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NOVEMBER/DECEMBER 2013

AEROSPACE TESTING INTERNATIONAL

UAS trials

How to plan and deliver a successful test program when the flight test pilot stays firmly on the ground

A350 XWB: LATEST

Aiming for airworthiness in 2014, the airliner has made huge strides into the next phase of flight testing

VERY LIGHT JETS

Testing on a tight budget – the challenges of bringing entry level jets to market

SPACE LAUNCH SYSTEM

The largest rocket ever designed by NASA has recently passed a key stage in its wind tunnel tests

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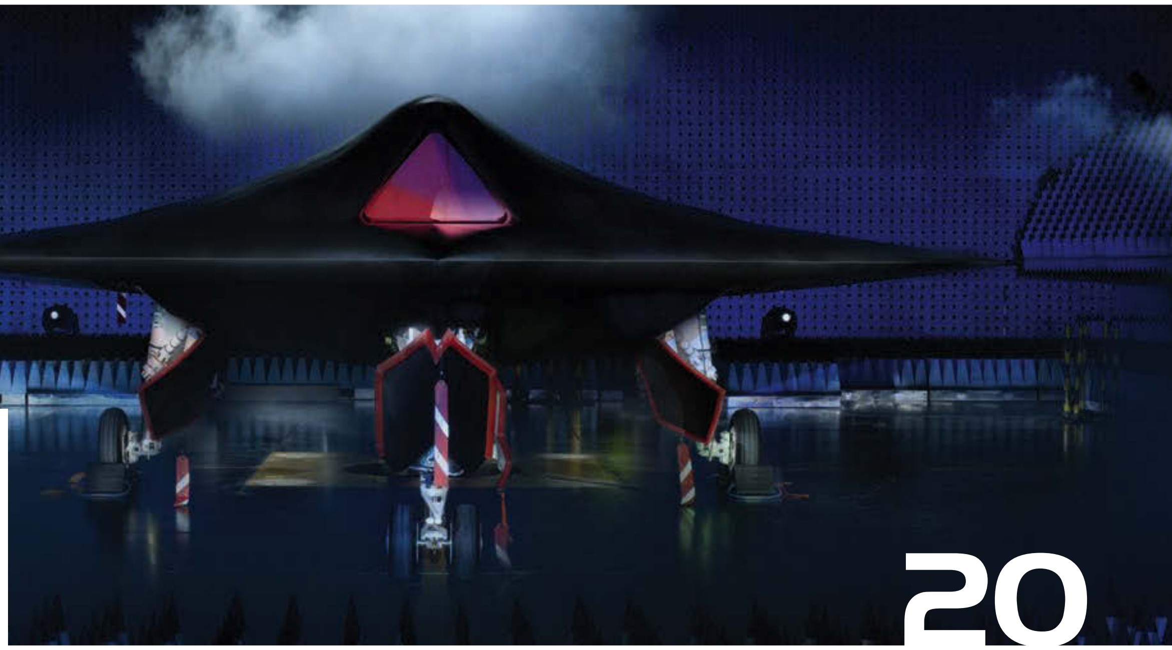
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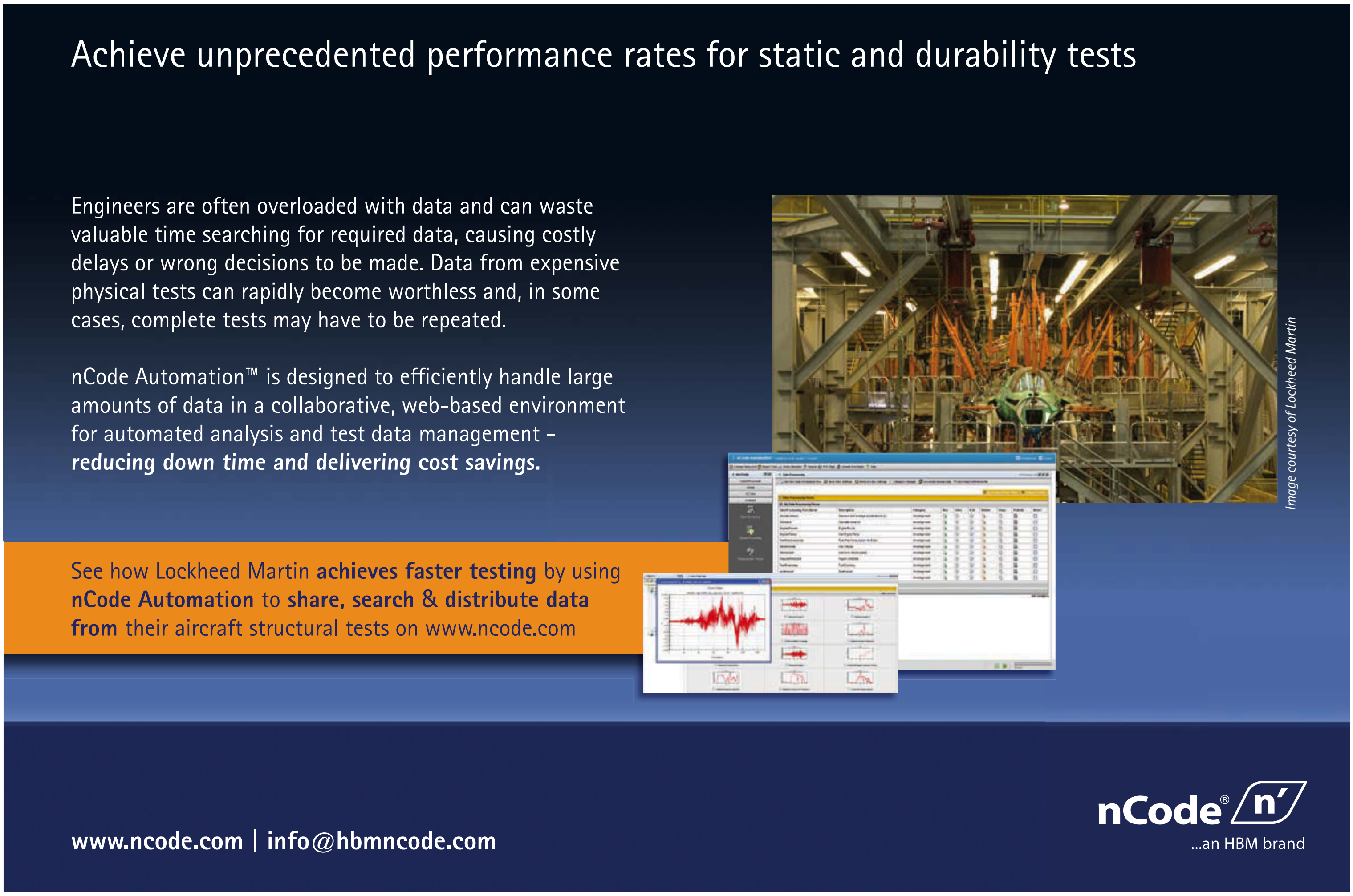
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SAMPE China, Shanghai - October 27-31 2013
AIRTEC 2013, Frankfurt - November 5-7 2013
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GPS crops up many times in this issue, in articles about all manner of test programs, from scramjet to very light jets. And it is of course essential for all unmanned aerial systems! GPS is a hugely important factor in the development of tracking and navigation systems across so many industries, and in aerospace it not only serves the industry but, with GPS satellites, is very much part of the industry.

