engine but he found out how to make one at low cost," he says.

The private way forward

Like Ford in the early days, Musk keeps production of every component of his vehicles under one roof. SpaceX even fabricates its own circuit boards. This, Musk feels, is key to keeping costs down since it cuts out component-manufacturer middlemen. Rocket engine testing takes place at the company's dedicated test facility in McGregor, Texas, where each engine is qualified with test firings before final integration with its rocket booster.

In the commercial space age, NASA and other government entities will benefit from pay-for-flight pricing, buying only the flights they need and letting other customers and investors share development and overhead costs. But governments aren't the only potential customers for the new vehicles.

In a newly competitive market, in which companies compete to fly payloads and astronauts with increasing safety and economy, corporate and academic researchers too stand to benefit from lower cost and more frequent access to space. Already we've seen private cosmonauts paying to ride Russian Soyuz space capsules to the International Space Station. That market is bound to expand if, as promised, private companies can cut the cost by two-thirds.

There's no predicting what finally realizing the unfulfilled promise of the Space Shuttle will bring about. But Las Vegas real estate developer Robert Bigelow, for one, is betting that routine space flight will make commercial space stations profitable as a business. His Bigelow Aerospace plans to launch the first of the inflatable habitats it is developing by 2014.

Regardless of what ultimately comes of commercial space flight, for NASA it seems a good bet for keeping its astronauts flying American ships in the post-Shuttle era. ∎

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

Left: Burt Rhutan in the fuselage of SpaceShipTwo

Right First Dragon capsule, postflight (picture courtesy Michael Belfiore)

Below: The SpaceX erector system raised the 180ft tall rocket to vertical using massive hydraulic cylinders

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Firing on all cylinders

THE MANUFACTURER OF THE SHUTTLES' ROCKET MOTORS IS CHANGING DIRECTION TO FOCUS ON THE LATEST MOTOR FOR NASA'S HEAVY LIFT VEHICLE

BY GEORGE TORRES

Since the inaugural flight of Space Shuttle Columbia, 268 shuttle solid rocket motors have been launched and 53 full-scale ground tests performed, enabling the manufacturer ATK and NASA to constantly improve safety, techniques, and processes.

The recovery and reuse of boosters after each flight has enabled NASA and ATK to collect vital post-flight information and performance data, confirming a safe and robust design. The post-flight data that has been gained from recovering the boosters over the past three decades has provided the knowledge to understand the motors' performance and make improvements throughout the program, leading to the most understood and reliable human-rated solid propulsion system in existence. As the USA's space launch system is developed, it is vital that this expertise is leveraged.

While continuing to safely fly the space shuttle, ATK is furthering the development of its upgraded five-segment solid rocket motor. The company is currently preparing to ground test the third full-scale development motor (DM-3) in Utah and plans to complete a 90% design review during 2011.

ATK is extremely encouraged by the data that has already been collected from the first two ground tests of the five-segment motor. With this new motor, it has been able to leverage the knowledge and hardware from the heritage shuttle program, and upgrade to better materials to build a higher performing, more reliable solid rocket booster that can support NASA's heavy lift vehicle.

The next stage

Modifications to the motor include an added fifth segment, changes to the propellant grain, a larger nozzle opening, and an upgraded liner and insulation material – all designed to meet performance requirements and increase reliability while lowering manufacturing costs.

The company has moved the final segment of NASA's five-segment solid rocket motor into the test stand as part of the DM-3 ground test. The test will be conducted in September 2011 in temperatures of 90°C (194°F). Data from this test will augment the data set from the DM-1 and DM-2 tests in 2009 and 2010, which were fired at nominal and cold temperatures respectively. DM-3 data will further validate the upgraded solid rocket motor performance and move toward supporting NASA's new heavy lift launch vehicle (HLV) system.

ATK incorporated many design changes during the development of the five-segment motor. These had been identified during the shuttle program but it was not possible to implement them, given the shuttle vehicle's operations tempo. The company also incorporated many new materials and streamlined processes that were flight-proven in its commercial programs. ∎

George Torres is vice president, communications, ATK Aerospace Systems Group

The NASA slant

NASA reports that a decision on the configuration of the space launch system (SLS) HLV is due now. One of the decisions will be regarding 'solid versus liquid' boosters on the SLS. So far NASA meetings have only committed to solids being used 'initially', although well-placed sources expect the solid variant will win out as the long-term solution for the evolved SLS. A 'non-official' proposal to use liquid boosters on the HLV was created. It cites the liquid option as advantageous, due to the simplicity of handling, superior impulse, and the logistical advantages of pad fueling simplicity, enabling a wider range of missions for the same cost.

ATK appear to be fully aware that its long-term role in SLS is not set in stone. The company has been busy providing costings and options to the Marshall team and the 'people in power' in the US capital.

Solid as a rocket

JAXA IS DEVELOPING A NEW TYPE OF SOLID-FUEL ROCKET, THE EPSILON LAUNCH VEHICLE. IT WILL REDUCE COSTS BY USING ARTIFICIAL INTELLIGENCE – A FIRST IN ROCKET HISTORY

BY YASUHIRO MORITA

The next-generation solid-fuel rocket that JAXA has been researching as a successor to the M-V launch vehicle was renamed the Epsilon launch vehicle (LV) in the summer of 2010 when it entered the full-scale development stage. It was perfect timing that Epsilon started its full-scale development just after Hayabusa returned to Earth carrying samples from the asteroid Itokawa. For future space development, it is equally important to launch small and responsive satellites, rather than just launching large-scale satellites on board the H-IIA and H-IIB LVs. It is the Epsilon that will perfectly respond to such needs. Indeed, the first Epsilon is set to launch a small-scale planet-observing telescope, SPRINT-A.

The Epsilon uses the existing H-IIA solid rocket booster in the first stage, and an upgraded version of the upper stage of the M-V LV in the second and third stages. Japan's solid-rocket history began with horizontal flight tests of pencil rockets in 1955. All the technologies accumulated over the last half century, from that time until the retirement of the M-V LV in 2006, are reflected in the Epsilon.

Until now, the performance of a rocket has been evaluated simply by the launch capacity and the orbital accuracy. However, in this coming new space era, if we hope to make access to space much easier, more sophisticated factors are required. The Epsilon is not only trying to enhance the advantages of conventional solid-fuel rockets but also develop into a next-generation rocket to meet the demands of the future.

In other words, JAXA is trying to make rocket launches much simpler events. One of the challenges in achieving this goal is to develop advanced technologies such as an automatic check-out system by making the rocket – as well as the mobile launch control system – intelligent. A large control room could be integrated into a single laptop PC. JAXA has already successfully completed the examination on a prototype model of the mobile launch control system and the real model will be realized soon.

The launch vehicle

The Epsilon LV uses upgraded versions of technology used in the M-V and H-IIA rockets. Because these are tried-and-true components, the development of the Epsilon began life with guaranteed reliability. And with the addition of artificial intelligence (AI), the rocket's reliability will continue to improve.

Applying AI is not just about installing a sophisticated electronic brain. For example, a rocket's orbit is controlled with a nozzle that expels combustion gas; orbit deviation is corrected by changing the direction of the nozzle. The nozzle is controlled with electricity, and by looking at the corrugated pattern of the electric current we can tell if it's moving correctly. The corrugated pattern is equivalent to an electrocardiogram of our bodies, and it is very much like checking the heart of a rocket. Everything JAXA knows about how to use this pattern to judge normality or abnormality will be implanted in the rocket. More precisely, the team will create a thorough list of how malfunctions of each component would impact the rocket overall, and implant that information into its AI brain. Through this process, which will enhance the rocket's reliability, the development team can also clarify which parts have to be particularly tough.

Because the autonomous check and mobile launch control system are new elements, they are probably the main concern. Needless to say, using artificial intelligence in the rocket is something that has been made possible only because of achievements made to this point. These achievements are not written in manuals; they are ideas that people have dreamed up and made reality. But now it is important to organize the ideas and compile a database. The key to this development is to sort out and systematize the foundation of what has been achieved to date and make the knowledge usable.

It may be an overstatement to say that JAXA is over the hump, but it has been able to verify the possibility of mobile launch control using a prototype model. So the development is coming close to the stage at which JAXA can build a reliable LV and finish production in time for launch in 2013.

JAXA is now in the final stage of design, moving toward the launch of the first Epsilon rocket in 2013. The team has made models of the hardware components, and is testing them one by one. The rocket launch control and autonomous check systems, which use two desktop computers, have been verified with the actual hardware. (The desktops will eventually be replaced by laptops.)

As for the motor case, which no longer requires an autoclave for manufacturing, a small carbon-fiber prototype has been built and is now being tested. It is possible to make a lighter and stronger motor case, and the plan is to make a full-size model to test within the next two years.

Solid-fuel rockets

With liquid-fuel rockets, it is possible to stop the engine and still control the thrust after launch. But with solid-fuel rockets, the engine cannot be stopped in mid-air once it is ignited. This is why solid-fuel rockets are said to be difficult to guide and control. But this does not mean they have poor accuracy in guidance and control.

To control the orbit of a satellite, you have to acquire information on its location and velocity at a given point. The location is determined by the three spatial dimensions, latitude, longitude, and altitude. The three-dimensional information also includes the speed at each dimension, so the velocity is also three-dimensional information. With these six coordinates – three for location and three for velocity – we can determine the orbit of a satellite.

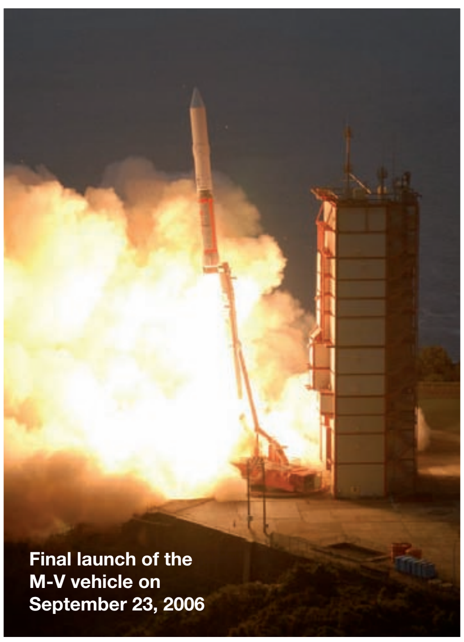
The engine burn of a solid-fuel rocket cannot be stopped, which means it is impossible to adjust it for all six coordinates to meet the needs of a satellite. So the question is, what can one do? Each satellite or planetary exploration spacecraft has its own specific coordinates that take precedence, so that can be a focus. For example, the solar physics satellite Hinode was launched into sun-synchronous orbit to travel in a north-south direction above the earth. What was important in that case was the relationship between the angle of inclination of the orbital plane to the equatorial plane, and the height of the apogee (the height where the satellite is furthest from earth). As long as we can ensure that the correlation of these two parameters corresponds, a satellite can be launched into its desired orbit.

However, to achieve this, the satellite developer has to have a good understanding of the performance of the rocket, and the rocket developer has to have a good understanding of the performance of the satellite. At the Institute of Space and Astronautical Science, rocket developers and satellite developers work in the same building, so problems can be solved by dropping in on each other and asking for advice.

So the plan is to install a small liquid-fuel engine, which was used to control the attitude of the M-V LV, on Epsilon's third stage. This will enable orbit insertion with similar accuracy to a liquid-fuel rocket. If access to space becomes easier, there will be more rocket users. With the Epsilon, JAXA would like to greatly lower the barriers for reaching space.

Next stage

As discussed, in the first stage of development, a desktop computer replaces the enormous

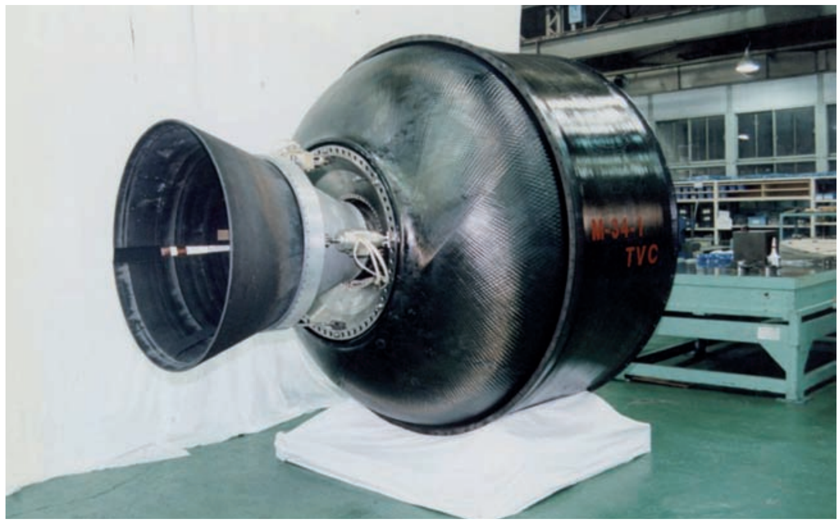


Final launch of the M-V vehicle on September 23, 2006

"With the Epsilon, JAXA would like to greatly lower the barriers for reaching space" launch-control room. This is the first step in JAXA's efforts to simplify the rocket launch system. In the second stage, around 2017, JAXA hopes the LV monitor will judge its own flight safety autonomously. This way, the radar and antenna used to track and send commands to the rocket can be removed. The role of the tracking radar and antenna on the ground are to track the rocket's orbit and, in the event of an abnormality, send a destruct signal in order to prevent people on the ground being harmed. A tracking antenna for this purpose is up to 10m in diameter. It works well, but it is also very expensive to build and maintain. Therefore, JAXA plans to further improve the AI of the rocket so that it can take care of its own fight safety. It will autonomously determine its orbit and condition, and self-destruct when it

Right: M-V rocket motor case (all pictures courtesy of JAXA)

Below left and far left: The Epsilon Launch Vehicle (graphic artist's rendition)



Watch this space

Tetsuro Yokoyama is JAXA's ISS program manager. He recognizes the space shuttle's huge impact on today's rocket developments: "The space shuttle undoubtedly marked an epoch in human space flight," he says. "I feel mixed emotion about its retirement. JAXA, as an International Space Station (ISS) partner, really appreciates those shuttle flights for assembly of the Kibo Japanese Laboratory Complex on the ISS. On the other hand, I envy NASA for taking a bold step forward to future human spacecraft development, which this retirement actually enabled. I hope more countries participate in a collaborative endeavor to explore the space frontier."

recognizes something unusual. If this can be achieved, there will be no need to use expensive tracking radar, and we'll be able to further simplify ground facilities.

After that, it would be great to build a system for weekly rocket launches – e.g. a Mars exploration spacecraft this week and a space telescope next. If the number of rocket-launch opportunities could be increased like this, it would be a drastic change from today's environment, where launch opportunities come only once every 10 years. By reducing the cost and increasing the frequency of launches, we can create a new environment to encourage and facilitate new challenges.

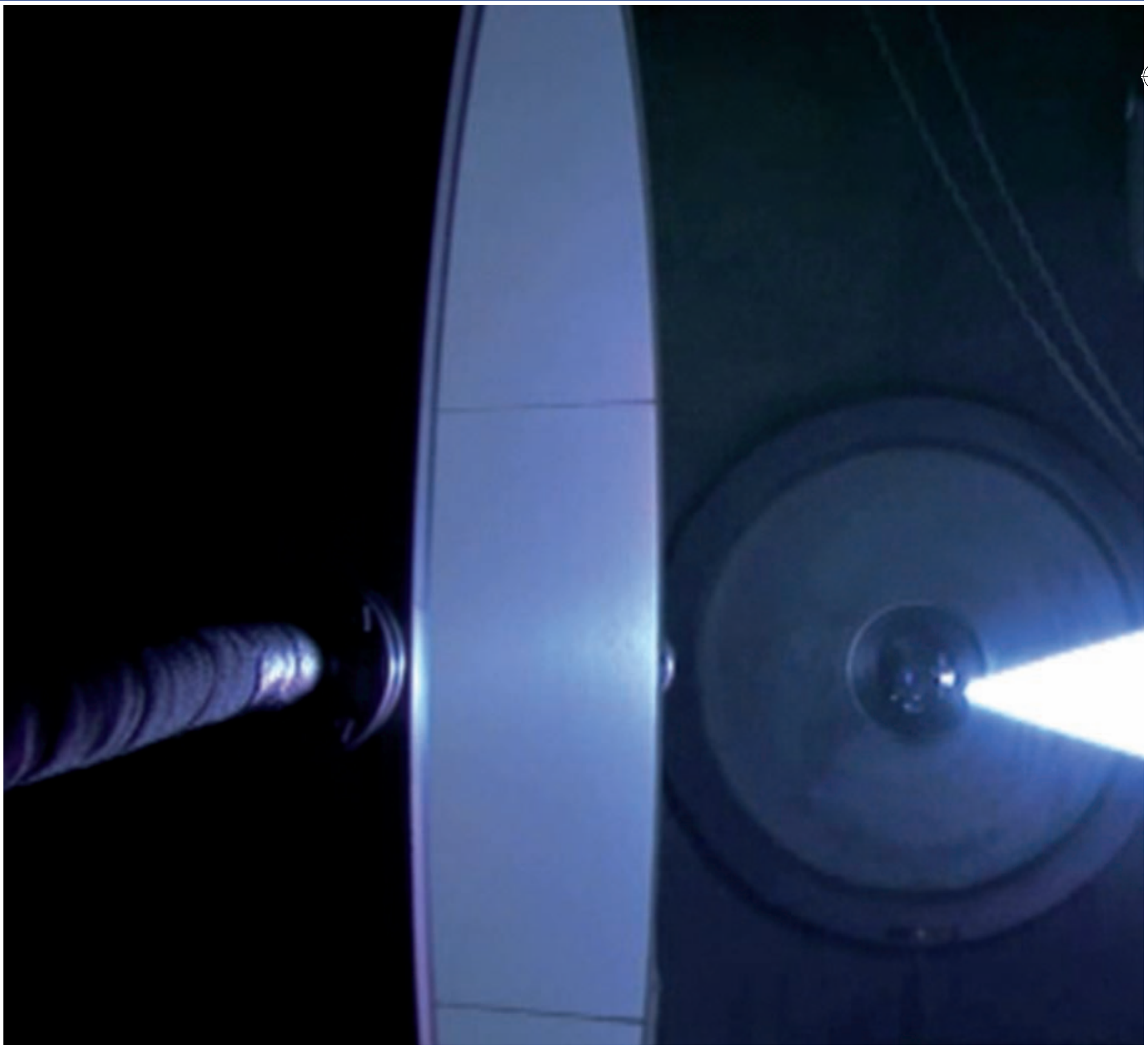
It is also important to use commercial, off-the-shelf components for rockets. In rocket technology, out-of-date systems are still commonly used because they are known to be reliable. Rockets are made with a mixture of very reliable but old-fashioned parts – like the ones used for a cathode ray tube TV, for example. Light, cheap, and sophisticated commercial off-the-shelf technology would help to reduce costs significantly. This could start a revolution in the world of rockets. ∎

Dr Yasuhiro Morita, PhD is professor of the Department of Space Systems and Astronautics, Institute of Space and Astronautical Science/JAXA; and project manager, Epsilon

From desert plains

SCIROCCO, THE ITALIAN PLASMA WIND TUNNEL, HAS BEEN FIRED UP ONCE MORE FOR TWO ESSENTIAL TEST CAMPAIGNS, BOTH DEALING WITH RE-ENTRY TECHNOLOGY PROGRAMS: EXPERT (EUROPEAN EXPERIMENTAL RE-ENTRY TESTBED) AND IRENE (ITALIAN RE-ENTRY NACELLE)

BY LUDOVICO VECCHIONE



In the framework of the space exploration and manned spaceflight programs of the European Space Agency (ESA), the development of large space transportation systems triggered the design and construction of new facilities throughout Europe. To specifically support the Hermes Development Program, ESA and the Italian Ministry of University and Scientific Research commissioned the Italian Aerospace Research Center (CIRA) to develop the world's biggest and most powerful plasma wind tunnel (PWT).

The name chosen for this facility was Scirocco, after the hot wind blowing across the Mediterranean Sea from the Sahara. Initially it was justified by the development and qualification-test requirements for reusable Thermal Protection Systems (TPS) of space vehicles. Despite the Hermes project termination in 1993, a group of European experts recommended the completion of the Scirocco project because of its utility for potential future space transportation activities, as there would not have been similar facilities in Europe.

Completed in March 2001, many experimental campaigns have involved Scirocco and its team of engineers, such as the tests required by ESA for the X-38 nose cap, by NASDA (today JAXA) for the HYFLEX nose cap, the test for the ISRO Indian Space Agency Re-entry Experiment (SRE) capsule, and the testing campaigns performed on the nose cap of CIRA's Unmanned Space Vehicle (USV), which was made of two materials: UHTC (ultra-high-temperature composites) and CMC (ceramic matrix composites). The Scirocco PWT is an arc jet type, capable of producing

Left:: CIRA headquarters

Below: IRENE test qualification in the plasma wind tunnel

"The flow velocity at the nozzle exit can reach a value of 7,000m/s"

a low-pressure high-enthalpy plasma flow of large dimension to be used for testing and validating the TPS materials on samples in scale 1:1, with a test duration up to 30 minutes, a period that corresponds to the typical duration of re-entry in the earth's atmosphere. In addition to these primary features, it can operate with gas different than air to simulate re-entry conditions in other planet atmospheres and for experiments in the field of propulsion systems such as scramjet and ramjet engines.