As GPS satellite capabilities are part of virtually every ship, aircraft, smartphone and most new automobiles, it is easy to take it for granted.

The development of GPS came after World War II, but proper funding and research did not occur until the Cold War was well underway in the 1960s, when it was deemed that absolute accuracy was needed with the potential use of ICBMs; and with two-thirds of the nuclear arsenal with the USAF, it needed a very reliable navigation system.

The US federal government owns the GPS system and gives it free use (there are of course other systems: Russia's GLONASS, and Europe's Galileo program – due to be operational next year). It was after the Korean Air Lines Boeing 747 was shot down in 1983, having strayed into USSR prohibited airspace, that President Reagan issued a directive making GPS freely available, once fully developed, for civilian use, although it was deliberately sub-standard. Its use is ongoing.

These days you can even download an app to test your own personal GPS on your cell phone!

I have actually officially tested a GPS system, as I was an early guinea pig in its military use back in the beginning of the 1990s. However, it nearly cost me my life – well, it gave me a big scare, anyway!

Without giving away too much information, the British Army wanted to test its first-ever handheld GPS system – until this time all positions had relied on map and compass. It was decided that my platoon, stationed in a location close to the Middle East, would be ideal to trial the system. First we went to a number of triangulation points on the map where we knew for sure the absolute grid reference down to eight figures. Each time, the GPS result was never more than 10m away – and probably more accurate than that. Now proven, it was decided we would test it operationally.

Nearby was an area of very disputed territory marked with barbed wire lines and defensive positions. We suspected the local forces had expanded their area and moved the wire forward, so I decided to check the ground with my new toy – and took an armed patrol for company. On arrival at the location, I could see the wire had moved forward again, and by holding up the trusty GPS, I could see that it was substantially further forward than was shown on the map.

At this point, based on my highly accurate information and with none of the opposing force in sight, I ordered my soldiers to pick up the barricades and at least make the gesture to move them partially back – a frightening mistake. The moment my soldiers picked up the wire, a whistle blew from nowhere and soldiers poured out of hidden slit trenches and went to ground directly in front of us, pointing at least 20 rifles at me.

An officer charged forward screaming in a foreign language. I looked around for my soldiers, who had cleverly taken cover. Exposed, I explained that the boundary was set incorrectly and my technology proved this. He pulled out his pistol. I could hear my soldiers cock their rifles; I had my hand on my Browning 9mm. The officer continued to shout rather loudly, and pointed his pistol at my head, at a range of 3m, which gave me a distinctly uncomfortable feeling. We were outnumbered at least four to one (and that was just those I could see). It occurred to me at this point that we could deal with this diplomatically. Hand away from pistol, I slowly backed off, told my guys to do the same, and an incident was avoided.

Not quite a Mexican stand-off, but enough to make food pass through me swiftly for the next couple of days. My slightly bad day did not actually end here. On the continued patrol we slowed down for a breather, and I noticed, by the sudden absence of the soldiers, that I had trodden on a very live, very unstable, old, rusty hand grenade. My boot had made the pin crumble away. Thinking that some greater power had decided I was not going to make it to the officer's bar that night, I just walked away. It did not go off. However, using my GPS, I was able to give an exact coordinate reference and the engineers disabled it the next day.

The GPS proved via technology that we were correct about the barbed wire line. My incident was resolved diplomatically, and the wire was returned to the correct boundary. Within a year, the system had been distributed to all military units and installed across all armored vehicles.

GPS is now such an important part of our lives – but not worth losing your head over!

Christopher Hounsfield, editor

PRODUCTS & SERVICES

REGULARS

CORRECTION

In the September 2013 issue of *Aerospace Testing International*, an interview with Dave Mackay, the chief pilot of Virgin Galactic, stated that he was the first Scotsman in space. This was incorrect. We apologize for any embarrassment this may have caused.

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COVER IMAGE: JD MacFarlan, head of the F-35 program (Lockheed Martin)

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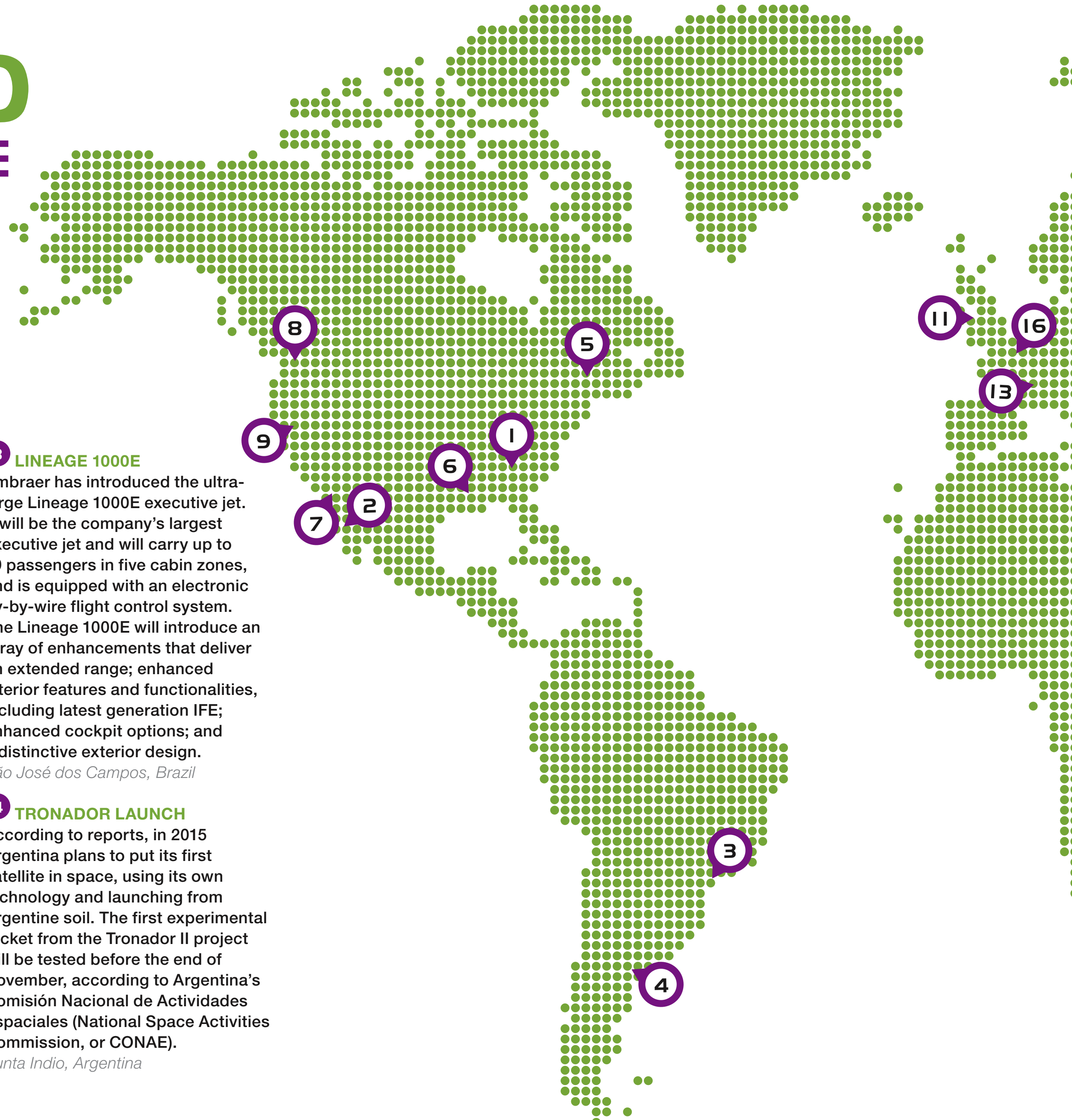
WORLD
TEST UPDATE

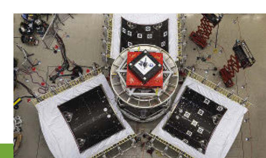


1 757 TAILPLANE
NASA's Ames and Langley research centers, in partnership with Boeing, have completed wind tunnel testing of a full-scale Boeing 757 vertical tail model equipped with active flow control technology. A major objective of the tests was to show that active flow control can enhance the performance of a vertical tail enough to enable future designers to reduce the size of the structure for a whole family of airplanes.
Arnold AFB, Tennessee

2 ANTI-SHIP MISSILE
The Long Range Anti-Ship Missile (LRASM) recently achieved another successful flight test, with the missile scoring a direct hit on a moving maritime target. The test was conducted in support of the Defense Advanced Research Projects Agency and Office of Naval Research program.
Point Magu, California, USA

3 LINEAGE 1000E
Embraer has introduced the ultra-large Lineage 1000E executive jet. It will be the company's largest executive jet and will carry up to 19 passengers in five cabin zones, and is equipped with an electronic fly-by-wire flight control system. The Lineage 1000E will introduce an array of enhancements that deliver an extended range; enhanced interior features and functionalities, including latest generation IFE; enhanced cockpit options; and a distinctive exterior design.
São José dos Campos, Brazil

4 TRONADOR LAUNCH
According to reports, in 2015 Argentina plans to put its first satellite in space, using its own technology and launching from Argentine soil. The first experimental rocket from the Tronador II project will be tested before the end of November, according to Argentina's Comisión Nacional de Actividades Espaciales (National Space Activities Commission, or CONAE).
Punta Indio, Argentina



5 LEARJET 75
Bombardier Aerospace has announced that Learjet was awarded FAA Certification for its Learjet 75 aircraft on November 14, 2013. Certification and delivery efforts and activities are in progress for the Learjet 70 aircraft. With a maximum range greater than 2,000 nautical miles at cruise speeds up to Mach 0.81, the Learjet 75 will be able to fly four passengers and two crew members non-stop from Los Angeles to Toronto.
Montreal, Canada

6 ROLLS-ROYCE TEST STAND
Rolls-Royce North America officially opened its second outdoor jet engine test stand in October 2013, an investment of US$50m, at the Rolls-Royce outdoor jet engine test facility at NASA's John C Stennis Space Center. The site conducts jet engine testing – including noise, crosswind, endurance and other tests.
Mississippi, USA

7 F-35 AMRAAM
The F-35 Lightning II executed its first live-fire launch of a guided air-to-air missile over a military test range off the California coast. The AIM-120 advanced medium-range, air-to-air missile (AMRAAM) was fired from an F-35A (AF-6) conventional take-off and landing variant fighter operating from the F-35 Integrated Test Facility at Edwards Air Force Base.
Edwards AFB, California, USA

8 SECOND 787
The second 787-9 Dreamliner has completed a successful 4-hour, 18-minute first flight. As the only 787-9 test airplane to be fitted with elements of the passenger interior, ZB002 will test systems such as the environmental control system in addition to avionics and other aspects of airplane performance. Boeing has conducted a series of ground tests on the second 787-9 since its completion in late September 2013.
Everett, Washington, USA

9 ORION FAIRINGS
Testing at Lockheed Martin's facility in California using a series of timed explosive charges, proved that the Orion spacecraft can successfully jettison its protective fairing panels. The spacecraft has three fairings that protect the service module radiators and solar arrays from heat, wind and acoustics during ascent. Strip heaters were used to heat one of the fairings to 200°F, simulating the heat the spacecraft will experience during its climb to orbit.
Sunnyvale, California

15 MARS MISSION

India's first mission to Mars blasted off successfully on November 5, 2013, completing the first stage of an 11-month journey that could see New Delhi's low-cost space program win Asia's race to the Red Planet. A 350 metric ton rocket carrying an unmanned probe soared into a slightly overcast sky, monitored by dozens of scientists at the southern spaceport of Sriharikota.