The gas used for the tests is dry compressed air with mass flow variable from 0.1 to 3.5kg/sec. Air is heated by a 70MW electrical supply, generating an electric-arc discharge confined in a 5.5m-long column (arc heater). Air is then accelerated through a convergent-divergent conical nozzle with interchangeable exit diameters up to 1,950mm. The flow velocity at the nozzle exit can reach a value of 7,000m/s. A powerful vacuum system working via the action of 12 steam ejectors is located downstream of the test chamber. The facility is provided by a very advanced control system for automation and safety. All the test phases are automatically executed and controlled by this

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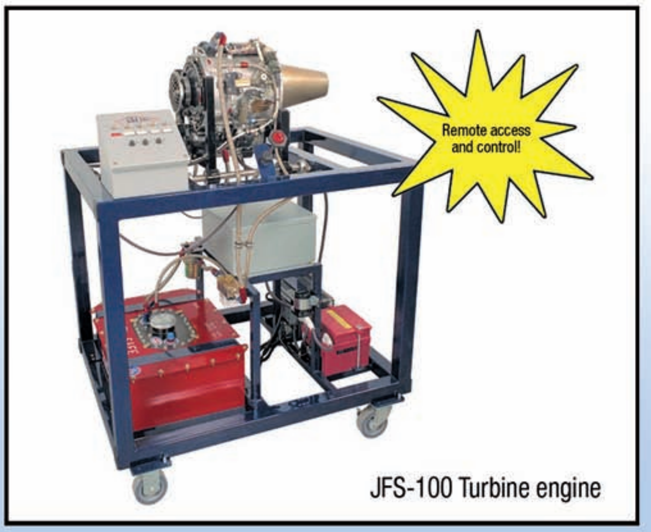

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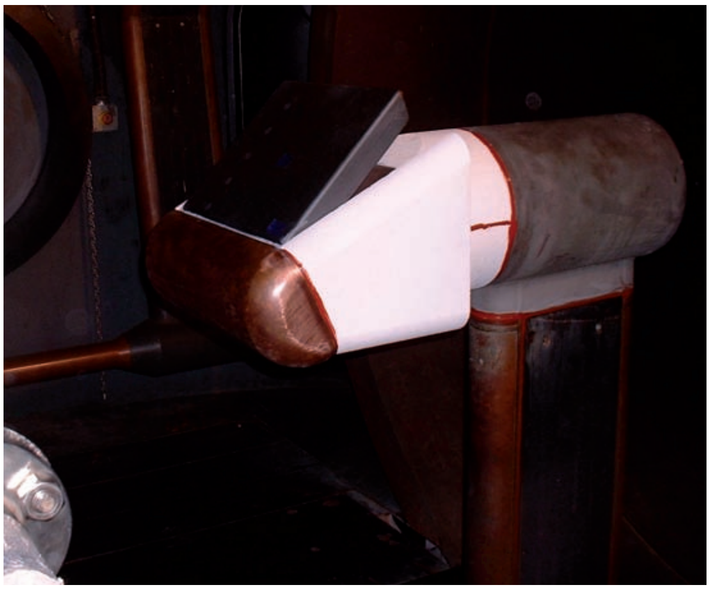


Left: The IRENE test qualification

Below: European Space Agency EXPERT qualification test

Small and light

IRENE is an Italian research program conceived and funded by the Italian Space Agency (ASI). The main objective of the program is the development of a small and light (150kg) re-entry system, using low-cost and safe technologies already in order to simplify and fasten access to space. The capsule for space re-entry has been designed and realized in the Campania region by the Consortium ALI (Aerospace Laboratory for Innovative Components), which includes the following regional SMEs: Aermec Sud, Arm SpA, Astro Srl, Avio Import, Canale Otto, Euro soft, Form & Atp, Its, La Fabbrica, Lead Tech, Mars, Naos, Parco Tecnologico Technapoli, Srs – Engineering Design, Stt, Tes SpA, with the scientific support of the Department of Aerospace Engineering of the University of Naples Federico II and CIRA for qualification tests.

control system, which is designed to generate a variable heat flux during the test, simulating a full re-entry trajectory.

The Scirocco PWT facility is equipped with an extended test instrumentation (intrusive and not intrusive) to fully characterize the flow properties in the test chamber, the thermodynamic properties on the model surface, and the flow properties along the test leg in terms of temperature, pressure, heat flux, and chemical composition.

EXPERT test campaign

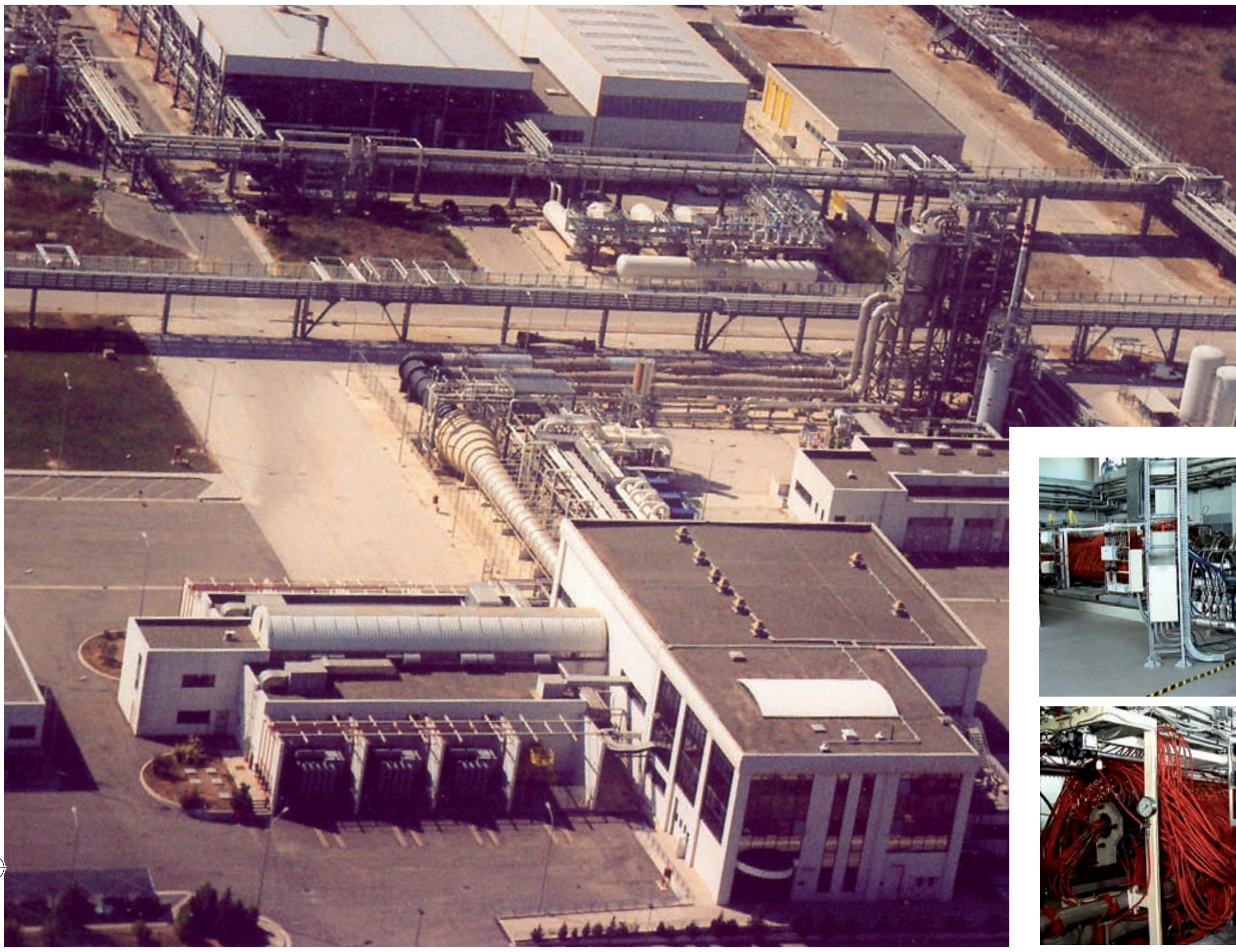
On April 13, 2011, a model of the flap of the EXPERT capsule was successfully tested in four different 're-entry into atmosphere' conditions. The test conditions were designed to get significant heat flux and temperature on the flap symmetry plane. The model was exposed to a very high level of energy (enthalpy of 13MJ/kg), reaching a surface temperature of about 1,500 K, therefore providing data on the critical aerodynamic and thermodynamic phenomena encountered during the atmospheric re-entry phase.

"The model was exposed to a very high level of energy (enthalpy of 13MJ/kg)"

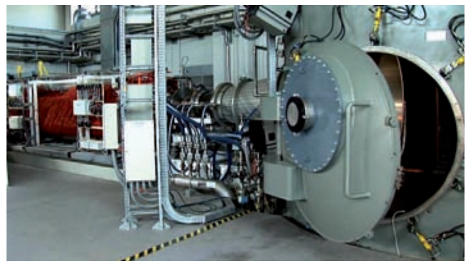
The Open Flap Assembly (OFA) test campaign has dealt with the capsule real-size open flap and instrumented with the same flight qualified sensors (thermocouples and pressure) and measuring systems (IR thermo camera from the inner side of the cavity under the flap, collecting the back-radiated flap energy).

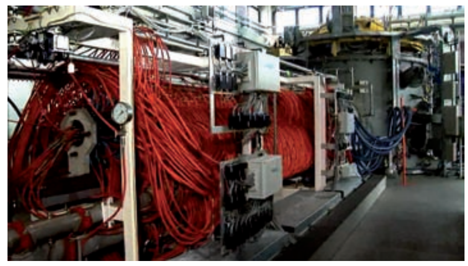
The use of optical not-intrusive on-ground facility instrumentation, such as IR thermo cameras and spectrograph, has increased the experimental outcomes, providing additional data for improving CFD and TMA design tools and the important ground-to-flight extrapolation process. ESA and other national member delegates were attending the tests and a first technical overview of the results has been already presented at the 7th ESA Symposium of Aerothermodynamics held in Bruges (Belgium) in May 2011.

Following up the EXPERT test campaign within a few weeks, on May 12, 2011, Scirocco heated up again for a simulated re-entry test on a scaled 1:4 model of the IRENE



The View from above - the CIRA Plasma wind tunnel, and within the complex





Complete experts

EXPERT is the European Space Agency (ESA) experimental flight testbed, aimed at collecting aerothermodynamics (ATD) flight data in atmospheric re-entry conditions. To overcome the lack of hypersonic flight data, the ESA EXPERT Program was started in 2001.

The re-entry flight-test program focuses on a generic configuration, designed to enhance the most interesting aerothermodynamic phenomena of a typical re-entry vehicle. Each phenomenon will be separately analyzed through a specific experiment and all these phenomena will be characterized by employing state-of-the-art measurement techniques to improve the understanding needed to design, and safely fly, future hypersonic space vehicles.

One of the most critical areas under study is the flap. Italy is the main contributor to the EXPERT program with 40% of the total value (other contributors are Austria, Belgium, the Netherlands, and Switzerland). The first re-entry flight is currently planned in the second half of 2011.

"The test performed at CIRA has proved the validity of the concept, of the selected materials, and the innovative technologies"

capsule. Hypersonic flow (about Mach 10) was generated for this specific test. A detailed experimental characterization of the flow has been realized using intrusive and advanced non-intrusive diagnostics systems: a total enthalpy of about 11MJ/kg and a total pressure of about 2.5 bar have been measured into the arc heater reservoir, and at the nozzle exit a static pressure of 0.07 mbar and a static temperature of 280°C (536°F) were recorded and have been revealed.

The test lasted about 281 seconds (270 provided by the re-entry mission profile of IRENE, plus 11 seconds required to stop the facility) with a thermal flow of 350kW/m^2. For the first time in its operational life, the test section of the facility was instrumented with two color thermo cameras, four dual-color pyrometers, and the model equipped with 18 thermocouples (type K) to acquire the thermal loads on the internal and external sides of the demonstrator.

This test realistically simulated the thermostructural conditions generated during a ballistic re-entry flight of the space capsule, and the model surface has reached a maximum temperature of more than 1,600 K. One of the main innovations of the IRENE re-entry capsule design is the management of the 'descent' phase, due to a variable-geometry thermal protection system that works like an umbrella, opening when needed to increase the surface area exposed to the atmosphere, so reducing the thermomechanical stress peaks of the exposed structure. The test performed at CIRA has proved the validity of the concept, of the selected materials, and the innovative technologies conceived by the Italian team. ∎

Ludovico Vecchione is the air vehicles division manager with CIRA. Other contributors: L. Paparone & S. Alguadich from CIRA's air vehicle division, business development, based in Italy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Good vibrations

THE TESTING OF A SMALL SATELLITE HAS BEEN OPTIMIZED BY USING LASER VIBROMETRY TO DEVELOP A FINITE ELEMENT MODEL

BY JAY ANDERSON

Researchers at the US Air Force Institute of Technology (AFIT) have developed a process for extensive modal testing of a small satellite, using a Polytec PSV 400-3D scanning vibrometer to create a finite element (FE) model whose dynamic response closely matches the measured response of the structure. One of the senior capstone design courses offered at the US Air Force Academy (USAFA) is the Department of Astronautics' FalconSAT program. It is a student-run, faculty-led program to design, build, test, and eventually launch a small satellite.

FalconSAT-5 is the latest in the series of FalconSAT satellites from USAFA. The second of the FalconSAT-5 structural engineering models (FS-5 SEM II) was constructed in March 2008 to validate design modifications resulting from a change in customer/payload requirements. The satellite was launched on November 19, 2010 on board a Minotaur IV launch system.

Accurate predictions of the dynamic responses of space launch payloads are required by launch vehicle integrators, but are not achieved easily. The FE method has proved to be the best approach in creating accurate dynamic models of complex structures. Previous research efforts used measured vibration data from only a few locations on the surface of the satellite to validate the first three predicted modes of the FE model. The capability to collect dense vibration data over thousands of grid points presents an opportunity to develop a more accurate FE model.

Structural dynamics and tuning

Researchers at AFIT have developed a process for extensive modal testing using the PSV 400-3D scanning vibrometer to create an FE model with a dynamic response that closely matches the measured response of FS-5.

The first step in the tuning process is generating the untuned FE model. Because the primary structure of the FS-5 SEM II is comprised of relatively thin panels, bilinear plate elements are predominantly used in the FE modeling approach. The second step in the tuning process is hand-tuning or adjusting the mass of each component of the FE model to match the measured mass. Measuring the mass of each structural component and carefully modeling the components leads to very accurate FE mass matrices.

The third step in the tuning process is measuring and extracting modal data from each panel and tuning the corresponding panel FE models by adjusting the Young's modulus of the panel materials. The vibrometer scans a grid of points spaced approximately 1in apart over the surface of each panel, collecting the operating deflection shapes through 1,000Hz as they are excited with an automated impact hammer. With each panel accurately modeled, a full satellite FE model is assimilated, leaving only connections between the panels, modeled by three columns of six-degree-of-freedom (6DOF) springs along each edge, as the design variable to tune.

The fourth step in the tuning process is measuring modal data from the integrated satellite and tuning the corresponding FE model by adjusting 6DOF spring constants and Young's moduli of the adapter ring material, which represents the launch vehicle mating and ejection rings.

Experimental setup

For panel testing, a harness that imparts the smallest amount of strain in the panel is desirable to simulate free vibration. To accomplish this, a horizontal test harness was built that uses a mesh of bungee cords to suspend the panels above the floor. The frame is adjustable in height to enable the excitation source to fit underneath. Excitation is provided via an electromagnetic shaker, programmed to impart periodic impulses with an arbitrary waveform generator and amplifier.

A force cell located between the stinger and the impact plate enables the vibrometer software to accurately estimate frequency response functions (FRFs). This approach also provides a much better coherence than other methods. With the panels supported and excited, data is collected on the dynamic response over the frequency range 0-1KHz. Given the size of the SEM II panels, noise levels as low as those generated by people talking can impart erroneous inputs or overrange the lasers, so care was taken to collect data at night only, when noise levels were lower. Overall, eight modes were recorded for the side panels, six for the top

The FS-5 SEM II satellite is the latest in the series of FalconSAT satellites from the US Air Force Academy (USAFA) and has been launched on board a Minotaur IV launch system


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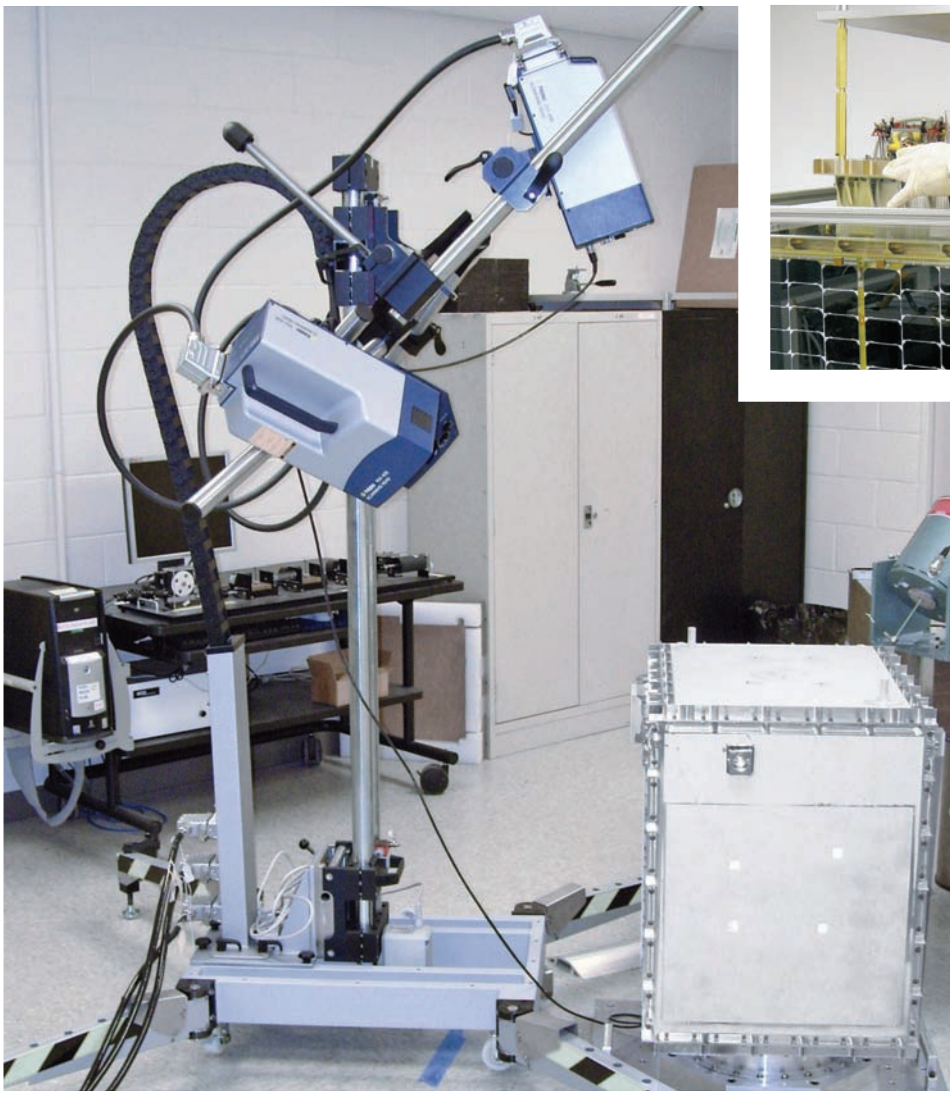

Above: USAFA cadet and faculty member integrating the payload onto FS-5

Left: Setup for testing the full SEM II begins with bolting the satellite stand plate to the floor

"It is a student-run, faculty-led program to design, build, test, and eventually launch a small satellite"

panel, and five for the base panel. Setup for testing the full SEM II begins with bolting the satellite stand plate to the floor to provide rigid boundary conditions.

The same automated electromagnetic ping hammer that is used in panel testing is positioned at a 45° angle to the satellite horizontal to excite the greatest number of modes possible while maintaining excellent coherence. Aliasing and leakage are issues that can be remedied with sampling rate and window functions. Unlike the panel data, three translational velocities are measured at each measurement point, resulting in three FRFs for each measurement point. A best practice is to keep all scan points within 10-12° of the field of vision for each head. To meet this restriction with the side panels, only one panel is tested at a time, with the heads positioned directly facing the panel.

With data collected, complex-valued modal data is extracted from the raw data using curve-fitting software then converted to real values for use in tuning. With a set of spatially dense real-valued data, optimization may begin. Optimization software algorithms vary the design variables (stiffness for panels and spring constants for the full satellite) while attempting to minimize a cost function based on differences between measured and analytical eigenvalues and eigenvectors. To keep the modal parameters from departing too far from the nominal values, constraints are specified in the optimization input that keep the design variables within desired bounds. The end result is a tuned FE model that closely matches the modal measured data in the frequency range of interest.

Results

The laser vibrometer collection process for the panels yields modal data for the first eight modes of the side panels, six modes of the top panel, and five modes for the base panel in the frequency range from 0-1KHz. Over 400 locations were scanned on each panel to collect this data. Over 6,500 FRFs were collected on the full satellite from approximately 2,200 measurement points on the five visible surfaces. Every panel's FE model was successfully tuned to match the measured data up to at least 600Hz.

Overall, the tuned panel eigenvalues matching the squared measured natural frequencies to within 2%, and the general decreases in the cost functions indicate successful panel tuning. The tuning process also reduces the cost function for full satellite model tuning – although generally the value of the cost function increases with increasing numbers of modes tuned.

The process enabled tuning up to the first five modes. Overall, the tuned FE model eigenvectors for modes four and five yield modal assurance criterion (MAC) values that are 31% and 33% better respectively than the untuned FE model. Natural frequency accuracy improved by an average of 7% when tuning the first five modes.

A 3D Scanning Vibrometer was successfully used to develop and improve an FE model for FalconSAT-5. Several approaches used during creation of the tuning process were critical to its success.

First, creating nodes on the untuned FE model directly from the structure geometry files enables the panel models to predict modal data that closely matches the measured values before adjusting design variables. Next, collecting vibration data using the Polytec laser vibrometer only at night is a major reason the measured FRF data has very low noise content. During the tuning stages of the process, the quality of the results and the ability of the software to converge are most sensitive to the desired allowable eigenvalue deviation. ∎

Jay Anderson, Cole Doupe, Professor Jon Black & Professor Eric Swenson are from the Air Force Institute of Technology, Wright-Patterson AFB, Ohio, USA. Article courtesy Polytec

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Weather watch

AN ADVANCED LIGHTNING WARNING SYSTEM PROTECTS SPACECRAFT LAUNCHES AT NASA'S JOHN F. KENNEDY SPACE CENTER

BY CARLOS T. MATA

NASA has designed a ground-breaking lightning monitoring system for the Florida-based, John F. Kennedy Space Center (KSC) using a series of unique high-precision transient recorders and digitizer transmitters. The system safeguards launch operations of the Space Shuttle and future-generation rockets. Lightning is a particularly formidable risk to launch operations, as spacecraft are particularly vulnerable to damage caused by high-induced strike currents and voltages. In 2009, the Space Shuttle Endeavour launch pad area was struck at least 11 times during strikes to the lightning mast and water tower, leading to costly launch delays.

With its proximity to the equator, Florida is an ideal launch locale. The earth's natural rotation effectively provides an extra push during launch, ultimately reducing fuel requirements to reach space. KSC can also be a challenging launch site, as it has one of the highest rates of lightning strikes to ground per square kilometer in the USA. To combat these dangers, NASA required a lightning monitoring system to work alongside a lightning protection system, both needing to remain effective at each critical spacecraft launch point.

Spacecraft are initially assembled inside the large Vehicle Assembly Building. They are then transported to the pad on special heavy-duty transporters, or Mobile Launcher Platforms, for final prelaunch preparations and mission checks. A spacecraft is vulnerable to lightning strikes from the moment it emerges from the Vehicle Assembly Building until final launch. During this time, it is important to continuously monitor numerous internal and external spacecraft points to identify potential negative effects from induced area lightning. Special considerations included the humid surrounding climate of KSC, which required a system highly resistant to corrosion and moisture. Also, the high risk of damages from shock, vibration, and high ambient temperatures nearing +70°C that are typically present during launch required a system that met specific military standard specifications. Transmitter input must also solely be DC-powered for battery operation and complete system isolation while lightning is in the area. Equally important was the ability to switch in a DC charging circuit via a remotely controlled output switch on the transmitter during a thunderstorm, to maintain continuous system monitoring.

The lightning protection system uses tall towers to support metal cables which intercept nearby lightning strikes and divert current from the launch vehicle. In the test area, two launch pads are protected. Launch Pad 39A, used for Shuttle launches, has one lightning protective device located on top of the pad, while Launch Pad 39B – designed for next-generation launches – has three 180m high lightning protection towers. Effective multipoint monitoring makes it possible to identify locations where high-induced currents may have occurred due to lightning induced electrical transients.