Sriharikota, India

16 LEAP 1-A ENGINE

Testing of the first full LEAP engine has been completed successfully. The LEAP-1A from CFM International fired for the first time in September, two days ahead of the schedule set in early 2010. The engine, which was operating smoothly at full take-off thrust in a matter of hours, logged a total of 310 hours and more than 400 cycles, during approximately five weeks of testing.

Melun, France

17 FIRE-FIGHTING DRONES

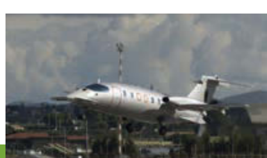
When fires raged across parts of New South Wales in October, a remotely piloted aircraft captured the full drama of the destruction. Queensland researchers are developing responsive unmanned aircraft for use in disaster prevention and response. Rowland Marshall of the Australian Research Centre for Aerospace Automation says drones could take on undesirable jobs previously done by humans.

Queensland, Australia

18 CRUISE MISSILE

An advanced version of the BrahMos supersonic cruise missile system has been successfully test-fired by the Indian Army at the Pokhran test range in Rajasthan. The block III variant of BrahMos, with deep penetration capability, was test launched from a mobile autonomous launcher. After launch, the missile followed the predetermined trajectory and successfully pierced the designated concrete structure.

Rajasthan, India



10 HAMMERHEAD UAS

Piaggio Aero, together with Selex ES, announced at the Dubai Air Show 2013 that the P.1HH HammerHead unmanned aerial system has achieved the demonstration and validation phase of the program with the maiden flight of the P.1HH demo, Piaggio Aero's UAV technology demonstrator. This flight is a fundamental milestone that paves the way to the next phase of the program development.

Dubai

11 TRANCHE 3 TYPHOON

The first Tranche 3 Typhoon, BS116, has successfully completed engine ground runs at BAE Systems' de-tuner facility at Warton, UK. The Tranche 3 jet offers a number of provisions that future-proof the aircraft, including e-scan radar, conformal fuel tanks and a high-speed data network. Engine ground runs are the last stage of testing before the aircraft makes its first flight, on target to take place before the end of the year.

Warton, England

12 FIFTH FIGHTER PROTOTYPE

The fifth prototype of the 5th-generation aviation complex (PAK FA, T-50) made its maiden flight at the Sukhoi A Gagarin KnAAZ aircraft plant. The fighter aircraft spent 50 minutes in the air. The test flight was in full accordance with the flight plan. The stability of the aircraft and the propulsion system were tested during the flight. The aircraft performed well in all phases of the planned flight program.

Komsomolsk-on-Amur, Russia

13 A320NEO

The engine pylon for the first A320neo has been assembled to fly. The pylon, which has just been completed in Toulouse, is the first major airframe component assembly to take place for the NEO program. In parallel, other major NEO components will shortly be taking shape. In Hamburg, Germany, the center wing-box will be integrated in the fuselage, and the rear fuselage will also begin assembly. Forward fuselage assembly will start in January 2014.

Toulouse, France

14 LONG-RANGE DRONE

Iran has developed a drone, which, it says, enjoys unique strategic capabilities, including 30-hour flight durability. According to the Defense Minister, Brigadier General Hossein Dehqan, it has been developed for combat and surveillance missions. Dehqan said the drone, Fotros, has been designed and built by the Iranian Airplane Manufacturing Industries Company.

Tehran, Iran

BOMBER BOAT BLITZ

US Air Force heavy bomber crews have been testing and evaluating new tactics and procedures to allow them to attack maritime targets on instrumented test ranges in the Gulf of Mexico.

A single B-1 from the 337th Test and Evaluation Squadron (TES) at Dyess Air Force Base carried out the test in September. The aim of the maritime tactics development and evaluation, or TD&E, which was conducted alongside other bomber and fighter aircraft, was to improve and better understand the aircraft's capabilities. During the trials, the B-1 dropped a total of six munitions, including a laser-guided 500 lb bomb GBU-54, as well as 500 lb and 2,000 lb satellite-guided joint direct attack munitions.

"Many of the dynamic targeting skills we've refined over the past decade on land are directly applicable in the maritime environment," said USAF Captain Alicia Datzman, 337th TES's chief of weapons and tactics. "This is the perfect opportunity to validate and refine these tactics."

Lieutenant Colonel Alejandro Gomez, 337th TES's special projects officer, added, "This evaluation solidifies what our crew members already knew – that we can strike surface targets. The knowledge we gain from these events gives combatant commanders assurance that we can be called on to complete the mission."

The B-1's role in the tactics development and evaluation was to detect, target and engage small boats using currently fielded and available weapons, released in all weather conditions. Gomez said that, as prime aircraft, B-1s are capable of protecting important assets at sea and patrolling allied shipping lanes, because of their speed and ability to stay in the air longer than most aircraft.

"Future wars might not all be on land. Some may include surface combat, so we are evaluating the way we employ the B-1 to aid in completing the mission," Gomez said.

With the platform constantly upgraded and new applications for the aircraft being discovered regularly, the 337th TES is often called on to find new and innovative ways to use the B-1.

"We are the 9-1-1 of the B-1 community," Gomez said. "When something needs to be adjusted or improved for our aircraft, we are called on to find the solution.

Gomez stated that one of the most useful tools the 337th TES has in its arsenal is the TD&E. During a TD&E, data is collected in flight of all information contributing to the mission. Once completed, the aircrew examines data from the mission to determine how efficiently they tracked, engaged and destroyed the target. From there, the 337th TES develops future tactics, techniques and procedures manuals using the knowledge gained.

"Success in these sorts of tests gives our sister services confidence that the B-1 can get the effects they need to meet combatant commander requirements over land and sea," Gomez said.

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ROBOT TANKER TESTS

Flight trials of air-to-air refueling technologies for use in future US Navy unmanned aerial vehicles got underway in September. The US Navy aims to use the trials to demonstrate the multiple technologies needed to greatly increase the endurance and range of aircraft carrier-based unmanned systems.