Working with NASA, HBM Inc, developed a system to measure induced currents and voltages at various points, with the Genesis High-Speed, high-resolution data acquisition system with Perception software to facilitate review, control, and analysis of captured data. The system monitors with 25MHz bandwidth at speeds of up to 100MS/s, with 0.1% full-scale accuracy at lengths of nearly 800m. Equipment at the test point included a fiber-optic transmitter rated at 100MS/s with 14-bit resolution and 25MHz bandwidth, housed in corrosion-resistant 304 stainless steel. Use of fiber optic cable supported up to 12km between numerous measuring points.

IRIG time codes were used to achieve synchronization between multiple mainframes. Fiber optic transmitters were linked to a receiver accepting up to four units for single mode fiber-optic transmission with 900MS transient memory. Individual measurement points could be isolated for independent testing from the recording system, with ability to produce a remotely controlled test signal for signal path verification, and capability to analyze and generate any automated reports for each lightning event. ∎

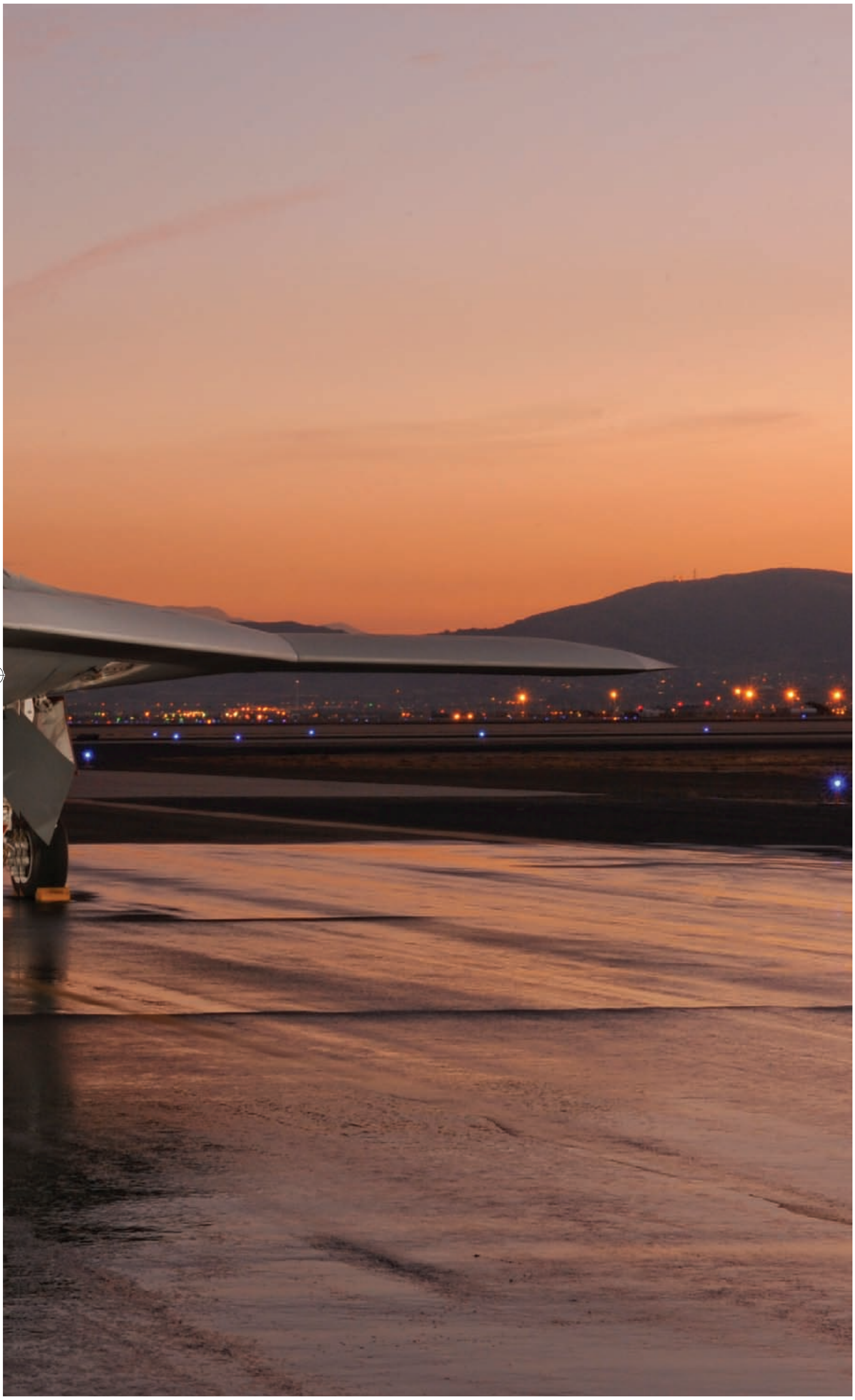
Warning signal

In 1988, KSC pioneered a two-phase lightning warning policy. In Phase I, an Advisory was issued that lightning is forecast within five miles of the designated site and within 30 minutes of the effective time of the Advisory. The 30-minute warning gives personnel in unprotected areas time to get to protective shelter and gives personnel working on lightning-sensitive tasks time to secure operations in a safe and orderly manner. A Phase II Warning would be issued when lightning was absolutely imminent and occurring within the five mile area.

Carlos T. Mata, Ph.D. is a subject matter expert, ESC Kennedy Space Center, Florida, USA

Launch, trap, and take gas

PROOF-TESTING PUT NORTHROP GRUMMAN'S SECOND X-47B UNMANNED COMBAT AIRCRAFT SYSTEM DEMONSTRATOR (UCAS-D) UNDER SIMULATED STRESSES OF CARRIER TAKE-OFF AND LANDING AND AIR REFUELING. FRANK COLUCCI LOOKS AT GROUND TESTING AN UNMANNED AIRCRAFT BUILT TO FLY FROM A SHIP



by Frank Colucci

Without a pilot, the X-47B Unmanned Combat Aircraft System Demonstrator (UCAS-D) is expected to launch and recover from a US Navy aircraft carrier by late 2013 and refuel from a flying tanker in 2014. The Northrop Grumman Flight Test and Evaluation Group proof-tested the structure of the stealth-shaped low-observable-relevant demonstrator under launch, recovery, and refueling loads without a static test article. Locked in a test fixture and loaded by computer-controlled hydraulic jacks, the second UCAS-D air vehicle (AV-2) mimicked take-off, landing, and flight conditions to complete five weeks of proof testing in January 2011. The cost-saving ground test monitored a mix of ground- and flight-test structural sensors with the same data-collection hardware and software used for flight tests. Engineers watched proof test data in the same telemetry trailer used for X-47B flight testing.

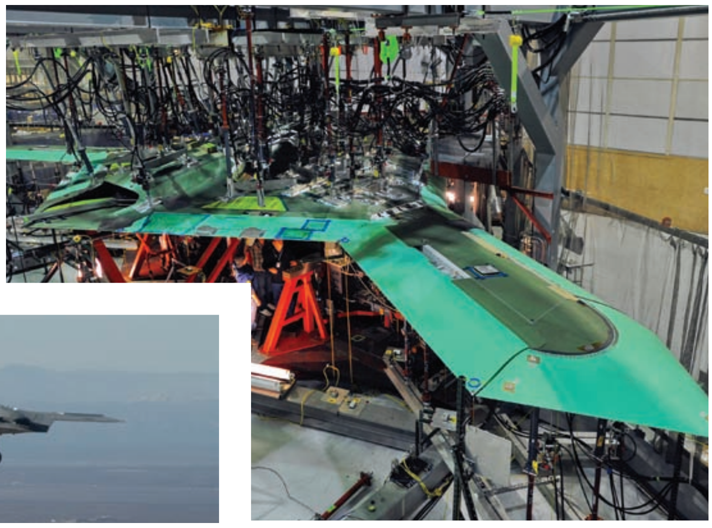
"To me, it looked just like an airplane flying," observes Keith Nelsen, AV-2 structural test lead for Northrop Grumman Aerospace Systems Sector, Advanced Programs and Technologies.

Northrop Grumman built two X-47Bs on adjacent jigs at Site 3 in Palmdale, California, previously the center of B-2 bomber manufacturing and now the Assembly Integration, and Test facility for the Global Hawk UAS and F-35 Joint Strike Fighter fuselage. X-47B AV-1 completed structural proof testing in 2009 and flew for the first time on February 4, 2011 at Edwards Air Force Base, California. AV-2, slated for carrier and refueling demonstrations, is structurally identical but for the air refueling provisions and slightly greater empty weight.

"We've now got data on two aircraft," explains Nelsen. "The data from the proof test overlaid with flight data."

The Navy's UCAS-D goal is a system compatible with carrier control area (CCA) operations; catapult launches and departures; and recovery approaches, arrested landings, wave-offs, and 'bolters' (go-rounds after failure to hook the arresting cable). UCAS-D requirements called for 90 minutes CCA loiter time 150 nautical miles from the ship and eight bad weather/night approaches. The autonomous demonstrator is expected to come aboard with a safe longitudinal landing dispersion and ultimately share the deck with manned aircraft. AV-2 will receive both probe and receptacle refueling gear during flight test.

The current UCAS-D program emerged from the Joint Unmanned Combat Aircraft System (J-UCAS) program run by the Defense Advanced Research Projects Agency (DARPA) for the US Navy and Air Force. The 5,500 lb X-47A flew once in 2003 at China Lake,



The second X-47B Unmanned Combat Air System Demonstrator, built by Northrop Grumman, completed structural proof testing in January 2011. The custom test rig positioned some 70 hydraulic jacks to apply static and dynamic loads

California and landed autonomously near a pre-determined touchdown point to simulate a tailhook-arrested landing on a carrier. The Office of the Secretary of Defense refocused the J-UCAS effort on Navy requirements in 2006, and Northrop Grumman won a contract in 2007 to design and build the 44,000 lb X-47B demonstrators.

The tail-less, near-Hornet-size UCAS-D air vehicles are not designed to an operational requirement. They are risk-reduction articles meant to mature critical technologies for a possible operational application. AV-1 is cleared for maneuvering loads to 2.2g; AV-2 to 2.4g. Proof testing verified structures would be able to absorb carrier and refueling loads. "We don't pull 9*g* on this airplane," says Nelsen. "Just because of that, our loads are lower. It is a flying wing, so the loads are distributed."

Test and demonstrate

The X-47B industry team includes GKN Aerospace in St Louis, Missouri, manufacturer of the X-47B center fuselage and wings. The complex fuselage plug covers aluminum and titanium structure with composite skins. The outer wings have an aluminum structure, covered with about 16ft-long and 4ft-wide carbon-epoxy skins. Each wing incorporates a spoiler for flight control and a fold for carrier parking.

GE Aviation Systems (formerly Smiths Aerospace) divisions in Santa Ana, California; Yakima, Washington; and Los Angeles, California designed and built the X-47B landing gear, catapult holdback bar, and gear-retraction mechanisms. The new but derivative UCAS-D landing gear system is designed for a 25.2ft/sec sink rate, the same standard applied to carrier aircraft today with more than six times the energy-absorbing requirement of land-based military aircraft landing gear.

X-47B landing gear components were qualified individually, and as a system. System-level testing included drop testing at sink rates to 27.3ft/sec for the main landing gear, static strength testing to 150% for critical design load cases and up to 200% for ultimate strength, fatigue testing (three lifetimes for the nose landing gear), and endurance testing. The landing gears on both X-47Bs are instrumented for flight test.

Lockheed Martin Aeronautics Skunk Works locations in Palmdale, California; Marietta, Georgia; and Fort Worth, Texas designed and built the X-47B aerodynamic edges, inlet lip, and control surfaces. The UCAS-D subcontractor tested the critical control surfaces to design and failure loads and supported Northrop Grumman in proof load testing. Lockheed Martin Palmdale with help from Marietta, Georgia and Fort Worth, Texas divisions was also responsible for the design, production, and testing of the stealth-styled UCAS-D arresting hook system fitted between the aircraft exhaust duct and lower skin.

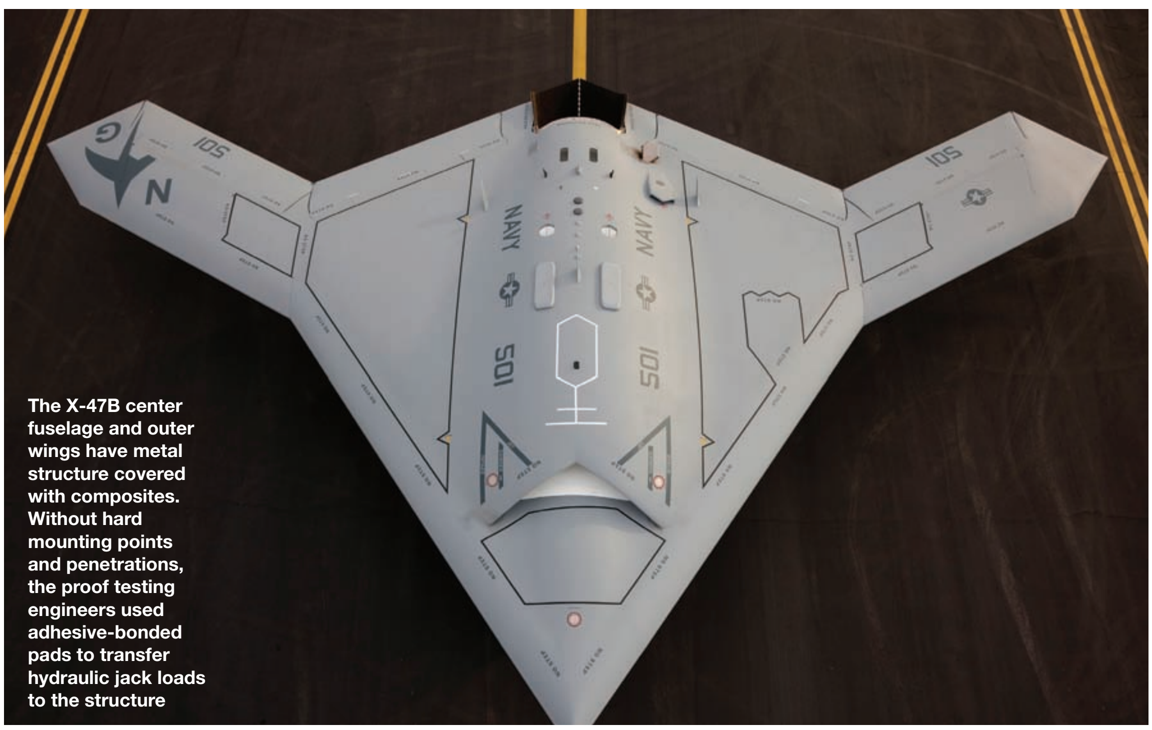
Dayton T. Brown, Inc based in Bohemia, New York static tested one hook system to ultimate strength at 150% design limit load and subsequently to more than 200% design limit load in the axial direction without failure A separate dedicated assembly underwent fatigue testing equivalent to three lifetimes initially. A material flaw was then inserted into a critical point and two more lifecycles completed. Following the fifth simulated lifetime, the hook assembly was pulled to 122% of design limit load with no failure. A fully Low Observable UAS would hide the hook in an internal bay with doors absent from the UCAS-D demonstrator.

Northrop Grumman subjected the assembled X-47B airframe to proof loads. The test scheme for the Low Observable airframe required only a few hard attachment points in the landing gear bays, weapons racks, and tail hook structure. A custom test rig supported hydraulic jacks operated by a Cyber Systems Fatigue-Master 7000 digital control system.

"The only things we pulled off of it were the main and nose landing gears, and the tail hook stinger – otherwise it was complete," said Nelsen. The landing gear was replaced by a dummy fixture that looked like real gear with load attachment points.

Just over 70 hydraulic jacks applied coordinated push-pull loads to some 200 adhesively bonded pads. Keith Nelsen explains, "Our goal was to use a few jacks as possible – the more jacks the more cost." The machined aluminum

"Because we had so few jacks, we were probably running double the normal pressure a normal test would see"



The X-47B center fuselage and outer wings have metal structure covered with composites. Without hard mounting points and penetrations, the proof testing engineers used adhesive-bonded pads to transfer hydraulic jack loads to the structure

The Fire Scout

The carrier-borne UCAS-D is not the only Unmanned Aircraft System meant to share aviation-capable ships with manned aircraft. Two Northrop Grumman MQ-8B Fire Scouts are deployed aboard the frigate USS Halyburton with an SH-60B Seahawk on anti-piracy patrol off the coast of Africa. A follow-on Fire Scout deployment is planned aboard another frigate in January 2012. Successful Operational Evaluation late this year should launch Fire Scout full-rate production in 2012 and may give the Navy up to 168 MQ-8Bs for its new Littoral Combat Ships (LCSs).

The Halyburton cruise across the Mediterranean and around the Horn of Africa is only the second operational deployment for the US Navy vertical take-off and landing tactical unmanned aircraft system (VTUAS). A Caribbean cruise aboard the frigate USS McInerney from October 2009 to April 2010 demonstrated the utility of the Fire Scout and gave fleet users their first chance to work with the unmanned helicopter. The McInerney air detachment from Seahawk squadron HSL-42 included 28 dual-trained Navy maintainers and aircrew supplemented by four Northrop Grumman field representatives. The Halyburton has an identical Air Det, but benefits from a simplified user interface at the Air Vehicle Operator's station and other lessons learned. Unlike the first deployment, integrated flight operations now enable manned and unmanned helicopters to fly at the same time.

Without the Seahawk's history in dynamic interface testing, the Fire Scout has a smaller launch and recovery envelope than the SH-60B. The 3,150 lb MQ-8B completed Phase One Dynamic Interface (DI) testing on the LCS-1 USS Freedom last November following essentially the same process used for manned aircraft. DI testing starts with no-to-low wind and deck motion and takes the aircraft through approach and landing. The unmanned common automatic recovery system (UCARS V2) uses a transponder on the helicopter to help shipboard radar determine aircraft position. A recovery data link carries precise distance and slant range data between the unmanned air vehicle and the moving deck. The data is reviewed to determine if the control inputs are reaching their limits of travel. Once the no-wind condition is cleared, the wind speed is increased and the landing evolution repeated for angles all around the ship. If the helicopter control limits are approached because of wind or deck motion, the limit is established. Phase One testing on the LCS-1 Freedom will be followed with additional testing, and the process will be repeated on the competing LCS-2 Independence.

The MQ-8B Fire Scout is currently deployed on an Oliver Hazard Perry class frigate to build operational experience for the coming Littoral Combat Ships

pads with their integral jack lugs were bonded to 1in-thick rubber pads themselves bonded to the aircraft.

"We just glued those things on," says Nelsen. "We had significantly fewer pads, which means fewer jacks. We had very high tension and compression forces." Naval Air Systems Command (NAVAIR engineers were on hand to oversee the test process. "Our Navy customer was very adamant we match the internal load distribution on the aircraft."

"Compared with an F-18, you probably would see fewer pads on this than an F-18," says Nelsen. "Because we had so few jacks, we were probably running double the normal pressure a normal test would see. We had to develop a very special bonding process to keep these pads on the aircraft, otherwise they'd rip off." Though AV1 lost some pads during proof testing, AV2 testing showed the bonding technology effective.

Sort of flying

The load profiles applied to the X-47B were modeled on past test programs. Programmed flight test loads include maximum and minimum symmetric g conditions, maximum asymmetric loads to simulate a rolling pull-out, maximum drag loads, and vertical loads. Take-off and landing profiles included maximum catapult loads and maximum tailhook loads applied aft and to the sides.

"We actually used our experience from other aircraft," said Nelsen. "One engineer had B-2 and F-18 experience. Essentially we covered all corners of the design envelope. We calibrated the strain gauges on the wings like we have calibrated in flight." X-47B AV-2 was tested to higher loads than AV-1 in part to accommodate air refueling maneuvers. "We know when we chase a tanker, the airplane that is chasing could see slightly higher gs than the vehicle it is after because it has to react," notes Nelsen.

In addition to the strain gauges, AV2 had about 60 displacement transducers. "We measured all the applied loads and the reactive loads," said Nelsen. "We had a prediction in test for every piece of data every load, displacement and reaction, and strain gauge." One test condition applied simultaneous loads to catapult and tailhook points to measure the high reactive loads: "We fondly call that our wishbone condition."

The aircraft will be used to demonstrate carrier launches and recoveries, as well as autonomous inflight refueling with a probe and drogue

Data aquisition

AV-2 lab data will be correlated with flight measurements, and the X-47B proof testing leveraged the same data-acquisition hardware and software used in flight. The data collection system trafficked some 1,200 channels of strain gauge inputs. About 40% of the X-47B strain gauges were used just for ground testing; the remainder are also used for flight test.

About 60% of the AV-2 proof test data was recorded by the flight data acquisition system already aboard the X-47B. The same flight test trailer used to monitor AV-1 at Edwards Air Force Base was parked outside the AV-2 proof test facility. Video displays showed digital readouts from each sensor. "In most cases, we were reviewing strain from the gauges versus design limit load applied to the aircraft," says Nelsen. "I could track any piece of data I wanted. This test went really smoothly, our predictions versus our actual values were incredibly good."

The second X-47B was ultimately shipped to Edwards Flight Test Center without x-ray or other Non-Destructive Testing: "We didn't go to high enough loads to be concerned." Nelsen credits the judicious use of flight test equipment with reducing the cost of X-47B proof testing, "We walked away knowing It took us a significant amount of preparation time to make sure all those displays were up and running, but it's your testing time that's expensive." ∎

The Boeing 720B FTB with the HTF7000 turbofan engine installed in a special flight-test nacelle

"The 720B was an outstanding test platform in terms of overall performance (low speed and high altitude) and absolute high altitude"

Flying start

ALMOST 50 YEARS SINCE THEIR FIRST IMPLEMENTATION AT ARIZONA'S SKY HARBOR AIRPORT, FLYING TESTBED AIRCRAFT ARE STILL PROVING TO BE AN INVALUABLE TOOL IN THE TESTING PROCESS

BY IAN C. BELL

Specially modified flying testbed (FTB) aircraft have been operated from Sky Harbor Airport in Phoenix, Arizona since 1962. These FTBs facilitate the development and certification of complete powerplant and airborne systems. An FTB is an excellent tool for this work as it permits the full evaluation of an engine or system throughout its operational envelope, in flight.

The overall testing process employs myriad special devices, from dedicated component test rigs to full-scale ground test cells. The FTB aircraft compliments the entire process by facilitating the acquisition of accurate, repeatable, and cost-effective data at altitude. The Boeing 720B (N720H) was retired in 2008 after a very productive 20-year testing life. Replacing the 720B would prove to be a challenging undertaking given the aircraft's versatility in the flight-test role.

Flying testbed selection

The replacement aircraft for the 720B had some pretty big shoes to fill. The 720B was an outstanding test platform in terms of overall performance (low speed and high altitude) and absolute high altitude (45,000ft). Mission lengths were usually around five hours, but six- or seven-hour tests were not uncommon. Some endurance missions lasted more than eight hours and covered half the continental USA. Of the 154 Boeing 720s built in Seattle, the last three airframes were used in the role of propulsion flying testbeds, a testament to the unique capabilities of this aircraft type.