As part of its Unmanned Combat Air System Demonstration (UCAS-D) program, the US Navy and industry partner Northrop Grumman completed the current phase of its Autonomous Aerial Refueling (AAR) test on September 6 at Niagara Falls, in New York state, to demonstrate that unmanned aircraft could be refueled in flight.

"The AAR segment of the UCAS-D program is intended to demonstrate technologies, representative systems and procedures that will enable unmanned systems to safely approach and maneuver around tanker aircraft. We are demonstrating both US Navy and US Air Force style refueling techniques," said Captain Jaime Engdahl, Navy Unmanned Combat Air System program manager. The US Navy, US Air Force and the Defense Advanced Research Projects Agency (DARPA) have been working closely since 2001 to develop technologies and mature operating concepts for AAR, according to Engdahl.

In preparation for the most recent phase of the AAR testing, Calspan Aerospace developed, built, and tested an inert refueling probe that it installed on the nose of a surrogate unmanned aircraft, a Learjet. In August 2013, the AAR UCAS-D team arrived at the Calspan facility and a team from Northrop Grumman installed the X-47B's navigation, command and control, and vision processor hardware and software on the Learjet. The military team installed the government-developed Refueling Interface System and Tanker Operator Station on an Omega 707 tanker aircraft. The team then conducted initial ground and taxi tests, which culminated in the first AAR test flight on August 28. A series of flights using the surrogate aircraft equipped to fly autonomously behind an Omega K-707 Tanker then took place.

"Demonstrating AAR technologies and standard refueling procedures is the next logical step for our demonstration program. The team has shown that we can use the same systems architecture, Rockwell Collins TTNT datalink, and Precision Relative GPS (PGPS) algorithms to extend the concept of distributed control of autonomous systems from the aircraft carrier to the airborne refueling environment," said Engdahl. "The initial tests showed excellent system integration as well as good navigation and vision system performance."

The next phase of AAR testing will continue later in 2013, exercising end-to-end AAR concept of operations with a complete autonomous rendezvous, approach, plug and safe separation using X-47B software and hardware installed in the surrogate aircraft. Data from the demonstration will be used to assess system performance for multiple AAR refueling technologies, validate the AAR procedures and concepts, and support further development of future unmanned systems.

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SIKORSKY'S MATRIX JOINS TEST FORCE

The capability, reliability and safety of autonomous, optionally piloted, and piloted vertical take-off and landing (VTOL) aircraft is expected to be improved by Sikorsky Aircraft's new Matrix Technology research programme.

Sikorsky is working on the project with the United Technologies Research Center, with the aim of giving both rotary and fixed wing VTOL aircraft the high level of system intelligence needed to complete complex missions with minimal human oversight and at low altitudes where obstacle threats abound.

"VTOL pilots will increasingly become mission managers, either on the aircraft or when monitoring from the ground via datalink, because they will feel comfortable letting the aircraft fly itself," said Mark Miller, Sikorsky's vice president of research and engineering as he unveiled the Matrix Technology during the AUVSI Unmanned Systems trade show in October.

"The game-changing Matrix Technology we are developing and testing will provide order-of-magnitude improvements in system intelligence and contingency management, to ensure high levels of reliability and ultimately make unmanned missions by helicopters and VTOL aircraft of all sizes highly affordable."

While the aviation industry measures loss rates for current unmanned aircraft at approximately one per 1,000 flight hours, Sikorsky's Matrix Technology program aims to improve the unmanned aircraft loss rate to one per 100,000 flight hours. "Our robust architecture, multilevel contingency management and advanced system intelligence algorithms will enable this transformation," said Miller. The Matrix Technology project is spearheaded by Sikorsky Innovations, the same rapid prototyping organization that in 2010 proved the physics of efficient 250kt flight in a rotorcraft with the X2 Technology Demonstrator program.

For its autonomy initiative, Sikorsky Innovations has acquired and outfitted an S-76 commercial helicopter with fly-by-wire controls to act as a flying lab. Called the Sikorsky Autonomous Research Aircraft (SARA), it will enable rapid flight testing of software and hardware, including multispectral sensors, previously integrated in the systems integration labs at Sikorsky's headquarters in Stratford, Connecticut.

When not in flight, SARA can be configured as its own simulator to develop and test autonomy software and hardware. The SARA aircraft performed its first autonomy flight with Matrix Technology on July 26, 2013. For the early flight test work, a safety pilot will remain aboard the aircraft.

Through to the end of 2014, the program has set rigorous key performance parameters that will test and refine software apps and complex algorithms. These include demonstrating safe flight in obstacle rich environments, shipboard and brownout condition landings, and cargo transport using an optionally piloted fly-by-wire UH-60 Black Hawk helicopter. Beyond 2014, the program will continue to tackle new challenges, and address requirements that further advance autonomy capability for VTOL aircraft.

"Matrix Technology addresses the unique needs of vertical flight systems," explained Miller. "By our efforts we seek to expand the types of missions that can be flown, improve the efficiency of existing missions and continue to build on the safety and reliability that has been a Sikorsky hallmark."

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FIRST ARTIFICIAL ASH CLOUD TEST

UK airline EasyJet, along with Airbus and Nicarnica Aviation, has successfully completed the final stage of testing for the Airborne Volcanic Object Imaging Detector (AVOID) volcanic ash system through a unique experiment involving the creation of an artificial ash cloud.

An A400M Airbus test aircraft dispersed 1 metric ton of Icelandic ash into the atmosphere between 9,000ft and 11,000ft, creating conditions consistent with the 2010 Eyjafjallajökull eruption. A second Airbus test aircraft, an A340-300, with the AVOID technology fitted, flew toward the ash cloud identifying and measuring it from around 60km away. The experiment also used a Diamond DA42, from the University of Applied Sciences Düsseldorf (FHD), to fly into the ash cloud to take measurements that helped to corroborate those made by the AVOID system.

The ash cloud produced during the test measured between 600ft and 800ft vertically and was 2.8km in diameter.

To begin with, the ash cloud was visible to the naked eye but dissipated quickly, becoming difficult to identify. The AVOID volcanic sensor detected the ash

An Icelandic opinion

During eruptions of moderate size, but lasting for days or weeks, parts of the airspace in a large area, e.g. a sizeable section of the North Atlantic or a part of Northern Europe, may have some ash contamination, often discrete bands covering patches of the sky, while other areas may be largely ash-free.