Honeywell began looking for a replacement aircraft long before N720H retired. Key requirements were a large flight envelope in terms of low and high speed at high altitude, with 45,000ft being a guaranteed requirement for our internal and external customers. Since engine operability requirements are most demanding in the upper left side of the flight envelope (high and slow), excellent airplane operating characteristics in the low-speed regime were essential. The replacement aircraft had to be easily modified and have sufficient structural integrity to permit the radical structural and aerodynamic modifications needed to satisfy the test mission. Another important requirement was that the aircraft chosen would have to be safely operated near the edges of its design flight envelope and be relatively straightforward to operate, once the major modification work was complete. Finally, the new FTB aircraft would need to be easily integrated into existing flight-test facilities and support equipment at the Sky Harbor location.

A comprehensive evaluation was performed by the flight-test operations staff to assess candidate aircraft capabilities against key internal and external customer requirements. This included performance analyses, engineering design studies and actual flight-simulator evaluations of the final two contender aircraft. The 757-200 airframe was determined to best fit the flight-test requirement.

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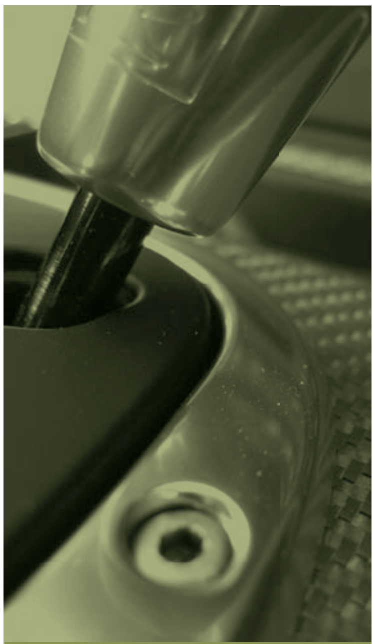

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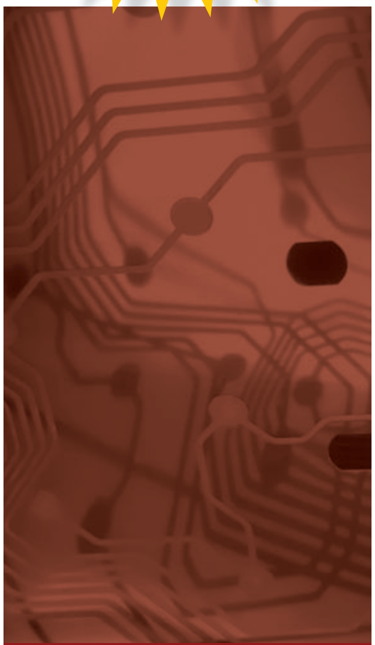

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Initial post-modification flight testing

There is an axiom in the flight-test business: 'one test is worth a thousand expert opinions'. This is particularly true when dealing with the initial operation of a highly modified airframe. Prior to the first flight, a detailed test process was established and reviewed with engineering management, as well as the FAA. This plan divided the initial 757 FTB testing into two distinct phases.

Phase 1 testing would ring-out the aircraft aerodynamically, without a test engine installed. Through a series of envelope expansion flights, the low and high speed operating envelope would be established. Phase 2 testing involved extensive ground running with a non-flying test engine to work out the kinks with the powerplant and data acquisition systems.

Once a properly functioning powerplant and data system was achieved, a special correlation engine would be installed. Phase 2 testing also involved a ground vibration test (GVT) and a flutter clearance flight test.

The correlation engine was previously flown on the 720B prior to its retirement, establishing a test engine-performance baseline. Although the correlation testing was expected to take only one or two flights, this activity eventually involved a total of nine separate flights. During this process, every aspect of the data acquisition system and our flight-test methodology was thoroughly scrutinized. The correlation testing ensured that absolute engine-performance measurement on the new 757 FTB was essentially identical to the 720B FTB, within the inherent measurement tolerances.

These flights meticulously established the necessary airspeed and altimetry calibrations so that the aircraft height and speed were accurately known. An added benefit of this effort was that the data generated was also used to qualify the modified aircraft for operations in RVSM (reduced vertical separation minimum) airspace. As total outside air temperature (TAT) is also an important engine performance parameter, special attention was also paid to the measurement of temperature. The 757 FTB employs three independent temperature-measurement sensors. One supplies the digital data system. A second feeds an AM-250 altimeter. The third temperature-measurement device is a duel-element Rosemount probe that supplies the air data computers.

A suitable 757-200 airframe with sufficient cycles and hours remaining was found in the UK.

The modification effort required solving three major problems. The first was how to install a third engine position on the aircraft without adversely affecting existing operational capability and safety. The second was how to structurally support the test engine and mounting pylon.

Engineering feasibility studies

Three engineering feasibility studies were performed to address these issues, falling under the broad topics of aerodynamics, structures, and systems. An aerodynamic evaluation of potential test engine locations was completed. This looked at the modifications from the standpoint of test engine/airframe interactions, aircraft stability, and control, minimizing static source position error and the elimination of potential test engine exhaust impingement on downstream portions of the aircraft. Computational fluid dynamics (CFD) methods were used to perform this work. The structural evaluation investigated potential test engine positions with respect to simplicity and overall cost, ease of fabrication and analysis, continuing airworthiness, and minimizing the risk of structural dynamic problems (flutter).

Finally the systems and instrumentation requirements were established to permit full flight-test capability (performance, operability, controls, and starting). In addition DC and AC electrical load extraction as well as hydraulic load extraction from the test engine gearbox would be provided. Special test capabilities would include hot fuel on demand and water injection capability for inclement weather testing. As part of the systems assessment, aircraft modifications to permit special airborne hardware testing (radars, avionics, APUs, sensors, and systems) were also evaluated.

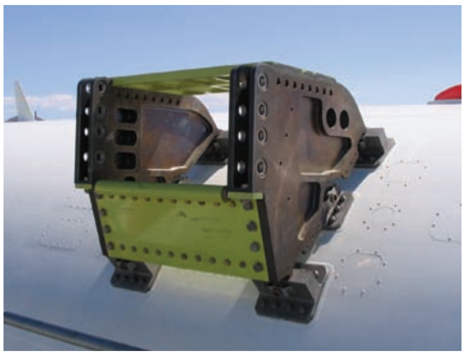
Based on the results of these preliminary evaluations, the configuration of the new flying testbed was established. The test engine and mounting pylon would be installed on the right hand side of the forward fuselage. The engine is mounted high on the fuselage to minimize installation effects so that the test engine inlet and exhaust performance is independent of the FTB (neutral installation effect). In addition, this high installation position significantly reduces the potential for test-engine exhaust impingement on the tail of the aircraft. As an additional bonus the right-hand number two entry door is still operational for both normal use and emergency evacuation. Test engine-mounting locations on both the fuselage and wing were evaluated. Forward and aft-fuselage positions were investigated also. The fuselage mounting was the lowest cost solution (simplest to design and implement). The forward fuselage mounting location made sense structurally, due to the lower flight loads and less potential for flutter issues associated with the aft mounted position.

Once the general configuration of the aircraft was established, the actual design and fabrication work was begun. As can be imagined, the modification effort in terms of engineering design, analysis, fabrication, installation, and flight-test evaluation is immense. These special purpose aircraft are essentially one-of-a-kind designs and the expertise required to create them is specialized indeed.

Aircraft modifications

Special-missions aircraft, and particularly flying testbeds, are very utilitarian in design. Form definitely does follow function. In the case of N757HW the most obvious change to the aircraft is the addition of a third engine – the test engine – on the right hand side of the forward fuselage. The vertical tail was also modified to make provision to extend a trailing static-cone behind the aircraft for accurate static pressure measurement.

The test engine pylon is attached to the side of the aircraft by a large machined support assembly which is then attached to the fuselage through two internal frames which extend from the crown of the fuselage to just above the cabin floor. This structure was designed to accommodate propulsion systems of a higher thrust-class than any currently being envisioned by Honeywell. To accommodate the numerous systems and instrumentation lines that need to pass from inside the cabin to the test engine, special reinforced cut-outs that resemble aircraft window-frames are installed in the fuselage skin, enabling test-engine systems, such as fuel, pneumatics, fire extinguishing, electrical and hydraulics to pass-through the fuselage



Above: 757 FTB CFD model used to establish the test engine location with external pylon support structure, and internal pylon support structure

Right: Flight-test engineering station

skin. The main benefit of this design feature is the ability to route large quantities of instrumentation wiring, and pressure lines with ease out to the test engine. In the event that additional instrumentation is needed, this can be quickly accommodated with no additional design effort.

The forward and aft pressure bulkheads were modified to incorporate instrumentation pass-thru provisions in support of APU and radar flight testing. Special systems modifications enable the test engine to be operated and tested both on the ground and in flight. The aircraft fuel system provides a continuous supply of fuel to the test engine and also enables fuel to be 'returned-to-tank', to simulate the effect of a motive-flow system. The test engine fuel system isolation provision ingeniously makes use of an existing valve inside the 757 tank plumbing. This eliminated the need to install an additional valve and associated wiring in the fuel tank.

The aircraft pneumatic system air for fuel heating and test engine starting is accommodated by a connection off the aircraft pneumatic manifold. Hot air can then be delivered to the test engine for fuel heating, engine starting and test pylon leading-edge anti-icing. One of the basic design requirements for all of the systems modifications was to minimize the points of contact with the aircraft systems and provide isolation devices so that the aircraft 'normal' operation can be easily and quickly restored.

The test engine and aircraft cabin fire control systems are independent of the basic aircraft systems. Duel fire-bottles are located in the cabin, just aft of the test-engine location. The system configuration facilitates special fire-agent concentration flight tests that are performed in the certification of propulsion systems on customer airframes. Crew oxygen for both the cockpit and test crew in the cabin are fully isolated from each other and installed to minimize the risk to the crew in the event of a catastrophic test-engine failure.

"The test engine and aircraft cabin fire control systems are independent of the basic aircraft systems"

A special nitrogen system is employed for data system calibration, purging and hydraulic load bank pressurization. The aft cabin features dedicated AC and DC electrical load banks. A hydraulic load bank is also installed in the forward cargo hold. These load banks are used to subject the test engine to varying amounts of gearbox load extraction during operability testing.

A removable water-injection system is used to inject a controlled quantity of water into the test engine core in flight to evaluate the effects of inclement weather on engine operation. A trailing static cone can be retracted into the aircraft and is stored in a large circular reel assembly mounted in the aft cabin. Electrical power for the data system is provided through the utility electrical buses and is automatically load-shed when the aircraft is down to single-generator operation. Instrumentation power is maintained via an uninterruptible power supply when aircraft power is lost.

Engine test on the FTB

The majority of propulsion system flight testing can be classified into four basic categories of testing: performance, operability, controls, and starting. Performance testing establishes the steady-state operational characteristics of the engine. Of primary interest is engine thrust at altitude and fuel consumption. This is defined by a parameter called thrust-specific fuel consumption, or TSFC. TSFC is a measurement of the mass of fuel burned by the engine in a given period of time divided by the engine thrust produced. The design engineers strive to design engines that have high efficiency, meaning low TSFC.

Operability testing is performed to understand the dynamic characteristics of the engine. Will the engine surge at the most severe flight condition under the worst gearbox horsepower load extraction in the worst degraded configuration? A surge is a momentary interruption in the continuous airflow through the engine. It produces an audible 'back-fire' from the engine and a visible flame out of the exhaust (and sometimes from the inlet). Severe surging can actually damage the engine and may be a hazard to the aircraft. Surge bleed valves and variable stator vanes are employed in the compressor section of the engine, in conjunction with the full authority digital engine control (FADEC), to mitigate the risk of surging. Controls flight testing is performed to ensure that the engine-control logic produces the desired dynamic operating characteristics (operability) in the engine. Controls and operability tests often go hand-in-hand.

The 757 FTB flight-test crew usually consists of the cockpit crew (pilot and co-pilot) and a test crew in the cabin of up to seven individuals including the flight-test engineer, a controls engineer, a project engineer, and an instrumentation technician who constantly monitors the data being recorded. The control of the test engine during a flight test is performed at the flight-test engineering station located in the aircraft cabin. Emergency systems such as fire extinguishing and fuel shutoff can be operated from either the cockpit of from the FTE's position. Since the test engine cannot be directly viewed from the test engineer's position, an external video camera provides a detailed picture of the test engine at all times.

With the 757 flying testbed now fully operational, engine development and certification programs are in full swing. The HTF7250G for the Gulfstream G250 aircraft has just been certified and development flight testing of the HTF7500E destined for the Embraer Legacy 450 and 500 airframes is underway. The 757 is also providing high-altitude flight testing of the RDR 4000 radar system and testing avionics such as SmartRunway, SmartLanding, and Required Time of Arrival (RTA) flight-management software. The development of the 757 flying testbed has been a significant undertaking. The company will continue to employ the airborne laboratory to ensure reliable and safe entry of its many aerospace products. ∎

Ian C. Bell is the staff flight-test engineer for Honeywell Aerospace, Engineering Test Services, based in Phoenix, Arizona, USA

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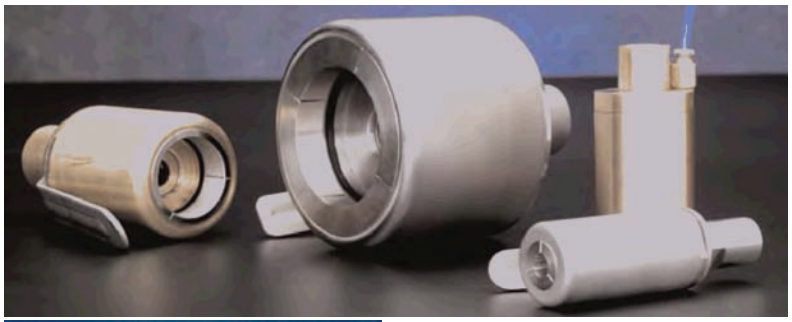


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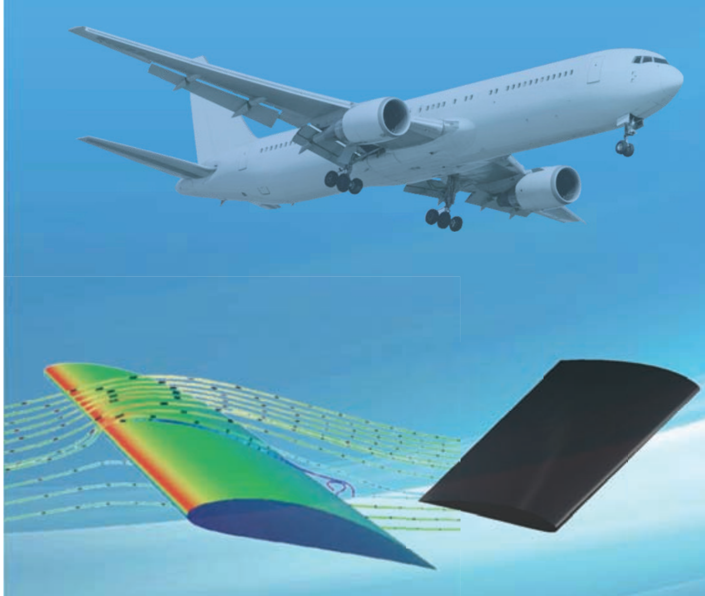

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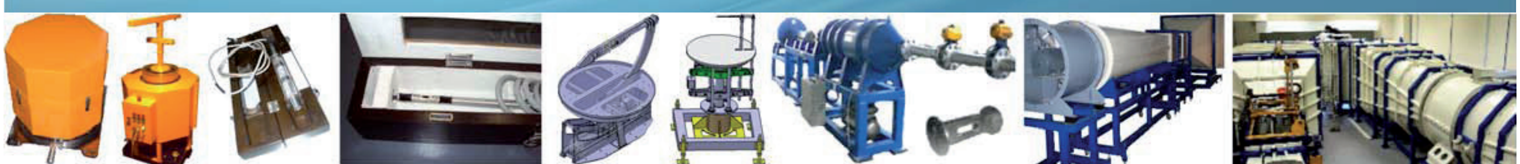

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Oklahoma!

AEROSPACE LEADERS IN THE MIDWEST USA HAVE INITIATED A MAJOR DRIVE TO ENCOURAGE THE AEROSPACE INDUSTRY IN THE STATE OF OKLAHOMA. INDEED, BOEING IS TO LEASE ITS SECOND FACILITY IN OKLAHOMA CITY

BY BUNNY RICHARDS

Oklahoma is home to the largest military and commercial MRO center in the world as well as a surprising 350+ aerospace companies, which employ more than 143,000 people.

Boeing invited *Aerospace Testing International* to the state as construction began on its second facility in the city, and it was here that Mike Emmelhainz, Boeing Oklahoma City site leader, discussed the expansion.

"Core to our success in the services market is to be affordable for our customers," says Emmelhainz. "We have worked in Oklahoma City to create a business environment that allows Boeing to be affordable and competitive. Our partnership with Oklahoma and the business climate here are helping us win new business, create quality jobs, and sustain our current work across all of our businesses."

The new facility is needed in order to incorporate an increase in the Boeing Oklahoma City workforce with further relocation of employees and growth in the services and business at the site.

The new six-story, 320,000ft^2 building will be designed and built by the Gardner Tanenbaum Group, a commercial real-estate company headquartered in the city, and is expected to open in the second quarter of 2012.

Boeing Oklahoma City houses programs for two divisions under its Global Services and Support business: maintenance, modifications, and upgrades; and defense and government services. The site focuses on engineering, contractor logistics services, and field support.

It was in August 2010 that Boeing announced plans to move the B-1 program and C-130 Avionics Modernization Program (AMP) to Oklahoma City from Long Beach, California.

"By moving B-1 and C-130 AMP, we are able to lower our operating costs and extend an increased value to our customer," says Mark Bass, Boeing vice president and general manager of maintenance, modifications, and upgrades. "Boeing appreciates the positive business environment created by the state of Oklahoma and its county and city governments. This environment contributes to our affordability, and the well-trained aerospace workforce already in place will be key to our success."

Boeing currently employs 945 people in Oklahoma, 745 of whom are located in Oklahoma City. Boeing will have nearly 1,500 employees in the state when the B-1 and C-130 transition is complete. ∎

The new Boeing Oklahoma facility

Making preparations

The C-130 AMP is making final preparations for five aircraft to enter the US Air Force Initial Operational Test and Evaluation (IOT&E) program in early 2012.

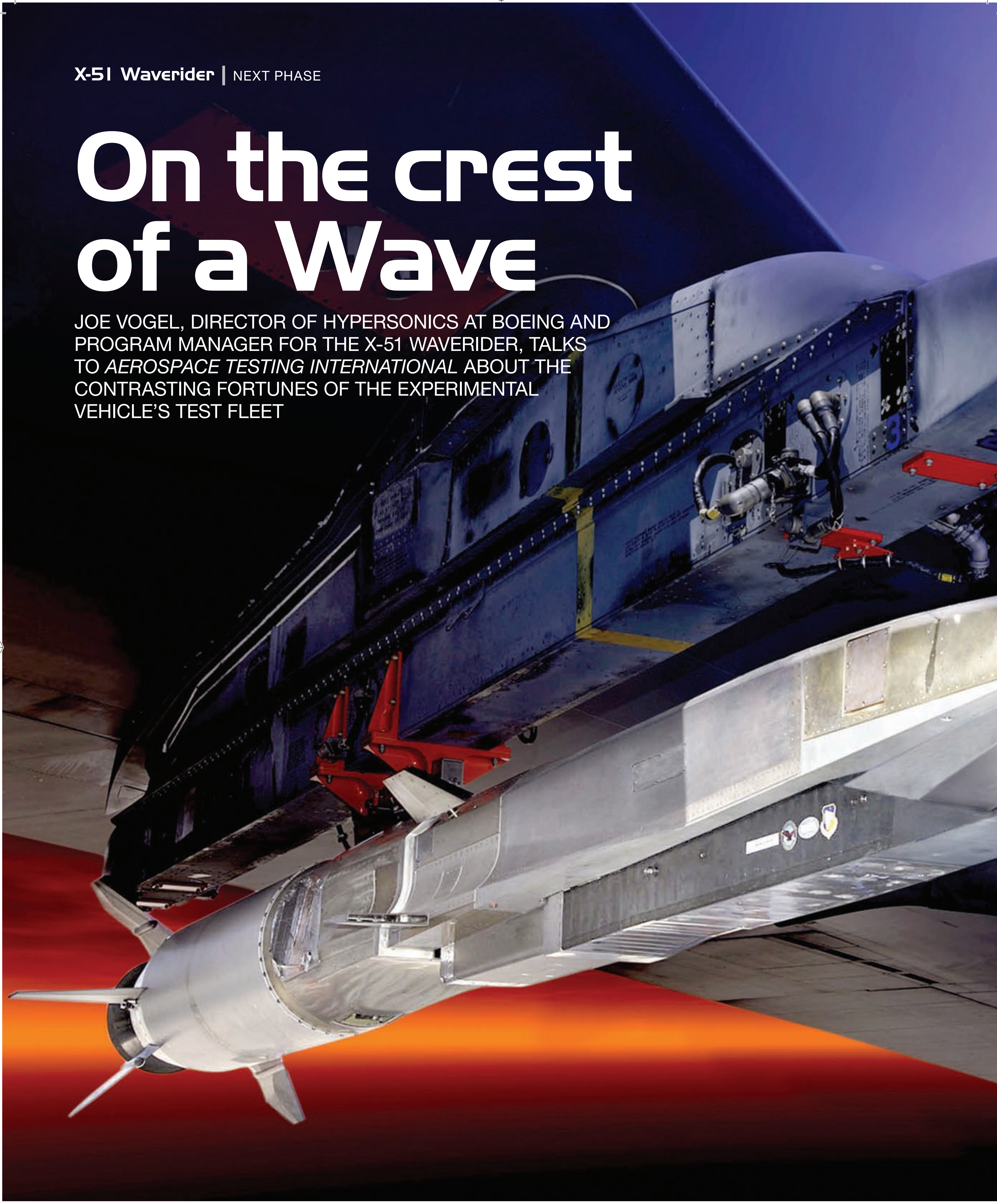
"Once evaluation is complete in late 2012, we will have a fully tested and proven weapon system that will offer more situational awareness for aircrews, increasing flight safety during their many mission types," says Mahesh Reddy, C-130 AMP program director for Boeing.

Three AMP aircraft have been in scheduled programmed depot maintenance at Warner Robins Air Logistics Center, Georgia, for the past year. Two of these aircraft received final software and hardware upgrades at Boeing's Flight Test Operations facility in Palmdale, California, bringing them up to production configuration. The first of these was delivered to Little Rock AFB in Arkansas on April 23, 2011, and the second was delivered on May 16. The third aircraft is receiving final upgrades at Edwards AFB, California, and will be delivered to Little Rock in July.

The first two low-rate initial production C-130 AMP aircraft were inducted at Warner Robins in August 2010. These aircraft will be completed in late 2011 and early 2012 and then will join the three other aircraft in the IOT&E program at Little Rock.