At present it is difficult to predict precisely where this ash may be located and therefore large areas may be closed to aircraft. But if passenger aircraft were equipped with sensors that detect volcanic ash in the air at distances of 100km, the patches of ash could be avoided and the aircraft navigated safely around them. Thus, the AVOID system has the potential to keep flight disruption down, leading to a much reduced regional impact.

EasyJet plans to continue development with a view to mounting standalone units on some of its current fleet of aircraft by the end of 2014, thereby providing a solution that would mean we should not encounter the widespread airspace closures of 2010 again.

Magnús T Gudmundsson is from the Institute of Earth Sciences, based in Iceland

cloud and measured its density, which was within the range of concentrations measured during the Eyjafjallajökull ash crisis in April and May 2010.

Talking exclusively to *Aerospace Testing International*, Professor Konradin Weber from FHD said, "The task of the FHD team within this ash dispersion experiment was to track the artificial plume with FHD instruments mounted on the Diamond DA 42 MPP research aircraft, and to measure the ash concentration within the plume with high accuracy. The in-situ measurement systems on the research aircraft are able to cover a range of particle sizes, from 250nm up to 50µm."

The detailed size distribution of the measured particles was determined during the experiment. Moreover, ash samples were captured from the cloud during the flight for later analysis by electron microscope. Through this analysis it was proved that the artificially generated plume consisted of volcanic ash particles very similar to airborne ash captured over Europe during the 2010 eruption. During the experiment the actions of the four aircraft were very successfully coordinated. The in-situ measurements performed by the FHD team within the plume compared very well with the remote detection of the AVOID system.

Inventor of the AVOID technology, Dr Fred Prata from Nicarnica Aviation, said, "The team has just executed a unique scientific and engineering experiment, conclusively demonstrating that low concentrations of ash can be identified by the AVOID sensor. The highly successful outcome of this complex experiment, which involved delivering 1,000kg of fine ash into a small airspace, controlling four aircraft and coordinating the measurements from two of the aircraft, is a testament to the commitment and skills of easyJet and Airbus engineers and a great example of industry and science coming together to solve an important problem."

Weber added, "In general, the experiment was very successful and can be regarded as a remarkable step for aviation safety. While the AVOID system can finally help aircraft avoid entering ash plumes, in-situ aircraft measurements have the aim of precise and detailed characterization of the ash cloud. In combination, these in-situ measurements, ground based ash plume tracking and satellite images can deliver important data helping to increase the accuracy of the maps and retro-stimulate the predictions of the VAAC's ash dispersion models. In this way detailed and accurate plume mapping with precise information about the actual threat becomes possible. The combination of all these means can greatly increase the availability of air transport in the event of a volcanic eruption, while maintaining aviation safety."

The AVOID system can be likened to a weather radar for ash. The system uses infrared technology fitted to aircraft to supply images to pilots and an airline's operations control centre. The images will enable pilots to see an ash cloud up to 100km ahead of the aircraft and at altitudes between 5,000ft and 50,000ft, thus allowing them to make adjustments to the aircraft's flight path to avoid the ash.

The 2010 Eyjafjallajökull volcanic eruption resulted in the largest air-traffic shut-down since World War II.

200m	The amount in US dollars lost every day due to the disruption caused by the Eyjafjallajökull eruption in April and May 2010, according to IATA
95,000+	The number of flights canceled due to the eruption
11,000	The height in meters that the ash cloud reached above the North Atlantic
10 million	Number of passengers to suffer flight cancellations
5,417	The height in feet (1,651m) of Eyjafjallajökull above sea level

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GARNET RIDGWAY

SOPHIE ROBINSON

TO BE THERE OR NOT TO BE THERE?

Is there really any substitute for physical attendance at trials?

For this issue, the authors of the head-to-head feature are taking the somewhat controversial position of agreeing with each other. Attending trials in person is undoubtedly the way to get the most out of the activity, and that is likely to be the case for many years to come. The aim of this column, therefore, is to explore the key enablers that would make remote 'attendance' at trials as good as the real thing.

The fundamental objective of a practical trial is data gathering, whether in the form of recorded parameters or pilot opinion. In the age of fiber-optic internet connections and mobile broadband, the transfer of data between physical locations may seem a trivial problem. However, aerospace testing (particularly when defence-related) almost invariably occurs at remote or isolated facilities, where communications can be unreliable at best. This in effect rules out the meaningful participation of team members that are not physically present at the test site.

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

In an ideal world with universal, high-speed, secure internet access, this need not be the case. Indeed, it could be possible to have the majority of the test team in a central location, managing a number of very small satellite teams. This could be beneficial in terms of resource allocation and project management.

Assuming the existence of this perfect internet connection brings additional opportunities – not just to make physical remoteness from the trial less of a disadvantage, but to enhance the whole activity. For example, network-enabled personal devices such as Google Glass could give trials engineers instant access to a huge support team, all of whom would be able to see and hear the test activity in real time. This could eliminate the need to frantically search through pages of notes in the back of a test aircraft as it hurtles through an aggressive maneuver; instead, the information could be provided in augmented reality, appearing as virtual notes that update automatically as the test progresses. Clearly the use of such technology presents huge challenges in terms of usability, safety and compatibility with aircraft systems, but the potential advantages are tantalizing.

It is again necessary to concede that there is currently no substitute for attendance at trials. However, emerging technologies present myriad opportunities, meaning that virtual 'attendance' at trials doesn't have to be the same as traditional attendance – it could be even better!

This article is brought to you from on board RFA Argus, a UK aviation training vessel. We're currently 130 miles off the Scilly Isles in the Celtic Sea, conducting a ship helicopter operating limit trial – so the theme of this issue's article is highly relevant! There really is no substitute for attending a trial – being present at the heart of the action offers a unique and valuable perspective.

The ultimate priority of any trial is safety, and the key to progressing a trial safely is to make observations and judgments based on what is happening there, and then assimilating information from a variety of sources to make an informed decision on what the next test point should be, or if it's time to call it a day. This would be an impossible task from anywhere other than the ship's bridge or the back seat of the aircraft.