On the crest of a Wave

JOE VOGEL, DIRECTOR OF HYPERSONICS AT BOEING AND PROGRAM MANAGER FOR THE X-51 WAVERIDER, TALKS TO *AEROSPACE TESTING INTERNATIONAL* ABOUT THE CONTRASTING FORTUNES OF THE EXPERIMENTAL VEHICLE'S TEST FLEET



BY JOHN CHALLEN

The longest-ever supersonic combustion ramjet-powered hypersonic flight took place a year ago, employing the X-51, an experimental vehicle, launched from a B52 Stratofortress bomber (see *Ride the Wave to M5*, June 2010 issue, p23). Following that initial flight, the X-51A program was due to include a further three missions in 2010, but the engineering team was stopped in its tracks by a number of issues.

The maiden voyage

Joe Vogel, X-51A's program manager and the boss of hypersonics at Boeing, explains that there were problems, the biggest being a hot gas leak, which led to the first flight being halted prematurely. However, from that one mission alone the team managed to collect 80-90% of the data expected from four separate flights.

"There are varying stories about what happened, but we deemed it a very successful flight," states Vogel. "We spent some time evaluating the data to see what the problem was, and then made the changes needed to fix it. We recognized there was something going on with the vehicle while it was flying, and upon further analysis of the data, we discovered a hot gas leak.

"We flew for 143 seconds of scramjet powered flight, at which time we terminated the mission because of communication problems. When something like that happens, we have to abort. Because of the history of test programs of this nature, there are a lot of unknowns.

"People have been attempting to do what we have done for over 60 years – we were the first to accomplish it," says Vogel. "We showed that you can fly a scramjet on its own power, and that you can get acceleration, and we did it for an extended period of time."

It was not quite a case of back to square one but there was a re-evaluation of the program, and of what the team hoped to achieve.

"We don't install the engine into the vehicles immediately, but we did have to pull it out of our second test vehicle," admits Vogel. "We had to make some modifications to the interface between the engine and the B-52 air vehicle, because that was where the leak had occurred, and some seals had burned in the process."

The extreme temperatures of 7,232°-9,032°F (4,000°-5,000°C) endured on the X-51A during the mission mean that there are not many replacement materials available that would do a better job at surviving such heat. Vogel was not prepared to disclose details.

"We have integrated new materials into the system where we suspected the leak patterns were," he says. "They are more resistant to the

Air breather

Joe Vogel, hypersonics director at Boeing, is clearly a very proud and excited man. Going into a historic second flight with X-51A is indicative of Boeing's current hypersonic work.

"The only thing that comes close was X-43, which flew for about 10 seconds at a much higher speed, and on hydrogen," he says. "We used a hydrocarbon fuel, JP-7, and the vehicle has been designed – if we had the capability and the money to put into it – to be recovered as a reusable system. So the engine would have come back and we could have used it again – and it will hopefully be of use at some point in the future."

All the hardware Vogel has ever worked on – space shuttle, space station – has flown hypersonically, so in a lot of ways it makes sense for him to carry the title of hypersonics director at Boeing.

"The title covers air-breathing systems that are used to get into outer space," he explains. "The goal of our organization is to develop systems for space access, and there are other directors that are building satellites that could go to outer space."

The X-51 program is a consortium between Boeing and Pratt & Whitney Rocketdyne; its launch vehicle is the B52 Stratofortress bomber

"We expect to get a good mission out of the second flight and we should get close to Mach 6"

extreme environment; and the attachment process has been modified to provide a better, more secure seal. We prepared a mix of materials, and added a variety of fixes. We learned a lot and improved the vehicle a lot. It was a fun experiment to learn about the effect of different materials on the vehicle."

The bulk of the engineering on the program is now being done by Boeing; the other parties involved – Pratt & Whitney Rocketdyne, NASA, and the US Air Force – have completed the bulk of the work that they were required to do.

"We partnered with Pratt & Whitney on the engine, but we are the primary integrator and developed some of the control systems so we know where the vehicle needs to go," he says. "NASA did some great work early on, providing 1.2 million CPU hours on the Columbia computers doing CFD, flying chase planes on the last mission, and generally filling in the gaps when we needed it. Engine testing on the original engine we flew with took place in the Langley wind tunnel."

Second flight

Right now, Vogel's team numbers around 17 people but he will increase that to 25 ahead of the second flight, which, as *Aerospace Testing International* went to press, was set to be as early as June 2011. For the director, the date cannot come soon enough. "The next flight was originally booked for March 20, but we had mechanical problems with the release mechanism on the B52 so we brought the vehicle back and refurbished it for the next flight," recalls Vogel. "We almost went flying at the end of May after going through all the checks but again that didn't happen, so we have moved forward to some time in the next couple of months [June/July]."

When X-51A does take to the skies, Vogel is expecting impressive results. The original target, stated by Charlie Brink (then program manager at the Air Force Research Laboratory, Ohio), was 300 seconds of hypersonic scramjet-powered flight. The Boeing man sees no reason why that couldn't be achieved in the future.

"We have a calculated value, looking at how fast, how long, and how far we can go, based on the fuel load," he explains. "The second vehicle is more pristine than the first, and we have done a lot of work to make the surfaces even finer. We expect to get a good mission out of the second flight and we should get close to Mach 6; it is within our grasp if all goes well."

Third vehicle

As for what comes after the protracted second test flight, not even Vogel is sure of the exact schedule. He will therefore attempt to limit the number of possible changes that may have to be made. Work will be done to get the X-51A close to flight-ready, with only fueling, battery installation, and charging left to be done.

"The third vehicle is awaiting government direction, and we will hopefully get it shortly after the second mission," says Vogel. "Then our client will tell us what it wants to do – maybe the same mission or something that involves changes to the program.

"Following the thermal leak on the engine/airframe interface, we have prepared the third vehicle under the assumption that we don't have that problem again," he continues. "But to limit the amount of rework we could have to do, we'll bring the modifications on those vehicles up to the point where we won't install the engine until after that flight."

The third flight is dependent on whether all of the remaining data is captured on the second mission. So the options are still open.

"Because we were so successful on the first mission, we are looking to collect the remainder of the data needed from the four missions on the next flight," says Vogel. "If we do that, there would be an opportunity for the government to modify the mission somewhat.

"The vehicles are built with a specific mission in mind, but there are different mission profiles we could run to collect additional data. We could have the opportunity to expand the start envelope or run at different speeds. It would need software modifications, and a good deal of extra analysis, and maybe even some ground tests on the engine. We'd rather do that than throw away the vehicle. We want to make sure we collect useful data."

And then? "The fourth vehicle, because we were short on funding, has been put on hold. It is built, ready to fly, but is awaiting direction from the government," admits Vogel. "If we are successful on the second flight, it could end up in a museum, as an historical achievement." ∎

John Challen is a freelance journalist based on the south coast of England. He's never gone hypersonic, but he has driven a Bugatti Veyron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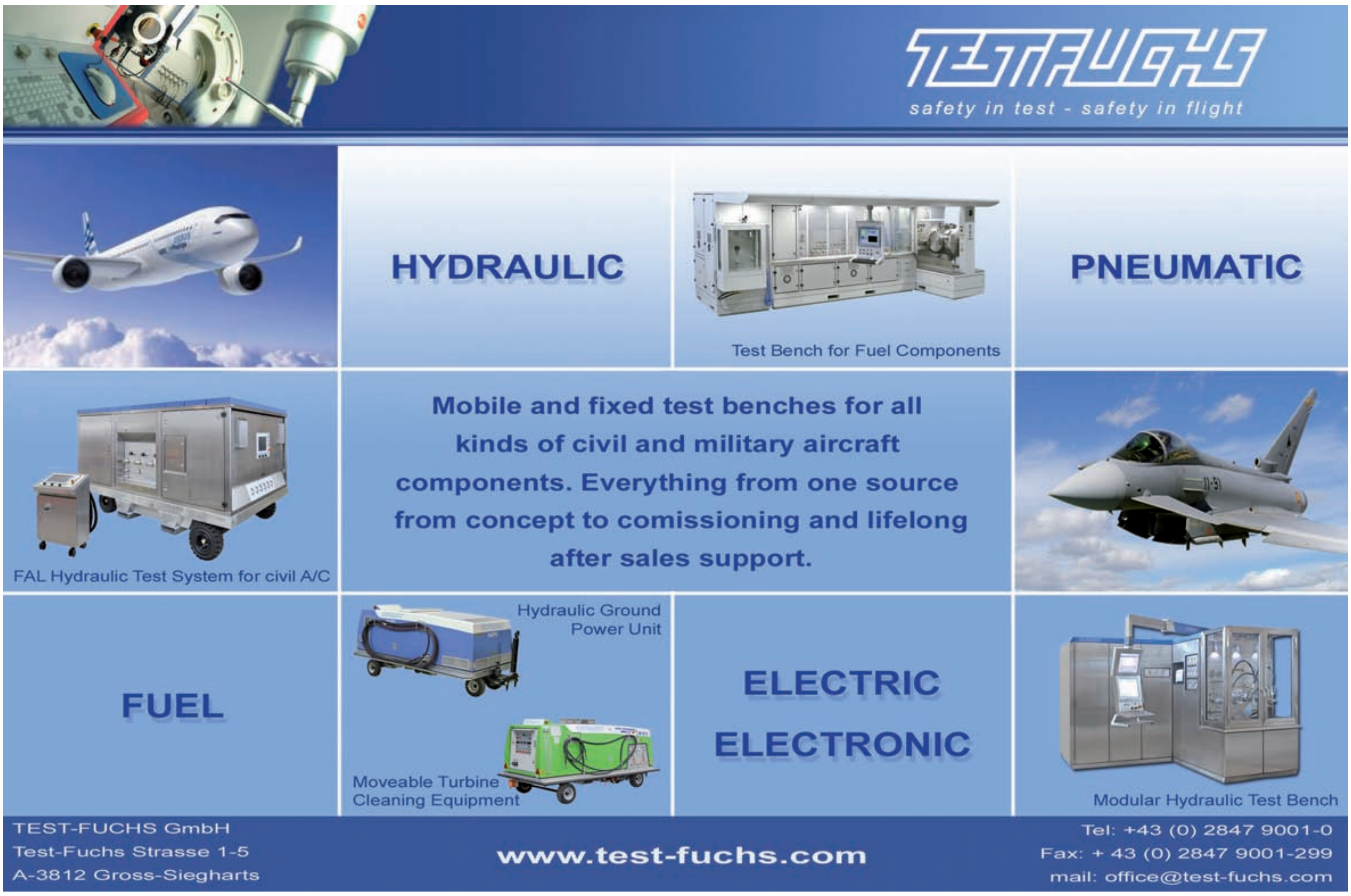
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Grand designs

THE PROVERB SAYS, IF GOD HAD MEANT US TO FLY HE'D HAVE GIVEN US WINGS. YVES ROSSY, AKA JETMAN, COULDN'T DISAGREE MORE. HERE HE TALKS ABOUT THE DESIGN OF THE WINGS THAT TOOK HIM 3,000FT ABOVE THE GRAND CANYON

BY CHRISTOPHER HOUNSFIELD

It was nearly four years ago that I first exclusively interviewed Yves Rossy, or Jetman, as he likes to be known, for *Aerospace Testing International*. He had just made the first official presentation of his personal strap-on jetwings in the article *To Infinity and Beyond,* December 2007.

In that time, things have moved on apace for Rossy. He crossed the English Channel using his wings, has looped-the-loop, and is a true pioneer of this form of flying. In May 2011 he finally completed his flight over the Grand Canyon, despite being forced initially to cancel his daring spectacle at the last minute due to red tape and safety issues. However, the Swiss adventurer did not give up and the next day he strapped on his wings and took to the skies for a spectacular eight-minute, five-mile flight in front of thousands of spectators.

The 51-year-old flying veteran (he was a Swiss Air Force pilot, and still flies a civil Airbus as a day job) had stepped casually onto the side of a helicopter before it took off and into the sky above Guano Point in the Hualapai Indian Reservation. Once it had reached 8,000ft, he simply let go, plummeting toward the ground below before firing up his engines.

Then, in his skintight jet-suit, he soared 200ft above the Canyon rim, reaching speeds of up to 190mph before opening his parachute and landing safely on the Canyon floor.

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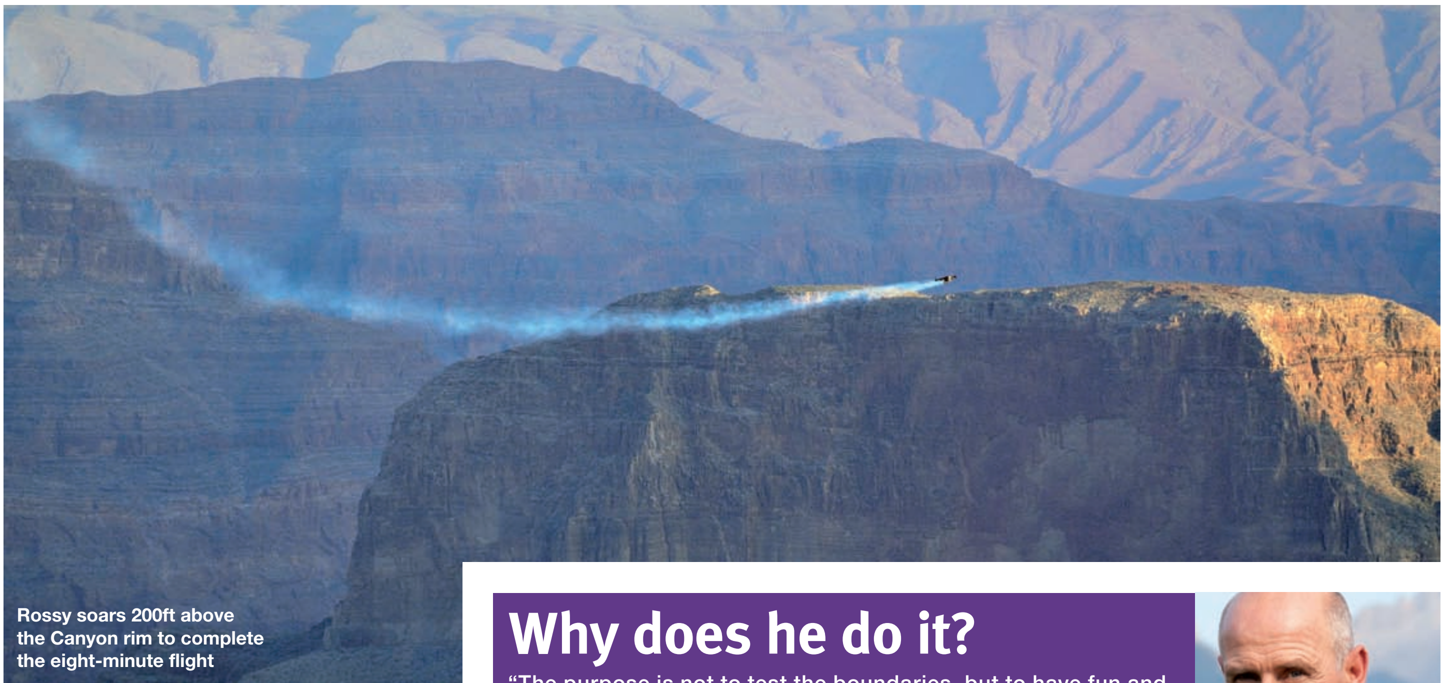


Rossy soars 200ft above the Canyon rim to complete the eight-minute flight

Rossy says the flight, his first in the USA, was one of the most memorable experiences of his life: "It was a wonderful flight, but unfortunately only one. We went to the USA for about two weeks with my old team, my three wings, and all the equipment to fly around the Grand Canyon. But instead of doing five, six or even eight flights, it was only one because of administrative difficulties. But I am really happy and I stay positive for the future. I had the opportunity to do one flight, which is good."

Rossy's US flight had taken two years to plan but was held up at the last minute because the final Federal Aviation Administration (FAA) approval had been given just 30 minutes before he was due to take off on the first day. This meant that Rossy had no time to practice. That would have been less problematic if the flight had been over open water, but with the Grand Canyon's jagged edges and jutting rocks, one wrong move could have proved fatal. "I was not ready. It would be unsafe and disrespectful to my team and everybody here to present something not well prepared," Rossy explains.

The Grand Canyon proved to be much more challenging than previous flights: "This was different, completely different. The English Channel was part of a National Geographic film, therefore it was a good idea to finish the film doing something great – but it was a straight flight, it's just adding fuel in the wing so you can go further. But this flight [in the Grand Canyon] was really to show that it's possible to fly with that wing in a very difficult environment, doing aerobatics and especially in front of people. That means, as the Grand Canyon has cliffs that are really high, I could present myself just 200-300ft in front of people but be 3,000ft above the bottom of the Canyon.

Why does he do it?

"The purpose is not to test the boundaries, but to have fun and to fly freely, as free as possible. Really the main thing is to have fun discovering a new kind of flight that is as pure as possible for humans. The purest thing would be to have a gene, a bird gene in your blood so you would have feathers... A brain of a human in a bird!

"It's as simple as this: keep the purity of flying like kids when they pretend to fly – you know, with their arms out at each side and doing an 'airplane'. That's liberty.

"I don't want to have anything between me and the element of air. When you are in freefall you are totally free. Unfortunately you are falling; I want to keep that freedom but really fly."

Rossy gently falls back off the step of the helicopter 3,000ft above the Canyon floor

Certification and design change

The only way Rossy could be cleared to fly was for he himself to become an aircraft. In fact he is the first human to be certified as an aircraft.

"I had to do a flight in a Bonanza aircraft with an instructor [to prove that I can fly an airplane]. I am certified, but it's certification just on paper. In practice, it's about the wing being able operate with fuel and fly straight.

"I've done loops, rolls, straight flights, aerobatics, formation flights... I've done everything in Switzerland, also in the Alps. The idea was to share [what I can do] with the American people and the best place to do this was the Grand Canyon."

Rossy made a number of design changes in order to upgrade the aircraft from the cross-Channel days. "The wing is not foldable anymore because of its complexity," reveals Rossy. "It is now only a 2m span, with a thicker profile, and it's more delta shaped. The wing I used over the Channel, it was in evolution, it was first a glider, and then after that I put two engines to fly level, and then I put four engines to be able to climb. But really, it was still a glider with some engines below, and studies in the wind tunnel had shown that this wing was unstable in a roll, and only just stable in pitch. That was when the engineers told me that these things should not fly.

"So as I have an adaptive structure, a flexible structure, I can fly this thing. But I had many problems with speed and stability; I had to maintain really high speed at declines and so on."

The four small engines were originally developed to fly target drones

Future flights

"The next really big step is to try to fly in formation with the Breitling Jet display Team, in July 2011.

"It will be quite difficult so we will see if it's possible. There will be no changes [to the wing]. I will keep that design because to change the whole design now would be hard. The construction is so complicated. It's like when you are building an airplane from the beginning – every new design is complicated and expensive, and it takes to long [to develop]. I've something that works quite well now so I want to go to the limit of this design and to use all the possibilities that I can with it. After that, I will perhaps change the design."

Wind tunnel tests

It was during the redesign that Rossy returned to the wind tunnel for further testing. It showed that the redesign and construction had (as claimed by Rossy) turned the wing design and suit from a glider into a 'fighter' aircraft.

"According to the studies in the wind tunnel we corrected with a new form, new profile, new stabilities… We'd made a fighter. So it's much more compact, much more agile, and with much more performance. Now I have something *really* great on my back," Rossy enthuses.

How were the wind tunnel tests conducted, in terms of procedures and outcomes?

"We did a study with me in the wind tunnel. I was hanging on the bottom of a measurement arm and we put up to 250km/h per wing in the tunnel and measured all forces on the wing, according to my position when I arch, bend down, move a hand, move my head, also a little bit in roll and in pitch, and with these measurements we had the first database of how the wing functions according to my movements. So we had forces, not really vectors, but forces that were acting on the wing, and then we corrected these instabilities. We now have the results and a new form and new profile.

"I did many test flights just with the wing on my back without an engine"

"I did many test flights just with the wing on my back without an engine, looking for the right place forward or aft on me that is ideal for stability and for the agility, and [once we had this position] I mounted my engines."

After Rossy had mounted the engines, he added the weight of the fuel, and this was then carefully balanced for stable flight.

"I mounted the engines and added fuel so The main concern was that the weight of the engine and fuel were nicely placed so that it flies, because if I am head heavy or tail heavy it doesn't fly nice. I have to find the really nice balance."

Spiritual flying and the next step

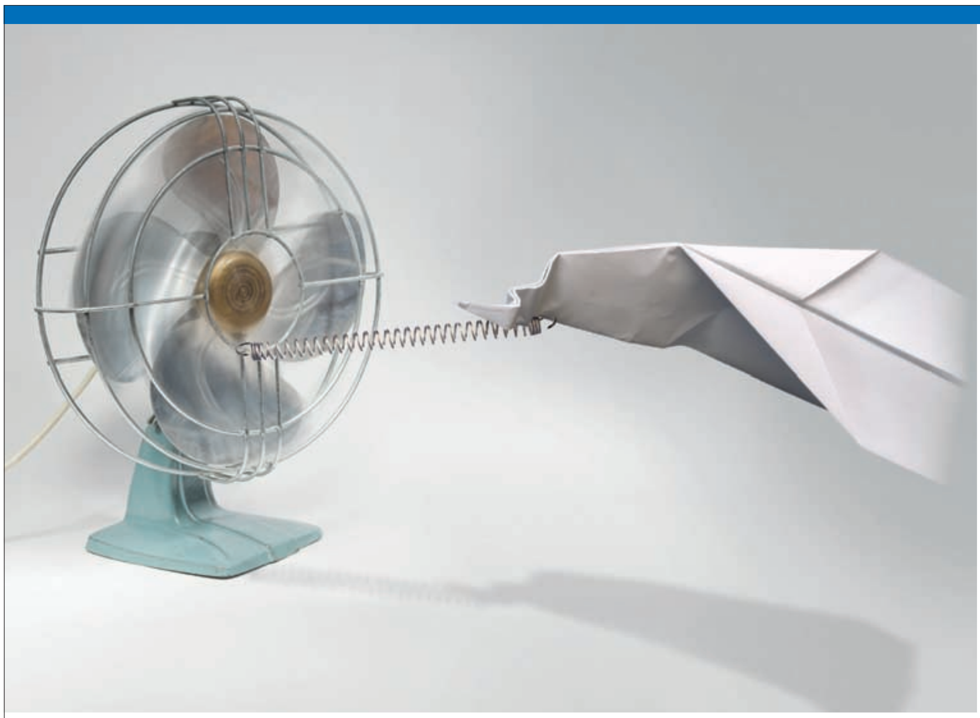
The Canyon flight certainly lived up to expectations: "The Saturday morning was fantastic; some Indians were watching the demo also. We took as many photographs as we could in one flight, and we wanted to fly a second and a third time but the weather and the winds were too strong, so that was the only flight I could do.

"What I am happy with is that the Hualapai tribe, the people from the region, were all there. They told me I am welcome any time. I hope that, now I have the certification, I will have the opportunity to fly there again because it's a fantastic place; it's absolutely grandioso! You know, with this place the nature is so strong, the colors, it really is the place to fly."

Last time I interviewed Rossy, nearly four years ago, I asked if there would come a time when he might not have to rely on other aircraft to get into the sky. He replied that because he had children, he felt it too dangerous (there lies an irony!). However, he did mention a plan to take off from a Porsche doing 150mph. I ask if that is still in the pipeline?

"Yes it is still possible but still too dangerous! I am preparing first to do jumps from cliffs with a catapult to see a little bit how it works when I am on a ramp, and we are studying this possibility. We are preparing this ramp and also we are preparing and instructing a younger guy so we will be able to fly in formation, and of course, I am preparing also to fly in formation with a jet from the Breitling Jet Team.

I suggest that he could test his cliff catapult on the White Cliffs of Dover, as he was already familiar with the English Channel: "Not high enough! Ideally I will do that at the Canyon; you have about 1,000ft cliffs there, maximum 3,000ft, which is ideal. But near my base in the Alps there are also some places to test that. We will see…" ∎



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Life support

SAAB HAS SIGNED A MAJOR CONTRACT WITH THE SCANDINAVIAN AIR AMBULANCE TO MAINTAIN AND PROVIDE TECHNICAL SUPPORT TO ITS ENTIRE FLEET OF FIXED-WING AND ROTORCRAFT IN SWEDEN AND FINLAND

BY ANNA EMANUELSSON

In March 2011, Saab started operations to provide technical support to the Scandinavian Air Ambulance (SAA) Service with responsibility for keeping the 20-strong helicopter and fixed-wing fleet airborne, enabling them to focus solely on aircraft and helicopter operations from bases in Sweden and Finland. SAA is one of Scandinavia's largest airline and helicopter ambulance companies and is based in both countries.

SAA Sweden began its operations in 2001, with helicopter bases in Stockholm and Östersund. Since then, several helicopter and aircraft bases have been developed in Sweden. In December 2010, SAA began operations in neighboring Finland.

The development of the company's business in Sweden has been driven by the centralization of specialist care for hospitals and the need to transport patients between these. This has led to a higher standard of medical care measures during transportation.

As well as transporting patients in Sweden, SAA covers the rest of Scandinavia and countries throughout Europe. In Sweden, the company carries approximately 10,500 patients in helicopters and aircraft – about 50% in each type.

Strategic development

The contract with SAA marks a strategic development of Saab's aircraft fleet-support capability both for the rotary wing and medical support sectors in the Nordic region.

The agreement is estimated to generate an annual turnover of approximately SKr50 million (US$8.1 million) during the agreement period. The air ambulances are used to transport patients under the care of contracted medical personnel provided by hospitals or via Falck Ambulance AB. The air ambulance helicopters can also be used for simple search and rescue missions, for air-, sea- or land-rescue operations.

The fleet is distributed across Sweden at 10 bases, from Gällivare in the North to Gothenburg in the South and Varkaus, Finland in the East. There are 10 helicopters including Dauphins and Eurocopter 135s and 145s. The eight fixed-wing aircraft comprise Beech King Air and one Learjet 35A.

As part of the contract arrangements, Saab invested in the acquisition of SAA's technical and maintenance arm, which included the transfer of 20 skilled personnel. Their capabilities have been bolstered by additional personnel from the Customer Alliance Solutions division in Saab Support & Services, responsible for delivering the contract.

The company has now taken over the technical program management and secure delivery of key functions, including tasks within the continuing Airworthiness Management Organization (Part-M), Maintenance Organization (Part 145), and purchasing and warehousing. It also has the ability to meet any customer demands for modification or upgrades to the fleet.

Saab is the support partner to the Swedish Coast Guard in maintaining its fleet of Dash 8 aircraft and was awarded an outsourcing contract from Sweden's Ministry of Defence to take over ownership and responsibility for the Swedish Air Force's SK60 training fleet and Aerial Target Service.

Responsibilities and undertakings

Program management is responsible for the business and secures delivery of the contract commitments to customers. Continuing Airworthiness Management Organizations (Part-M)

"Our strong and long-standing cooperation with Scandinavian Air Ambulance is now being further reinforced"

Ambulance helicopters may also be used for Search and Rescue (SAR) missions, for example in air, sea and mountain rescues

consists of the following overall responsibilities and activities: accountable manager, technical director, technical operations manager, planning management, engineering management, airworthiness review management, and the support desk.

Maintenance Organizations (Part 145) consists of the following overall responsibilities and activities: maintenance operations manager, maintenance planning, base maintenance, line maintenance, and workshops. Purchasing and warehousing consists of the following overall responsibilities and activities: purchase of spare parts and consumables, sales of spare parts, storage management, customs and transport issues, and incoming inspection.

The MRO program also covers management of the customer's requested additional services such as design (Design Organization Approval, EASA part 21J) and production (Production Organization Approval, EASA Part 21G) for upgrades or repair of the SAA fleet.

Technical support services to SAA in Finland have also been provided and a contract has been awarded to provide for its national air ambulance services. There is also a new purchasing process ongoing in Finland.

Additional agreement

In early May 2011, Saab signed the first additional agreement with SAA. The new agreement is an extension to the technical and maintenance services that are already being provided worth SKr25 million (US$4 million).

"Our strong and long-standing cooperation with Scandinavian Air Ambulance is now being further reinforced," says the head of the Customer Alliance Solutions division, Torsten Öhman, who is responsible for the operations within the support and services business area.

In the military market the company has signed a new contract with the Swedish Defence Material Administration for the support and maintenance of Helicopter 15 (Agusta 109 LUHS), operated by the Swedish armed forces.

The contract extends over a period of six years beginning in 2012, with an option for an additional two years and thereafter another two years. The contract includes support and maintenance of all 20 helicopters, including material and technical personnel, base staff (management, planning, and administration, logistics and material provision, and on-call services, providing additional technical personnel). "With this contract, we are consolidating our previous long-standing and strong cooperation with the Swedish Defence Material Administration and the Swedish armed forces regarding their helicopter operations," says Lars-Erik Wige, head of Saab's support and services business area. The commitment is part of the strategic development within the Swedish company toward a broader civil and military helicopter operation.

"For Saab, this commitment regarding Helicopter 15 is a significant and vital step in driving development further within this area," adds Öhman, who is also responsible for helicopter operations within the support and services business area.

Helicopter 15 currently operates from two bases in Sweden: Linköping and Ronneby. Linköping is the main base for maintenance, inspections, and repairs; with the majority of support and maintenance resources based there, including technicians, mechanics, and base staff. The base in Ronneby has the capacity for flights and limited maintenance, inspection, and troubleshooting facilities. ∎

Anna Emanuelsson is vice president and head of communications, Business Area Support & Services, Saab


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> "Video borescopes in the future will be much more geared to laptop connectivity, in that the kit will be powered by, and controlled through USB"

David Smith

Owner and managing director, Remote Visual Inspections Ltd, UK

RVI Ltd is an independent borescope inspection company based in West Sussex, UK. It specializes in the internal inspection of jet and turboprop engines for which it holds EASA part 145 approval. David Smith has been building the company since 2003.

What is your latest development in remote visual inspection, and its application in the aerospace industry?

RVI Ltd uses Olympus borescope equipment, and the last two kits purchased were the new IPLEX FX 6mm ones. These are radically different from the previous kits used. They are probably only one-quarter the size of the kits they replaced, these being the IPLEX SA. The reduction in size has come about because of the use of high-powered LED lights that are mounted in the distal tips. This means that big traditional bulbs and their associated cooling systems are removed. The resulting case is therefore much more compact and lighter, and is water resistant.

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

The main application for our systems is the internal inspection of jet and turboprop engines, however we have diversified and carried out inspections of aircraft control systems, aircraft structural components, pneumatic systems, and ducting along with non-aviation inspections including automobile engines and food processing plant ducting. The equipment we use has a working length up to 3m and a diameter of 4mm and above.

Did you encounter many problems? How were they overcome?

The company usually sends only one person to carry out the borescope inspection to reduce the expense for the customer. With the introduction of the FX kit, one aspect of the SA kit was lost: the ability to extend the remote control cable and operate the kit remotely while using a second screen. This enabled one person to turn the engine and carry out the borescope inspection at the same time. The fix for the new FX kits was to use a USB cable and a laptop running the originally supplied Olympus IPLEX manager software, enabling remote operation. One question I would like to ask is, can all manufacturers, including Olympus, allow a digital video output to go straight into a laptop? At present if the internal recording system is not used the video signal is converted to analog and then has to be converted back to digital to be used by a laptop.

Can you describe how your borescope systems are used in engine maintenance, and what makes the system special?

As mentioned previously, we specialize in the internal inspection of engines, so when an aircraft is on maintenance we would be called in to carry out the routine 'hot section' inspections or 'service bulletin' special inspections as laid down in the customer's maintenance planning document. We also respond to Aircraft on Ground (AOG) situations, such as bird strikes. Due to the high cost of purchasing these kits and the ever-increasing cost of having enough suitably trained engineers available, some MROs and airlines find it cost-effective to contract out these tasks.

What are the latest systems/developments on the RVI drawing board?

One area of borescope equipment where development is happening is in the field of measurement. The industry standard as I understand it is 'stereo measurement', however Karl Storz has had some success with laser measurement, and I believe GE is launching a new system called 3D phase measurement. The laser and phase measurement systems enable normal inspection with the measurement tips fitted. This means that when damage is found the probe does not have to be withdrawn, have the tip replaced, and be reinserted to carry out a measurement, therefore saving much time. We normally use stereo measurement and find it very accurate. I have used the laser system in the past and had some success with it.

An example of video borescope inspection

Where do you see the future of video inspection?

I think video borescopes in the future will be much more geared to laptop connectivity, in that the kit will be powered by, and controlled through USB, while the laptop will be used for the monitor and recording system. There are some USB videoscopes around today but they are aimed at very quick inspections within the automobile industry as there is insufficient power available at the moment for the aerospace industry.

What are the benefits of borescope inspection from your perspective?

Borescope inspection approval for the line or hangar licensed engineer is regarded as an add-on and not an approval in its own right by many companies. So an engineer can hold the approval but not use it from one month to the next. However, when asked to carry out a borescope, the engineer is expected to come to the correct result, usually under pressure. With the increase in complexity of all the new kits, more and more engineers would rather see an experienced organization to carry out the task rather than make a bad call themselves. Because RVI Ltd carries out these inspections constantly it can reduce the time these inspections would take.

WITH THE DOOR SLAMMED SHUT ON THE NIMROD MRA.4 PROGRAM, THE UK'S ONLY MARITIME AIRCRAFT IS THE MERLIN HELICOPTER. THIS PUTS IMMENSE PRESSURE ON ITS UPGRADE PROGRAM

BY DAVID OLIVER

In September 2010, the British Prime Minister, David Cameron, announced that the Royal Air Force's Nimrod MRA.4 Maritime Patrol Aircraft (MPA) would be cancelled forthwith, and all the completed airframes and those in production were to be destroyed. This decision was made after the aircraft that it was designed to replace, the Nimrod MR.2 MPA, was withdrawn from service in April 2010. To many, the unthinkable had happened. Britain, a maritime nation, had no maritime patrol aircraft and its submarine-based nuclear deterrent was left unguarded. Nor was there any MRA.4 replacement on the horizon. However, with the demise of Nimrod MRA.4, the Royal Navy's Merlin helicopters are now set to become the UK's premier, in fact only, maritime patrol aircraft. This will inevitably put increased pressure on the success of the Merlin HM.Mk2 upgrade program that is in its initial phase.

Lockheed Martin UK was awarded the original AW101 Merlin Mk.1 contract for 44 Anti-Submarine Warfare (ASW)/Anti-Surface unit Warfare (ASuW) helicopters in 1991 with AgustaWestland acting as sub-prime. The three-engined heavyweight Merlin Mk.1 entered service with the Royal Navy in 1998 and has been deployed on operations around

Merlin the magician

The first Merlin HM Mk.2 test aircraft, MCSP01, flew in September 2010 at Yeovil (Photo AgustaWestland) the world, including anti-piracy operations in the Gulf of Aden.

In 2006, the MoD awarded Lockheed Martin UK a £750 million contract to sustain the capability of the Royal Navy's multi-mission Merlin helicopter and at the same time AgustaWestland was awarded a £400 million contact for the upgrade of 30 EH101 Merlin HM Mk.1 helicopters to Mk.2 standard under the Merlin capability sustainment program (MCSP), with an option for a further eight.

The focus of the program is to enable cost-effective management of future obsolescence of the current aircraft's equipment and systems, and to introduce an Open Systems Architecture (OSA) into the helicopter along with improvements to the mission-system processing capability, a new human machine interface, incorporating large-area touchscreen flat panel displays, and improvements in the radar and sonar systems.

Avionics systems

In detail, the avionics system changes include a new cockpit display system with NVG compatible 10 x 8in LCD pane with touchscreen control units, a new avionics full duplex-switched (AFDX) aircraft data network to minimize EMC issues, a modified navigation system with added redundancy plus a civil GPS, NATO interoperable secure communications and a new search and rescue location system (SARLS) with integrated SARSAT decode.

> **"With the revised cabin layouts and underfloor radar installation, re-roling the Merlin Mk.2 is made simple"**

The rear crew have a new 24in primary tactical display, and a new secondary display for single-pilot operation, as well as a point and click GUI and a split-console design for role change. The tactical system has new radar and common acoustic processors, a new mission computer, datalink upgraded to Link 11, and a new tactical Ethernet bus.

With the revised cabin layouts and underfloor radar installation, re-roling the Merlin Mk.2 is made simple and eases the installation of additional role equipment such as the FN Herstal M3M 0.50in (12.7mm) NATO-caliber door-mounted weapon system, fast roping kit and ADS winch and funnel.

Thales UK has signed a new contract with Lockheed Martin UK for the next five-year phase of an existing 25-year integrated Merlin operational support (IMOS) program. This new contract covers the period April 2011 to March 2016 and continues to provide an availability-based support package for the acoustic sub-system for the Merlin Mk.1 and Mk.2 helicopters operated by the Royal Navy. The Merlin's acoustic sub-system comprises the folding light acoustic system for helicopters (FLASH) active dipping sonar.

As part of IMOS, Lockheed Martin UK is contracted to support and maintain the Merlin training systems to keep operators current with new systems and upgrades. The complete development test and execute factory acceptance test of Merlin HM Mk.2 training devices is scheduled for the fourth quarter of 2011 with Mk.1/Mk.2 conversion training at RNAS Culdrose in Cornwall, the home base of 824 Naval Air Squadron, the Merlin training unit, to begin in early 2012. This will be after the Merlin HM Mk.1 full-flight simulators (FFS) have been shut down for three months to upgrade to Mk.2 configuration. User training will commence in first quarter of 2013.

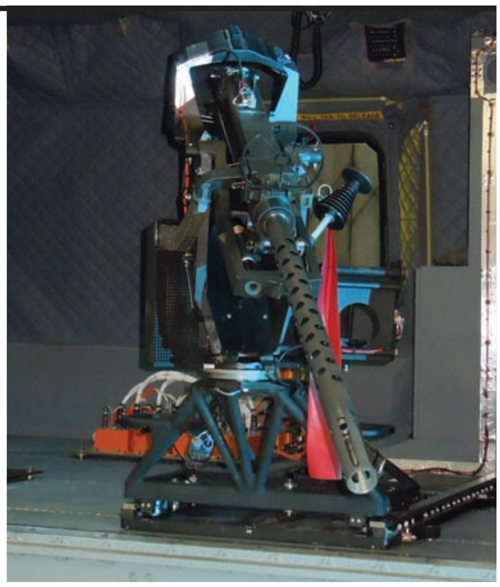
Merlin upgrades

MCSP01, which was the first upgraded Royal Navy Merlin Mk2 helicopter, performed a 35-minute maiden flight on September 30, 2010 at the AgustaWestland Yeovil facility. MCSP01 was virtually a new airframe having been in store at Yeovil and never released for service. The initial flight test phase focuses on testing the new avionics, aircraft management system, cockpit displays, communications and navigation systems. MCSP01 performed its first flight with a functioning mission system in November 2010, marking another significant milestone for the MoD/industry team.

The second of four trials aircraft, MCSP02 made its first flight on December 22, 2010 and is dedicated to test and evaluation of the new aircraft, avionics and mission systems. The remaining two test aircraft will be flown by mid-2011 with the first production aircraft to be delivered in the third quarter of 2011. The majority of flight testing will be performed at AgustaWestland's Yeovil site through to late 2011 when the test aircraft will transfer to QinetiQ, Boscombe Down to perform further mission-system performance evaluation and 'release to service' trials.

Aircraft conversion will be undertaken at AgustaWestland's Yeovil facility, with full-rate conversion being established in early 2012. The Mk.1s will be converted as and when their next deep maintenance is scheduled. As Merlin Mk.2s, they will begin to enter service in 2013 and the type will achieve full operational capability in 2014.

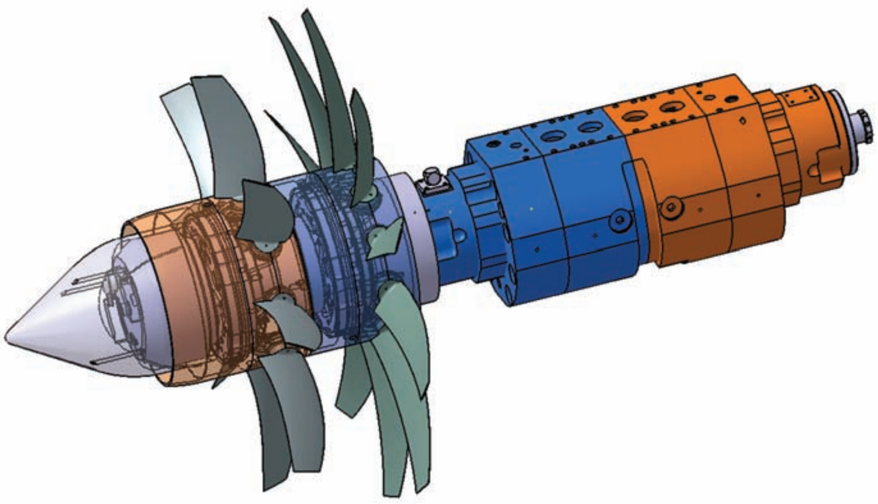
In addition to its ASW/ASuW roles, over the next two decades, the Royal Navy's multi-mission HM Mk.2 will be capable of carrying out search and rescue (SAR), casualty evacuation (CASEVAC), vertical replenishment (VERTREP), and troop transport missions. ∎



The FN Herstal M3M .50in (12.7mm) door-mounted gun can be installed in the Merlin HM Mk.2 for its contingency role (Photo David Oliver)

The new glass cockpit with touchscreen controls fitted to the Merlin HM Mk.2 (Photo AgustaWestland)

The Merlin HM Mk.2 production line at AgustaWestland's Yeovil facility (Photo AgustaWestland)



Back on the block

SWISS DRIVE FOR PRECISION INSTRUMENTS HAS LED TO A NEW FAMILY OF SIX-COMPONENT BLOCK-TYPE BALANCES FOR WIND TUNNELS

BY DR MICHEL GUILLAUME

Two high-performance low-speed wind tunnels are operated for the aerospace and automotive industry by Ruag. Driven by demand, wind tunnel equipment and especially high-accuracy 'six-component' strain gauge balances have had an ongoing development program since the 1950s. The combination of this lengthy experience in operation, design, and fabrication of balances with modern simulation tools has produced a scalable block-balance design: the '7xx' family.

These new balances benefit from an exceptionally compact design, specific load ratios exceeding the value of their predecessors by a factor of two to three, and high stiffness. Currently, four balance sizes are available and optimally cover the typical load ranges encountered in model-scale wind tunnel testing. The quality of these balances is confirmed by the positive feedback received from launch customers in the automotive industry and in F1 racing.

The balances use a multipiece design consisting of a non-metric base plate with seven integrated cantilever beams on which the strain gauge bridges are installed. Seven joint rods transmit the loads from the metric plate to the measuring elements. In contrast to a pure monobloc design, this principle enables better optimization of the most critical areas in the design and manufacturing process. Furthermore, the refurbishment of a severely damaged balance is usually much simpler as the readily exchangeable joint rods absorb most of the impact energy, leaving the measuring elements unaffected.

Dynamic loads

Wind tunnel tests increasingly involve not only static but also very dynamic loads; the model may be excited by unsteady aerodynamics or deliberate actuation with a model shaker to simulate realistic motion relative to the flow. As a result, critical components of the balances are sized and tested for fatigue life (their endurance limit).

Right: Family 7xx of six-component balances; sizes 767, 777, 788, and 796 are available

Left: Generic example of a CROR propulsor with hydraulic engines, rotating shaft balances, and telemetry systems

Below: Twin turboprop wind tunnel testing

> **"A balance is only as accurate as the weakest part in the measurement chain"**

A balance is only as accurate as the weakest part in the measurement chain. The comprehensive documentation that comes with the purchase of a balance not only includes calibration data but also information and recommendations on model interfaces, measurement practices, and installation procedures.

The first step toward accurate load measurement is the selection of the balance type. Ruag usually proposes that personal contact with its specialists is established for this important process. For a preliminary balance selection, an easy-to-use tool is provided. Based on specified load ranges, this Excel tool proposes the optimally matched balance and provides the most relevant characteristics.

The purchase of a balance is not only a technical process but also a financial investment that will bear fruit over decades of use. Support over the full lifetime of the sensor is therefore of prime importance. The possibility of renting a balance for a specific project at short notice and for a limited period of time may also be considered as an interesting and cost-efficient alternative.

Rotating shaft balances

In the last couple of years, and in close cooperation with both a major airframe and engine company, Ruag performed an extensive investigation into counter-rotating open rotor (CROR) technology on a full airplane model. In this project, the company was responsible for the development of the internals of the geometrically pre-defined nacelle and all the necessary peripherals for their operation.

New highly compact and reliable hydraulic engines were developed to drive the concentric CROR fans through a three-shaft system. Directly coupled to either of the two hydraulically driven shafts are two integral units consisting of a six-component rotating shaft balance (RSB); the blade, hub-mounted to the metric side of the RSB; and the wireless multichannel telemetry transmitter. The latter transmits the RSB signals, the blades strains, as well as temperatures and the angular position of the RSB to the non-rotating part.