Distance from the trial also makes it difficult to capture instantaneous feedback from the test environment. Decisions on trial progression are made using information from a variety of sources – it isn't just numbers on a screen. The tone of voice of a pilot; the extended periods of radio silence (where the pilot is normally cursing the trials manager for asking them to undertake a particularly tasking test point!); and awareness of factors such as increasing ship motion or an approaching patch of inclement weather all have to be assimilated to decide if it's safe to continue progressing the trial. It would be nearly impossible to do this without being there to see at first hand.

Working as part of a combined test team could also prove a challenge when distanced from the trial environment. Managing the conflicting priorities and expectations of all parties

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

involved in a trial can be taxing enough when everyone is in the same room together – never mind when they're scattered across the country, or even the world.

Attendance at trials is absolutely worth the expense, time and inconvenience. No matter how sophisticated predictive tools such as simulation and modeling become, there will always be a requirement to carry out real-life trials. If living on board a ship for five weeks has taught me anything, it's that, while tiring and occasionally stressful, trials can also be quite fun. As engineers, we like to go and 'do' – being shut in the office every day just wouldn't be quite the same, would it?

Life after first flight

Flight testing of the new Airbus A350 XWB is underway in France – what flight progress has been made since the aircraft first flew in June 2013?

BY IAN GOOLD

By the beginning of December, the first two (of five) Airbus A350 XWB (eXtra Wide Body) test aircraft was expected to have logged more than 600 flight hours (FH) in more than 120 flights since the type's June 14 maiden flight at the manufacturer's Toulouse factory. The lead aircraft – manufacturer's serial number (MSN) 001 – had recorded almost 460 FH in 95 flights by November 20, while MSN003 (the second A350 to fly, on October 14) was close to 140 FH in 25 flights, according to Airbus.

The manufacturer is aiming to obtain airworthiness approval (type certification) in time for entry into service in September 2014. Final assembly of MSN005, the last test aircraft, began on November 4, following arrival of its three main fuselage sections in Toulouse four days earlier.

The A350 XWB twin-aisle twinjet family comprises three models, with a possible fourth extra-long variant a distinct possibility, according to program officials. The family will offer capacity between 270 and a potential 400+ passengers in typical cabin configurations. New business announced at November's Dubai Air Show brought firm orders for the A350-800, -900 and -1000 versions to 764 from 39 customers.

CRITICAL PHASE

Reiterating the words of Tom Enders, chief executive of Airbus's parent company, European Aeronautic Defence and Space (EADS), executive vice president and A350 program head Didier Evrard says, "Airbus is now entering the most critical phase," one that contains "new challenges". In a first phase of testing, which saw MSN001 accrue nearly 100 FH in the first month of flying before it went in for routine maintenance in July, the A350 was flown by 10 Airbus test pilots involved in assessing handling qualities and behavior, which quickly resulted in clearance of the new aircraft's entire flight envelope.

"We have done a lot of tests. There was a four-week interruption while we upgraded flight test instrumentation. We have done really well with flight tests, and in the first phase we have gathered a lot of information," says Evrard. Initial testing of key systems covered engines, electrics, ram-air turbine, fuel, cabin pressurization, and landing gear and braking, as well as a preliminary consideration of the autopilot and auto-land functions. During maintenance, the A350's flight test instruments were upgraded for the second phase, which started in August 2013, while the Airbus design team analyzed the initial test results.

Also in July, Airbus performed a 'real virtual' test on the A350 verification and validation platform at its Hamburg factory, as it sought to ensure early maturation of MSN002. This five-hour 'flight' involved simulated boarding of 10 flight and cabin crew, plus 129 passengers, for a flight from the Canary Islands to Germany.

The first two flying A350s are scheduled to be joined by MSN002 and MSN004 in February 2014, with final test machine MSN005 following three months later, according to Airbus experimental test pilot Hugues van der Stichel. Providing a flight test update in late October, he reported that MSN001 had completed aero clean and landing configuration, aero identification, clean flights, and air brakes setting. The A350 had performed an automatic landing as early as its fourth flight.

As the manufacturer extended the A350's flight envelope, operations using basic – or 'normal' – flight-control laws were cleared to FL 430. Anti-skid and maximum-torque braking, using all available capability, were also demonstrated, along with

"ANTI-SKID AND MAXIMUM-TORQUE BRAKING, USING ALL AVAILABLE CAPABILITY, WERE DEMONSTRATED"

X-RAY, A KILOMETER AWAY

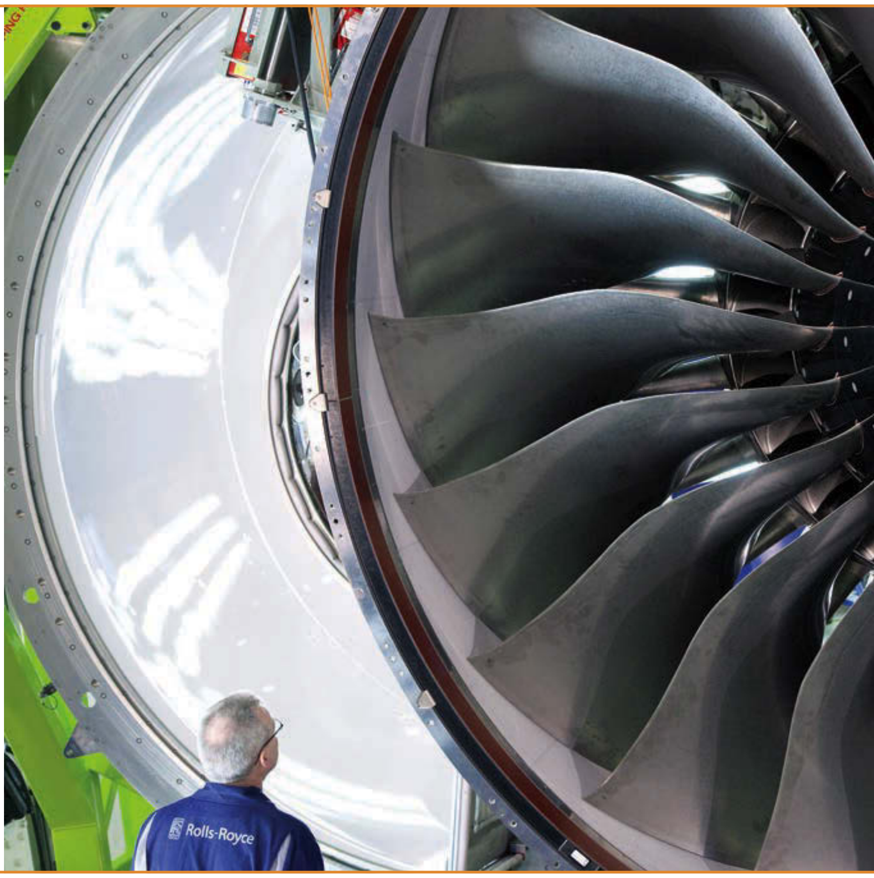
The Trent XWB aero engine being developed for the A350 has been computer modeled to the same level of sophistication and complexity as that carried out by the UK's Met Office to forecast the weather worldwide, according to Tim Boddy, head of marketing (Trent XWB) for Rolls-Royce.