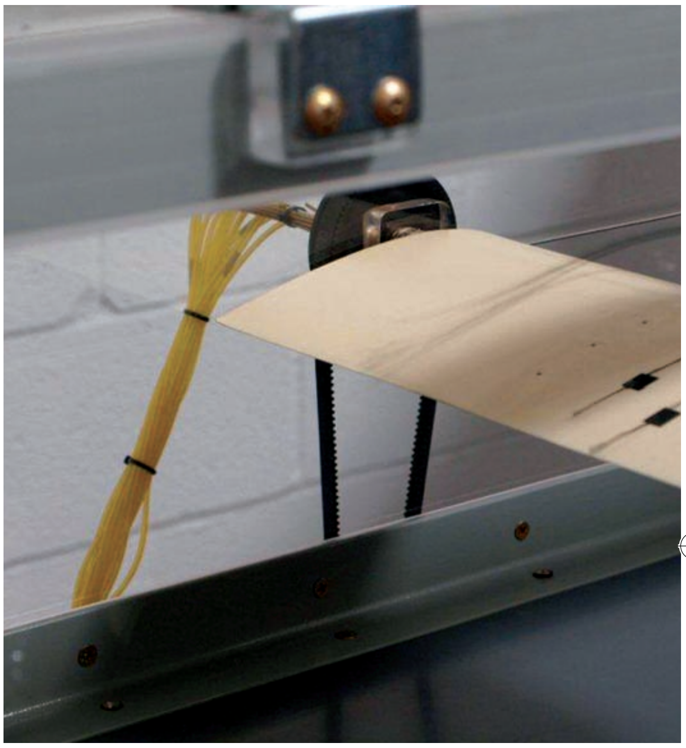
The design of the fully symmetric RSB is based on the specific geometric constraints, load requirements and the ever-important rotor dynamic stability requirements. Measurement sensitivity, simplicity of manufacturing, telemetry integration, and efficient installation procedures were other important design drivers. A total of 64 gauges are applied and wired to form six bridges, one for each load component. Static and dynamic calibration, as well as extensive model tests performed in the wind tunnel, show excellent accuracy under all operational conditions throughout the rpm range.

In contrast to the block-type balances, where the customer can pick an appropriate balance relatively easily from a standardized family with scaled designs, the rotating shaft balances with their complex installation situation, as well as their specific load requirements and signal-transmission demands, usually lead to customized solutions. ∎

Dr Michel Guillaume is the aerodynamics department manager with Ruag Aviation, based in Switzerland

Light at the end of the tunnel

DURING HIS TIME TEACHING AT AN AVIATION SCHOOL, JACK GILBERT FOUND THAT THE STUDY OF AERODYNAMIC PRINCIPLES FASCINATED HIS STUDENTS. MANY COULD GRASP MATH AND SCIENCE CONCEPTS IF THERE WERE REAL-WORLD CONNECTIONS TO THE FORMULAS



BY JACK GILBERT

Using a wind tunnel may not seem like an obvious tool to teach basic math formulas but surprisingly many of the aerodynamic formulas require only simple algebra. For instance, the continuity equation used with the Venturi is as simple as V1 x A1 = V2 x A2. This gains the students interest and gives them the confidence to continue with more and more complex math. Some of the more advanced lessons are calculus-based.

The important thing is that now the math becomes a tool to solve a problem. True engineering involves first asking the question, 'What do I want to achieve?' This is followed quickly by the question, "What do I need to learn before I can answer the first question?"

At this point many students may see a true need for learning how to do a particular math formula even though they are not currently achieving at a high level in math class; they see it as a first step to understanding why the math is important.

To provide data with the degree of accuracy required to conduct math formulas requires that the wind tunnel and data-acquisition system are of research quality. The wind tunnel must produce a laminar, low-turbulence airflow and all the instrumentation must be extremely accurate.

But how many US schools can afford a wind tunnel? None need to now, as Jack Gilbert and his company, MechNet, have developed an educational initiative where students design and operate their own wind tunnel experiments using remote internet control of MechNet's tunnels. The company's new service to enable schools and universities to operate research-grade wind tunnels via the internet will support science, technology, engineering, and math (STEM) education.

Operating the wind tunnels remotely removes the feasibility and cost issues for schools as they will pay only a low hourly fee for the time they are actually operating the tunnel. Plus, the wind tunnel will be completely configured for the test they have requested. The schools will not be required to change models and reconnect all the complex instrumentation tubing required.

Multiple FLOTEK wind tunnels by GDJ Inc will be equipped with a wide range of models such as wind turbine blades, different NACA profile airfoils, venturis, golf balls, and so on. An instructor will be able the show the difference in lift data between a NACA 4415, NACA 2415 and NACA0015 airfoil by just logging into a different IP address. They actually could operate two wind tunnels at once and show the data difference on two monitors simultaneously.

The wind tunnels will interface to a system based on National Instruments hardware and LabVIEW, which will control the wind tunnel and display performance data. The application was developed by Viewpoint Systems.

With this system the experience of operating the wind tunnel remotely, will be the same for the students as if they where in the same room as the wind tunnel. Interactivity will include adjustable test section velocity and airfoil angle attack giving the student complete control of the experiment.

By adding audio and video the students will be able to actually see the effects of stall on airfoil, as the angle of attack is increased. A side benefit of this process is that the ability to remotely control a device located in another distant location may well be more exciting to the student than a device that is immediately in front of them.

Wind tunnels will also be made available for students to send models to MechNet for testing. Students will make their own wind turbine blades, one tenth-scale car bodies and other experiments. Once the experiment is mounted, they will log in and conduct the experiment in real time on their own model.

Wind tunnel design

The tunnel hardware was designed in conjunction with NASA Glenn Research Center in Cleveland, Ohio, USA to provide ultra-low turbulence, straight-line (laminar) air flow, permitting true aerodynamic engineering, data acquisition and analysis. FLOTEK wind tunnels bring advanced aeronautic design principles to the high school and college laboratory. The standard models are the FLOTEK 1440 wind tunnel with 12 x 12 x 36in test section where air flow velocity can reach up to 185mph; and the Flotek 360, with a 6 x 6 x 18in test section.

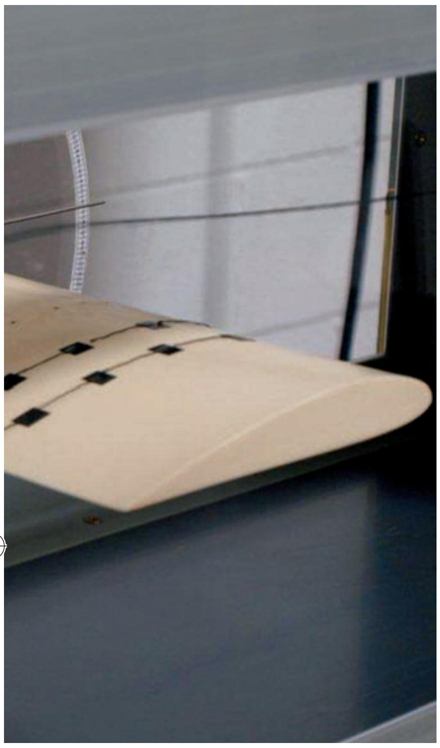
The tunnel is fitted with a 20-tube manometer for enhanced visual reference with a two-component balance-beam for measurement of drag and side force. Larger custom wind tunnels will be used for student-based model testing. A wind tunnel with a round test section is being developed for wind turbine-blade testing.

Data acquisition and control

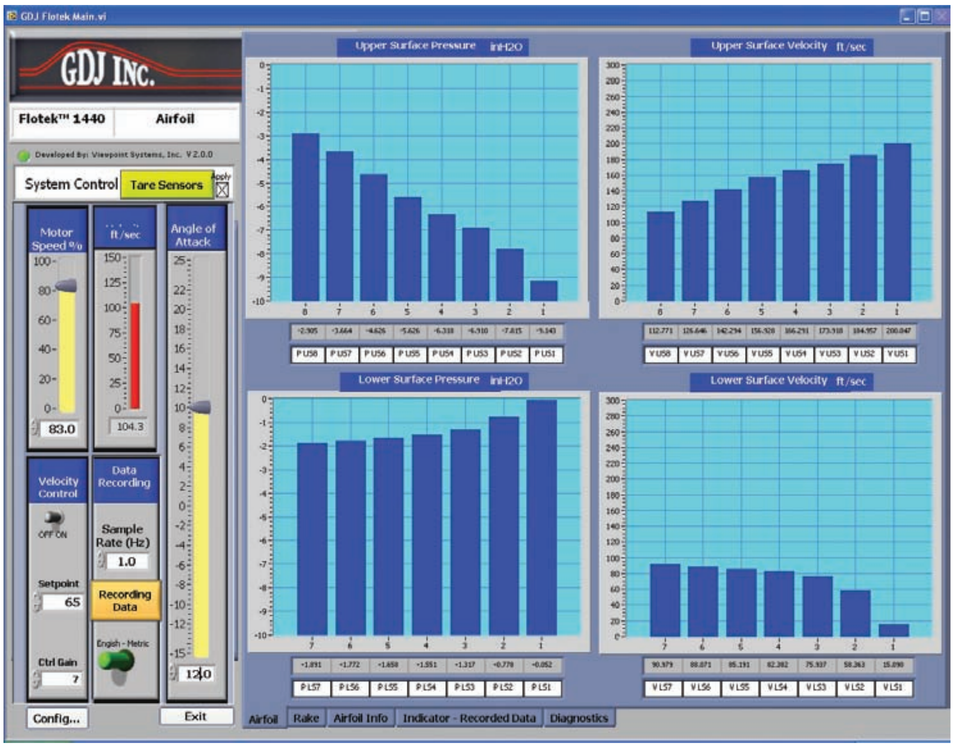
The National Instruments platform selected for data acquisition and control was the CompactRIO. This platform was perfectly suited since it offered the requisite size, channel count, signal conditioning, and real-time control capabilities. The NI CompactRIO programmable automation controller (PAC) is a reconfigurable control-and-acquisition system designed for applications that require high performance and reliability.

The system combines an open embedded architecture with small size, extreme ruggedness, and hot-swappable industrial I/O modules. CompactRIO is powered by

> **" Operating the wind tunnels over the internet enables access to expensive research-grade equipment at a very affordable cost"**



The NACA 4415 Illustrating laminar flow



National Instruments LabVIEW Screen developed by Viewpoint Systems, Rochester, New York used to remotely control the wind tunnel while retrieving real-time data

reconfigurable I/O (RIO) field-programmable gate array (FPGA) technology.

Software architecture

The software was written in LabVIEW Real-time and LabVIEW FPGA by Viewpoint Systems, a Select Partner of the National Instruments Alliance program. Other solutions for remote lab control had been looked at, but they didn't provide the tight closed-loop control needed for other applications, such as engine dynamometers.

The application allows real-time display of up to 16 readings of pressure and velocity over the test model while controlling the angle of attack and fan RPM. An airfoil stepper motor controller allows for computer control of the airfoil angle of attack from a slide bar on the remote panel. An additional stepper motor will be used to raise and lower a yarn streamer for visual enhancement. All sensors and control actuators are calibrated for accuracy.

Operating the wind tunnels over the internet enables access to expensive research-grade equipment at a very affordable cost. Schools will not have to maintain the equipment or change models. By combining the powerful feature-set of the CompactRIO and FPGA technology and the NI Remote Panel capability, the system is able to meet the needs of STEM-based education.

Jack Gilbert founder of Mech Net

Educators and students from all over the world can now log-on and deliver classroom instruction with real-time data and presentation of a model wind tunnel operating without the hassle of owning and maintaining one. This system also provides an excellent opportunity for a business to facilitate an outreach program for a local school, providing cutting-edge technology, with little or no actual time investment. ∎

Jack Gilbert is founder of MechNet Inc, based in the USA, www.mech-net.com

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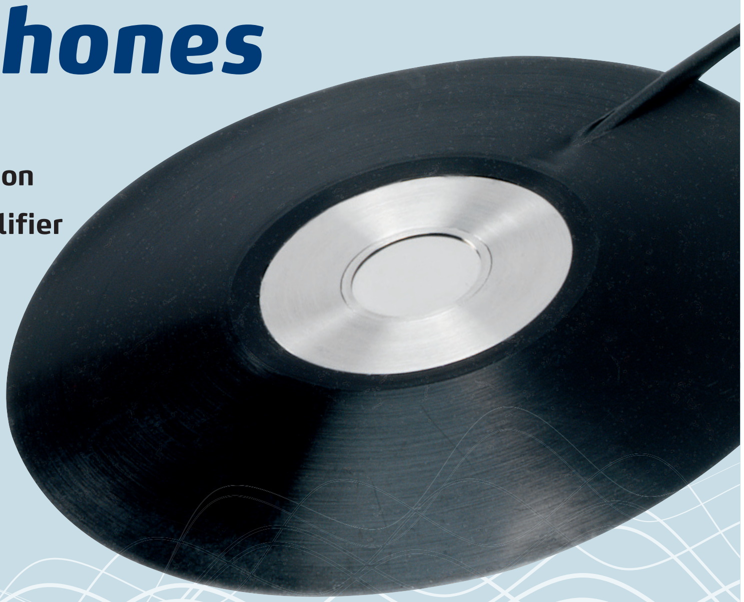

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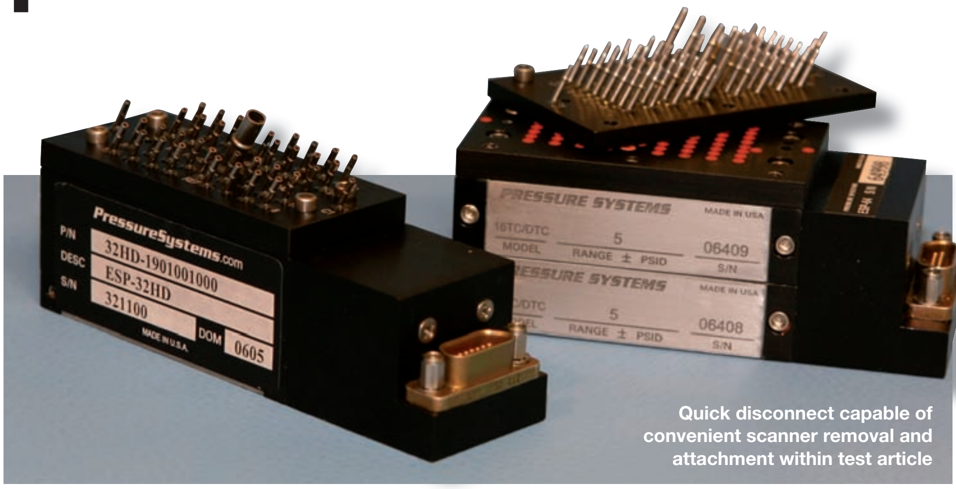
Electronic pressure scanners

Electronic pressure scanners are used to develop advanced aircraft, automobiles, and modern skyscrapers. Pressure scanning technology has advanced swiftly, building upon previous advances such as digital temperature compensation (DTC), bistable calibration valve, and online purge.

Electronic pressure scanners measure pressure from multiple locations within a concentrated area. Their small size has made them the 'go-to' technology for pressure profile measurements in wind tunnel models, vehicle on-road testing, aircraft flight testing, gas turbine engine testing, and a variety of general industrial applications. Pressure signals are ported from the measurement location to the scanner via thin plastic tubing. Inside the scanner, miniature silicon pressure sensors are combined with electronic multiplexers and one common amplifier to provide a high-level voltage signal into a data system. The data system selects the scanning rate and calculates the engineering unit value of the pressure using factory calibration coefficients stored in the memory of each scanner. Data is then transmitted to the host computer via communications interfaces such as Ethernet, CANbus, Intellibus, or IEEE-488.

Recent advances in pressure-scanner electronics now support continuous acquisition of all channels up to 650Hz per channel. This second generation (Gen-2) amplifier technology increases aggregate scanning rates by 250%. A modular scanner design and separate electronic assembly enable most existing pressure scanners to be upgraded to this higher data rate capability. Future developments in the data system will increase this rate to 1,000Hz/port with Gen-2 scanners.

Scanner cable lengths have previously limited scanner location. At 30ft maximum, the scanners would sometimes rely upon long measurement tubing to retrieve the pressure measurements. Pressure tubing acts as a pneumatic filter and where higher frequency events are involved, the scanners should be located as close to the measurement location as possible.



Quick disconnect capable of convenient scanner removal and attachment within test article

The Gen-2 amplifier advances now permit a 500% increase in the maximum scanner cable length up to 150ft. Consequently, longer cables simplify installations and bring scanners closer to the measurement point to reduce tubing length and maximize the benefit of increased scanning rates. Proper tubing connection to the scanners is important to ensure each port matches the desired measurement point so that one achieves leak-free operation. Software tools are available to assist with confirming and correcting measurement location tubing mistakes, and they also confirm leak integrity.

The new integral quick-disconnect tubing plates eliminate this concern by simplifying installation and removal. The tubing plate containing the measurement connections can be separated from the scanner by four screws. Users benefit from this feature by being able to send the top plates to a model builder while using the scanner for existing testing. Scanner change-out is also quick and easy, facilitating pressure range change or service while maintaining tight test schedules.

Each scanner contains an integral calibration valve in the form of a sliding manifold. This calibration valve provides users with three operational conveniences: online calibration, online purge, and measurement position. The operating positions are achieved with a simple pneumatic pulse from the data system to the scanners. Once this pneumatic pulse has been sent the calibration valve will remain in the commanded position without the need for additional external pressure until it is commanded to another position. This convenient and reliable feature is used to enhance accuracy and to remove contaminants such as moisture from the measurement lines.

Digital temperature compensation (DTC) provides ultra-precise thermal compensation. The process characterizes and compensates undesirable temperature effects on the scanner. Beside each individual pressure sensor is an associated temperature sensor. A 64-channel pressure scanner will contain 64 individual temperature sensors to measure the temperature of each pressure sensor. Sensor location, scanner construction and full factory characterization, over the complete pressure and temperature ranges, ensures the scanners will be virtually insensitive to temperature. This performance is guaranteed for life.

In 2010, manufacturer of precision level and pressure instrumentation, Pressure Systems was acquired by the sensor manufacturing company Measurement Specialties, joining several famous brands such as IC Sensors, Schaevitz, and Entran. Future development plans include increasing system speed, adding real-time data analysis, reducing scanner size, and integrating additional sensing technologies into the pressure scanning system solution.

Pressure scanning system for 512 channels of aerodynamic-pressure acquisition

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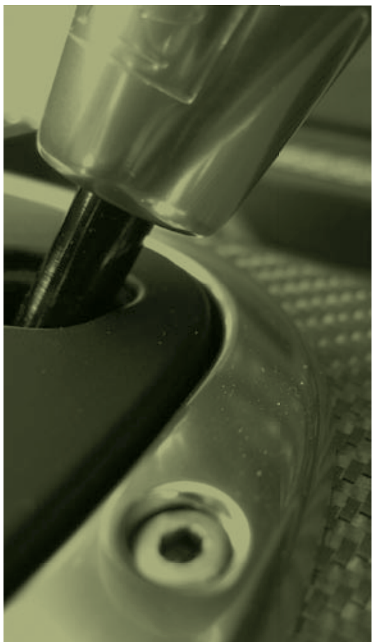

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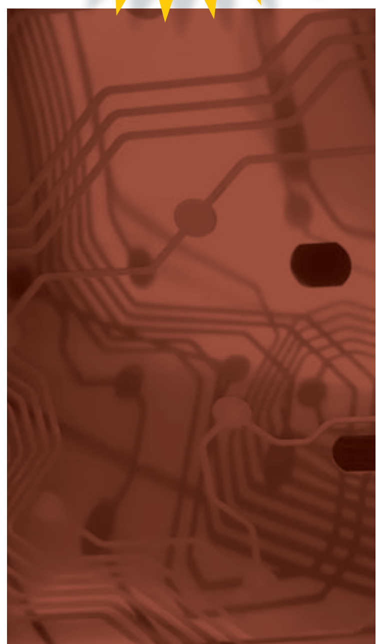

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Aircraft fuel cell-based emergency power system

The electricity an aircraft requires during a flight is normally generated through the engines. To ensure that there will always be a sufficient current supply to the flight controls and essential onboard functions, even if the engines fail completely, modern aircraft have a ram air turbine (RAT) – a deployable turbine that generates current through the airstream. However, RATs have a disadvantage. In some flight situations, such as when the plane is gliding at low speed, the power can drop dramatically because the airstream is too weak. Liebherr-Aerospace Lindenberg GmbH is using dSPACE hardware and software to develop an alternative, fuel cell-based emergency power system that supplies electricity, no matter what the situation is.

A flock of birds colliding with an aircraft can knock out its engines and its power supply. When this happens, emergency power systems have to supply energy to vital onboard systems

The fuel cell emergency power system (FCEPS) consists of a fuel cell and two tanks, one for hydrogen and one for oxygen, connected to the fuel cell via pressure reducers. The current, which is generated in the fuel cell, is independent of ambient conditions and can be used in an emergency to ensure that the aircraft's vital systems – the electric flight control and cockpit instruments – function reliably. The fuel cell itself also generates heat, which a liquid cooling circuit transfers to a heat exchanger that takes it to a suitable heat sink.

The FCEPS test bench includes a dSPACE system consisting of various I/O boards, a RapidPro signal conditioning unit and a RapidPro power unit. The ControlDesk test and experiment software provides the user interface for the inputs, signal recording, and monitoring of all processes. Between 70 and 100 signals are examined on the FCEPS test bench at a rate of 100Hz. The signals cover a wide range of parameters, including: hydrogen/oxygen supply and cooling; electrical parameters for the fuel cell and power electronics; total voltage; voltage of individual cell elements; current, and power.

With the dSPACE system, the FCEPS can be tested comprehensively by simulating different scenarios. The control models were designed by means of MATLAB/Simulink. Testing mainly focuses on the system's quick-start capability and on control optimization for the cooling circuit. If the FCEPS is ever modified or extended, the dSPACE system still has plenty of free capacity. With its modular design, it can be adapted to modified tasks very quickly. Liebherr-Aerospace Lindenberg intends to carry out tests with this system on a mobile platform.

The next major challenge will be to optimize the start time and the weight of the FCEPS. Airbus, Boeing and other aircraft manufacturers have expressed an interest in the system. So the FCEPS is more than just a back-up power system, it is also a pioneer for further fuel cell applications in aircraft to generate all the electricity required.

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Go to online reader enquiry number 102

Leak detection for tubes

Leak detection is essential to ensure tube or assembly integrity. Connection to tubes without surface marks is critical. The ability to use the same tool to test with gases such as helium and nitrogen, as well as fluids such as SKYDROL or equivalent, and water up to pressures of 5,000psi, is a big challenge.

However, the patented TestMaster LPH series of test tooling are used successfully in vacuum applications, as well as applications with working pressures up to 5,000psi on certain sizes and have been designed with the stringent requirements demanded in aerospace testing. The tooling can be lever or air actuated, and is pressure compensated. As the test pressure increases, so does the clamping and sealing force. This provides for a very safe test. The internal pre-clamp spring holds the tool in place in vacuum applications.

The same LPH series tooling can be used for burst tests, helium leak tests, vacuum, and refrigerant charging. Collets for round and flat tubing are available.

A pre-determined internal tube stop means no measuring is required to ensure proper tube-depth engagement. Also, non-marking collets and the seal design prevents tube-end collapse, eliminating tube-end scrap.

A high flow through-rate reduces the fill time and increases productivity, whereas, the lever-actuated collet release ensures fast, trouble-free chuck removal after each operation, decreasing cycle times

Special design

A specially designed collet locking principle can be used in applications where only a short length of tube or pipe is available for engagement, and built-in tube end tolerances mean square-cut ends are not required for efficient operation. The compact and balanced design reduces operator fatigue while all metal components are machined and made from heat-treated, stainless steel.

The TestMaster LPH series tooling is very easy-to-use. The operator simply depresses the handle and places the tool over the tube that does not have any fitting. When the tube is fully inserted in the tool, the operator releases the handle, allowing the collets to grip on the tube OD. Sealing is also done on the OD part. Test pressure may now be applied to desired level. The tooling is pressure compensated, which has the clamping and sealing force increasing as the pressure increases.

Once the test is completed and the test pressure is released to zero psi, the tooling can be removed from the test article. There is no need to do additional finishing to the tube end, post-test. The company also has pneumatically operated LPH tooling to be used where there is limited space to use a handle.

The challenge is to test tubes with different medium, at high pressures, which leaves no surface marks. The TestMaster LPH series tools accomplishes these requirements.

Other TestMaster series tools are available to operate up to 40,000psi with no, or minimum, tube-surface marking.

CONTACT

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Aerodynamic measurements

The study of aerodynamic phenomena encompasses a diverse range of acoustic and pressure testing requirements within inherently extreme environments, including aircraft altitude, airspeed and laminar flow measurements. The ultimate goal of such testing is the development of more lightweight, higher performance aircraft with greater fuel efficiency and reduced atmospheric pollution. Testing parameters must closely mimic actual in-flight conditions, factoring in such variables as external temperature, pressure, wind speed and meteorological factors, while closely adhering to budgetary constraints and internal production schedules.

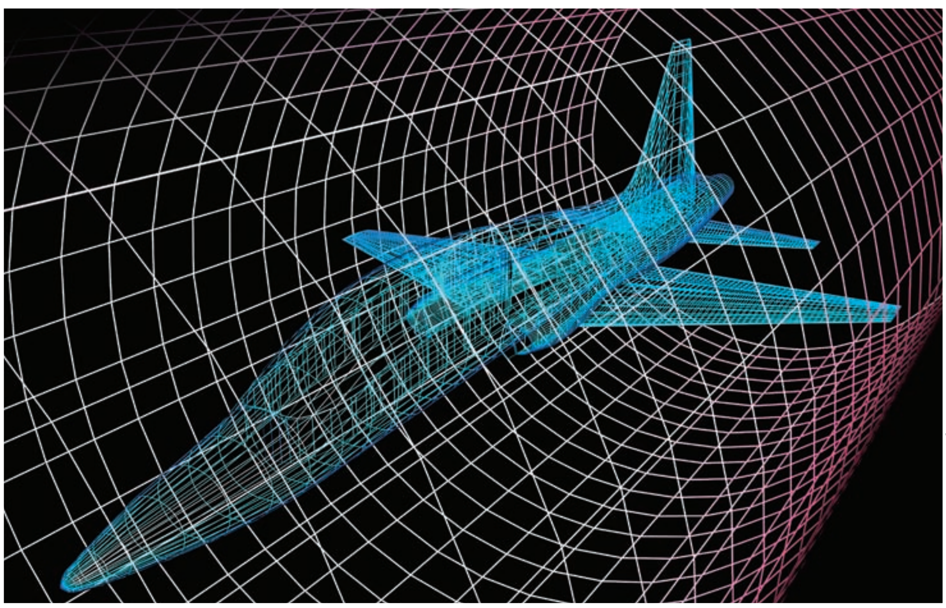
Wind tunnel testing is therefore a common means of achieving these objectives. Manufacturing time and cost limitations also create emphasis on the use of sensors and instrumentation with proven pedigree to effectively support these applications.

For more than 60 years, Meggitt Sensing Systems has been at the forefront of the design and manufacture of piezoresistive pressure transducers for aerodynamic measurements. For flight test airflow dynamic pressure measurements, the Endevco® model 8510C series, a rugged, miniature, high-sensitivity, high resonance gage piezoresistive pressure transducer with 225mV full scale output, is often specified at the 15psi range. Testing advantages associated with use of the series include a highly compact and lightweight package, with a face diameter of just 3.86 mm and a weight of 2.3 grams; excellent non-linearity of <1% to three times over-range with 4x minimum burst pressure; 20,000*g* shock resistance; high stability in thermal transients; and wide-band frequency response. Its proprietary four-arm strain gage bridge and sculpted silicon diaphragm design produces twicethe sensitivity of traditional flat diaphragms, resulting in improved resolution. Integral hybrid temperature compensation provides stable performance over a range of -18°C to +93°C. The model 8510C series also features a 10-32 UNF-2A mounting thread and comes standard with a 30in integral cable. Models include a vent tube that can be connected to any standard reference manifold used for differential pressure measurements or referenced to ambient atmosphere.

For small-scale wind tunnel testing, Meggitt offers the Endevco® model 8507C series of rugged, miniature high-intensity acoustic microphones and piezoresistive pressure transducers. Available in ranges from 1-15psig with 300mV full-scale output and minimum 20x burst pressure, the Endevco® model 8507C features the same active four-arm strain gage bridge design as the 8510C, with maximum sensitivity, high resonance frequency and wideband frequency response. Self-contained hybrid temperature compensation provides stable performance over a range of -18°C to +93°C, with excellent measurement stability during thermal transients. The sensors also feature linear performance to 3x range and high shock resistance. The 2.34mm cylindrical housing of the model 8507C is designed for space constrained installations, or those not requiring threaded mounting. Its small size even permits flush mounting on curved surfaces for use in supersonic jet airflow fields; hypersonic, transonic and 'quiet flow' wind tunnel testing; and turbulent airflow measurements.

For wind tunnel testing in higher temperature environments, the Endevco® model 8540 series is an alternative solution. These rugged, miniature high-sensitivity piezoresistive absolute pressure transducers offer internal sensitivity compensation and zero trim for high-temperature accuracy to +260°C and diminished lifetime operation to +316°C with excellent linearity and high resonance frequencies for static and dynamic pressure measurements. In addition, the series exhibits low photo-flash sensitivity and high stability during temperature transients. Available in ranges from 15-500psia, Meggitt's Endevco® 8540 series transducers also employ silicon strain gages, bonded to a micro-machined silicon diaphragm and housed in a rugged stainless steel case, for maximum sensitivity and wide frequency response, and with full scale output to 300mV. The 8540 series features a 3.8mm face diameter, facilitating flush mounting for aircraft skin pressure measurements. Its high-frequency response also allows it to be used within other aerospace testing applications such as rocket, jet engine and auxiliary power unit monitoring.

In addition to pressure transducers, Meggitt also offers a full range of acoustic sensors and instrumentation in support of aerodynamic measurements. Microphone and preamplifier combinations, available in 0.25in and 0.5in versions with TEDS onboard memory storage capabilities, are often specified to measure larger channel airflow conditions. Low-profile surface microphones, such as the Endevco® model EM40PS, are also used to support wind tunnel noise testing, turbulent flow measurements, acoustic radiation surface measurements and wind-induced airborne vehicle noise monitoring applications.



Above: Wind tunnel testing offers a cost-effective means of replicating real-life aerodynamic conditions of a typical flight sequence

Left: Endevco sensors are used to collect relevant data from a wind tunnel testing environment. Inputs are used with 3-D solid modeling to help better understand the effects of various aerodynamic phenomena on aircraft structures

CONTACT

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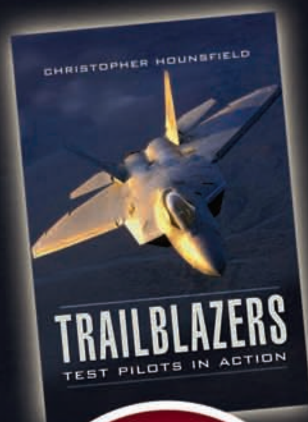

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Surface microphones

For more than 15 years, G.R.A.S. Sound & Vibration has delivered advanced microphone solutions to the aerospace industry. This includes large-scale array solutions to major aerospace manufacturers, such as Airbus, Boeing, Embraer, Lockheed Martin, Northrop-Grumman, NASA, JAXA, and research institutes such as DLR and ONERA.

Most recently, G.R.A.S. developed and delivered a new surface microphone for measurements both in wind tunnels and outdoors. The surface microphone has a diaphragm diameter corresponding to that of a 0.25in microphone (5.1mm) and a total height of 2.5mm. Building the design around a smaller diaphragm diameter gives a superior spatial resolution and enables validation of numerical modelling up to higher frequencies than offered by other available 0.5in types. Because a microphone measures the mean pressure over the diaphragm area, a large microphone diaphragm will not give the pressure in a point like the result of a simulation with fine spatial mesh.

The smaller diaphragm area also enables a low sensitivity so that the microphone can be used at high levels without overloading the system. The surface microphone includes a CCP preamplifier and TEDS for easy interface to signal acquisition systems, and yet the total outer diameter is only 16.2mm (excluding fairing). The small outer diameter enables the microphones to be mounted on curved structures, and many transducers may also be mounted in array configurations with tight distances for good spatial resolution. The microphone is optimized for minimum influence of changes in barometric pressure to minimize changes to both sensitivity and frequency response. This also enables the microphones to be used in-flight for mounting on the external structure of airframes.

As an example, this new surface microphone has been used in-flight for testing the acoustical stress on an engine mounting bracket with a dual line array of the G.R.A.S. 40LA.

Since the company began in 1994, it has been dedicated to developing and manufacturing high-quality measurement microphones and related acoustic equipment. It is therefore capable of offering the right acoustical solutions within the fields of aerospace, automotive, audiology, consumer electronics, noise monitoring, building acoustics, telecommunications, and naturally, microphone calibration.

The company is located in Denmark and founded by the Danish acoustics pioneer, Gunnar Rasmussen who, for more than half a century, has contributed to the world of sound and vibration with his unique ideas and designs.

Rasmussen's special understanding of acoustics, electronics, metallurgy and physics has, over the years, lead to many innovations in acoustic instrumentation and measurement techniques. From the first commercially available series of 1in measurement microphones to intensity probes and techniques, artificial ear simulators and hundreds of customized applications, the focus has always been on the users' needs and on the highest possible product quality.

This tradition of aptitude and working excellence is spun off and worked into every solution from G.R.A.S. Sound & Vibration for the benefit and satisfaction of our users. The company R&D team is continuously improving its solutions, as well as developing new products to meet the industry's demands and the recommendations of various, international standardization boards.

The G.R.A.S. measurement microphone technology has, of course, been developed over time and the company is proud to offer the best customer service available. All its microphones are solely produced in stainless steel and are of a quality that enables it to grant a five year warranty.

Should the user accidentally damage the diaphragm on a G.R.A.S. microphone, special techniques enable repairs to be carried out at reasonable prices – a feature often valued not only by the users themselves but also by their purchasing departments who are guaranteed a long-term investment in the equipment.

Worldwide, the company is represented in more than 40 countries by subsidiaries and distributors. Whether a user is searching for a multi-channel solution or just a replacement microphone for a sound level meter, a local G.R.A.S. distributor will be able to help solve customers' measurement needs, in close cooperation with the company centrally, as necessary.

The main line of instrumentation includes a broad range of standard measurement microphones and preamplifiers

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Go to online reader enquiry number 105

Compact low-frequency modules

Silicon Designs has expanded its offering of model 2260 series modules to include low-frequency versions to 0Hz, supporting aerospace testing requirements such as aircraft interior panels; lights and electrical systems; door assemblies and windows; UAVs and satellite components; and aircraft flight and flutter testing.

Tailored for zero-to-medium frequency applications, the model 2260 series provides high-drive, low-impedance buffering for high-reliability. Its compact size helps minimize mass loading effects within a footprint that is 37% smaller than comparable industry models. Accelerometers produce two analog voltage outputs that vary with acceleration and feature a four-wire connection, supporting single ended and differential modes. The sensitive axis is perpendicular to the bottom of the package, with positive acceleration defined as applied force to the bottom of the package. Signal outputs are fully differential about a common mode voltage of approximately 2.5V and may be powered with a 9V battery. Sensitivity is independent from the +8 to +32V supply voltage. At zero acceleration, output differential voltage is nominally 0VDC; ±4 VDC at full-scale acceleration. Onboard voltage regulation and an internal voltage reference eliminate precision power supply requirements. The model 2260 series is also relatively insensitive to temperature changes with quick, easy self-calibration.

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or go to online enquiry card 106

Engine-washing trolley added

Test-Fuchs has just added another promising product to its successful standard product range: the engine-washing trolley, MTCE1. The objective of washing engines is mainly to avoid 'compressor fouling', especially during start and landing, and also

in the taxi phase, when engines may be contaminated by the aspiration of various substances like dust, sand, and hydrocarbons, causing higher fuel consumption and CO_2 output. This is why all major engine producers have established sophisticated washing procedures reducing a.m. effects and extending the lifecycle of engines.

Test-Fuchs, being the specialist for aircraft testing and maintenance equipment, has responded to the increasing demand for engine-washing devices from airlines and MROs by creating this new product. The MTCE1 contains two washing tanks, containing 120 liters each and one 700-liter rinsing tank – all with up-to date thermal insulation to keep a stable temperature in the tanks.

If the waiting period for the cleaning process is more than one hour, the integrated generator, operated with standard unleaded fuel will enable boosting the tanks temperature. More important, the generator enables an independent drive to the two redundant washing-pumps without any connection to auxiliary power resources. Various additional features enable easy use by the operator.

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Web: www.test-fuchs.com

or go to online enquiry card 107

Digital high-speed cameras

AOS Technologies is a manufacturer of digital high-speed cameras. As part of its complete solution-provider philosophy, the company also offers certification for its products: all MIL products are certified by independent test laboratories. The environmental certification according to MIL-STD-810 is carried out by Ruag Land Systems. It includes low- and high-temperature, as well as temperature shock testing. For this, an environmental chamber with two compartments is used, where the device under test is automatically moved from one to the other several times. High altitude is simulated in a low-pressure chamber. For vibration and mechanical shock testing, a big vibration table, driven by a large electrical motor, is used. This table generates whatever frequency or acceleration is required. The product is tested at 95% humidity for several hours. EMI certification according to MIL-STD-461 is achieved in collaboration with Montena EMC SA.

For further information contact
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Web: www.aostechnologies.com

or go to online enquiry card 108

New test and measurement catalog

Dytran Instruments, founded in 1980, designs and manufactures a full line of piezoelectric and DC MEMS sensors for measurement and monitoring. The company has now published its latest catalog of piezoelectric and DC MEMS sensors for measurement and monitoring.

The 172-page catalog represents the most popular off-the shelf models of acceleration, acoustic, force, pressure, shock and vibration sensors. Products are presented in a series of technical specification charts, along with a description, line drawing and a partial list of some of the most popular applications, including aerospace and defense, automotive, power generation, and test and measurement applications. The products presented include: miniature and triaxial accelerometer models, high-temperature sensors with built-in electronics (IEPE), variable capacitance DC sensors with low-noise differential output, and sensors with TEDS capabilities. Dytran also offers a complete range of piezoelectric force and pressure sensors, impulse hammers, support electronics, cables and accessories for dynamic measurements, and has full in-house customization capabilities. The catalog is available for download on the company website or by emailing the marketing department.

For further information contact
Email: marketing@dytran.com
Web: www.dytran.com

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Intelligent and integrated vibration control

Safety, safety, and safety are the priorities for vibration qualification testing, making control accuracy and data integrity vitally important. That's why the new vibration controllers from sound and vibration stalwarts Brüel & Kjær enable up to 64 channels for control and limiting of articles under test. The controllers are also designed to integrate with their data-acquisition system, making more than 1,000 channels of measurement and monitoring possible with the system.

This abundant channel count comes from a unique approach that enables integration with Brüel & Kjær's PULSE data-acquisition hardware. With a simple LAN connection, the benefit of the PULSE modular architecture can come into play, enabling a scalable system with as many abort monitors as necessary, providing absolute test safety.

Having one complete system for vibration and data acquisition simplifies the test setup process as the same setup can be used for qualification and structural analysis, and simultaneously record data.

The company's open-data policy makes it easy to share data with dynamic analysis groups for finite element modelling and other analyses, and is facilitated by industry standard data formats, such as ASAM-ODS. Control accuracy is assured by the exceptional 130dB dynamic range of the input channels. Combined with similar 'Dyn-X' technology in the PULSE system, the net result is a testing system that can virtually guarantee to eliminate under-ranges and overloads – ensuring the integrity of all data.

Intelligent transducer conditioning cuts setup times further as they're instantly recognized and logged in the system, providing error-free test setup and execution.

For further information contact
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www.bksv.com

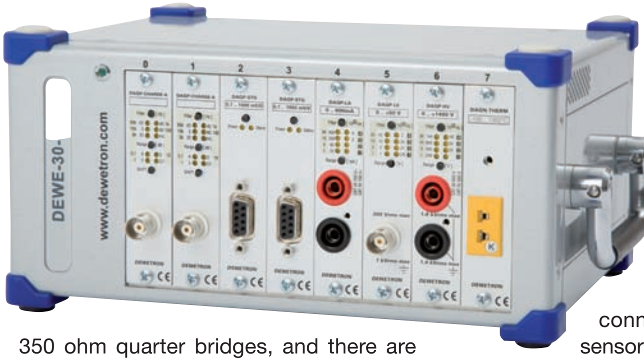
or go to online enquiry card 110

Top-notch signal conditioning

Galvanic isolation, 300kHz bandwidth and universal inputs are brought together by the DAQP-STG module by Dewetron. With its built-in high-precision DC and constant current sensor supply, the DAQP-STG enables direct connection of quarter, half, and full bridges, piezoresistive bridges, resistors, potentiometers, and Pt100 to Pt1000 sensors. It can also directly measure voltages to ±10V. Higher voltages to ±200V, thermocouples and ICP or charge sensors are supported, using modular smart interfaces (MSI).

The module is primarily designed as a high-end bridge amplifier, and accordingly meets all requirements for strain gauge/bridge sensors. Besides predefined measurement ranges from ±0.1mV/V to ±1000mV/V any sensitivity can be set, for example 2.27mV/V. This enables users to benefit from the full dynamics of measuring systems.

Internal precision resistors supplement any half bridges from 80 ohm to 10 kohm, and 120 or 350 ohm quarter bridges, and there are two further internal resistors for shunt calibration. Automatic balancing of sensor offsets up to 200% of the measurement range is possible. Naturally, the module supports TEDS sensors.



The user can select 0-12VDC or 0-20mA constant current as the sensor supply, both precisely created by 16bit DACs; and both fully adjustable. The module offers nine low-pass filters in the bandwidth to 300kHz. It is extremely low-noise, and combines the highest precision with very small dimensions.

As with all Dewetron DAQP modules, the output is an analog ±5V signal, suitable for practically any measurement card. The modules are plugged into racks from 4-64 channels.

The universal input enables connection of a very wide range of sensors. The electrical isolation and high overvoltage protection make this amplifier almost indestructible, and thus a safe investment for many years of use.

For further information contact
Email: sales@dewetron.com
Web: www.dewetron.com/int/products/signal-conditioning/isolation-amplifiers/

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Index to advertisers

Reach for the sky

BY FRANK MILLARD

Anticipation gripped test pilot Bill Bridgeman as he checked the instrumentation of his Douglas Skyrocket experimental aircraft just prior to it being dropped from a B59 at 35,000ft. Once the aircraft broke away there was a sensation of descending in an elevator, and the pilot engaged the rocket engines by the means of four switches. Number one chamber was engaged first, he recalled later, and when the fuel system pressures reached the required readings, Bridgeman "fired the trio of remaining chambers as fast as I could flip their switches", and was propelled forward in excess of the speed of sound. As he pulled the stick 50°, his vehicle climbed at 1,000mph, burning the equivalent of a ton of fuel per minute, and reached an altitude believed to be more that 77,000ft – higher than any human being had traveled before. "One look at the altimeter did convince me of the phenomenal climb rate I was experiencing," he said later.

As he tipped the aircraft ready for descent, he not only noticed a feeling of weightlessness that he could enjoy for a few seconds, but also that the sky was dark blue, though not as dark as he had been led to believe: "It wasn't purple, just a nice heavy blue. The land seemed blurred, and although I believe I saw the curvature of the earth, I cannot be sure that I did." He landed at Muroc Dry Lake (Edwards Air Force Base) on August 4, 1951 at 180mph and announced that in his opinion the aircraft was capable of flying much higher and traveling much faster.

The Skyrocket's test pilot was described by an article in *Time* magazine (September 10, 1951), which related his epic flight (summarized above), as 'The Fastest Man Alive'. The aircraft's designer, Ed Heinemann, was also one of a kind; he could certainly think more deeply and further out of the proverbial box than most of his contemporaries. He famously said, "A great many people think they are thinking when they are really rearranging their prejudices. Beware of such people."

Heinemann was a highly innovative and much respected military aircraft designer whose designs included the Douglas SB Dauntless dive-bomber, the A4 Skyhawk, and the Skyrocket. The first of his aircraft to see action in World War II, however, were used in the defense of European nations in 1940 by the French and Belgian air forces and the UK's RAF.

The most successful carrier-based bomber of the war was the SBD Dauntless. The dive-bomber required a means of reducing buffeting in a steep dive, which was provided by perforated dive brakes known as 'Swiss cheese flaps'. The Dauntless first flew in May 1940, entering service in early 1941. The Dauntless was an exemplary aircraft of its type operated by the naval, marine, and army branches of the US fighting services. Powered by a Wright R1820-60 engine, over 5,000 were flown in action during World War II. Admiral Nimitz personally thanked Heinemann and his team for designing the airplane that sunk four enemy aircraft carriers and 'stopped the Japanese' at the Battle of Midway. All together the Dauntless sank six aircraft carriers and a battleship as well as numerous other ships.

Two other aircraft stand out: The A-4D Skyhawk and the A3D Sky Warrior. The Skyhawk, or 'Heinemann's Hot Rod', as it was referred to by pilots, first flew in 1954 and was in active service until 2003. By the early 1950s Heinemann had become concerned about the increasing cost, size, and weight of contemporary combat aircraft and explored the possibility of a light fighter design. The US Navy was keen to order a lightweight carrier-based attack aircraft and set out a number of requirements that Heinemann exceeded – speed by 20% and range by 30% – with the building of the Skyhawk. The Sky Warrior was a nuclear bomber, but was also used in a number of different support roles. Both the Skyhawk and Sky Warrior saw service over Vietnam.

Heinemann was born in Saginaw, Michigan, on March 14, 1908, but moved to California where, in 1926, he joined Douglas Aircraft Company as a draftsman and 10 years later was promoted to chief engineer in 1936. Heinemann won the Guggenheim Medal in 1978 and in 1981 was inducted into the Aviation Hall of Fame. He was awarded the National Medal of Science in 1983. ∎

The D-558-2 Skyrocket was the first aircraft to reach (and exceed) Mach 2. It was built to withstand compression at transonic speeds and safely gather data relating to aircraft approaching the speed of sound. The first Skyrocket, the turbo-prop D-558-1, flew on February 4, 1948, but it was the 1951 flight of Bill Bridgeman in the rocket-powered version that caught the USA's imagination.

The combat production aircraft was not realized but all subsequent supersonic military aircraft benefited from Heinemann's flight-based research. He was particularly worried about the 'new phenomenon of supersonic yaw', reported *Time* magazine in February 1952. The Skyrocket was designed to minimize transonic buffeting with small ailerons, rudder, and elevators mounted on the trailing edges of the wing and tail surfaces. But this configuration brought its own problems at supersonic speed. On one occasion the aircraft began to oscillate violently and zig-zagged out of control before Bridgeman could cut the engines and correct the swings.

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