"The computer models predicted how the Trent XWB would perform – aerodynamically, thermodynamically and mechanically – under normal and extreme abnormal conditions, thereby enabling airworthiness certification for the engine," he says.

The design and modeling techniques were so sophisticated that advancements in engine testing were required to validate findings and identify further performance improvements: "An aero engine operates for the majority of its life in the cruise phase of flight at altitude," explains Boddy. "The engine's efficiency in these conditions significantly contributes to the total fuel consumption per flight. Cruise efficiency was therefore a primary design goal in developing the Trent XWB.

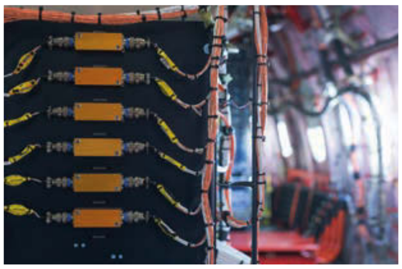
"To meet this objective, it was vital for the company to understand the performance of critical engine components, such as the turbine driving the engine's fan to generate propulsive thrust. The clearance between the tips of the turbine's rotor blades and the static seal of the outer case is key to achieving maximum efficiency from this part of the engine."

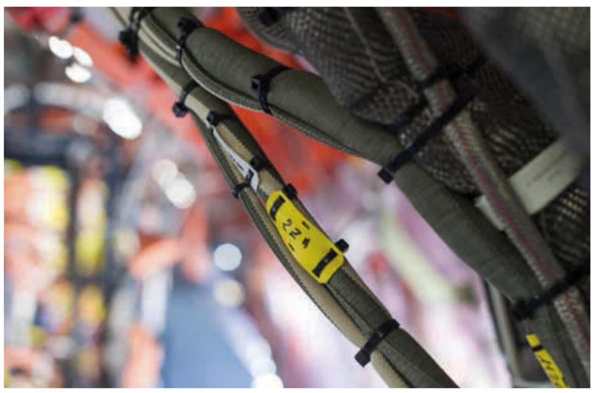
However, how do you get under the skin of an aero engine to see what's really going on while the engine is running at cruise thrust?



BELOW: A portion of the flight test instrumentation equipped on the first A350 XWB test aircraft to fly, MSN001

BOTTOM: The first A350 XWB development aircraft, MSN001, is fitted with heavy test instrumentation





landing gear emergency free-fall in the air (following initial ground demonstration with the aircraft standing on jacks). Other achievements involved systems testing (including failure cases) and in-flight ram-air turbine extension, which permits electrical power to be generated from the outside airflow in the event of loss of onboard generation.

VMU TESTING

Demonstration of the A350's minimum lift-off, or 'unstick', speed (known as Velocity, minimum unstick (V_{mu})) on the new jetliner's 57th flight in late September confirmed the optimum flap setting for take-off, showing that the aircraft is not stall limited, according to van der Stichel. The V_{mu} testing was conducted on the very long, 3.86km (12,660ft) runway at Châlons Vatry Airport in northeastern France. Van der Stichel declined to quote actual speeds, saying that engineers were still analyzing data.

V_{mu} tests, which were introduced after two early-1950s de Havilland Comet accidents that were attributed to over-rotation on take-off, are conducted with a hardwood-block buffer attached to the underside of the rear fuselage to prevent structural damage. The Comet had a wing aerofoil section that suffered from reduced lift at high angles-of-attack (or 'alpha', the angle between the aerofoil chord line and the relative airflow), before introduction of both a modified leading-edge profile and airworthiness regulations aimed at making over-rotation impossible.

During V_{mu} demonstration, the aircraft's nose is raised until sufficient lift has been generated for the landing gear to leave the ground with the solid buffer scraping the runway. Van der Stichel concedes that Airbus had been surprised at how much buffer material had been eroded in equivalent testing of the A380; during that flight test campaign the A380's fuselage skin had touched the runway – something that Airbus had been keen to avoid repeating, as valuable A350 flight test time would have been lost while repairs were completed. Another thing to be avoided during such testing is the risk of over-rotating about the tail damper (a device fitted to protect the extreme end of the tailcone against a tail strike).

Overall, Airbus has allocated 2,500 FH to A350 flight testing, with the heavily instrumented MSNs 001 and 003 earmarked for 800 FH and 600 FH, respectively. The next two aircraft,

Rolls-Royce invested in building Europe's most powerful x-ray machine. Capable of taking a medical x-ray image from a distance of 1km, the machine permitted a unique understanding of the interaction between the blade tips and the seal segment over which they pass. While the x-ray device seems an extreme piece of equipment for monitoring an aero engine, the investment produced important results.

During engine testing, Rolls-Royce was able to generate real-time images of the turbine's behavior, revealing a previously unknown axial movement of the blades. This movement was a relatively easy issue to correct, with the blades' axial position in the engine reset during the assembly process. The measure helped maximize the engine's efficiency by minimizing leakage across the turbine blade tips.

"Although the x-ray process is just a single test in a far larger program, this stage alone yielded an efficiency improvement equivalent to approximately US$30,000 of fuel saved per engine per year," says Boddy. "There could be no better demonstration of the value in pushing the boundaries of aero engine testing."

To date, Rolls-Royce has run 12 engines in the Trent XWB test program, in the process accumulating more than 5,600 hours of data. Two Trent XWB-powered A350 XWB aircraft are now conducting test flights; the second aircraft having taken to the skies for the first time on October 14. "The vast amounts of knowledge gained through this testing regime should ensure we are on track to meet the program's aim of maximized engine performance and maturity before the A350 XWB enters service next year."

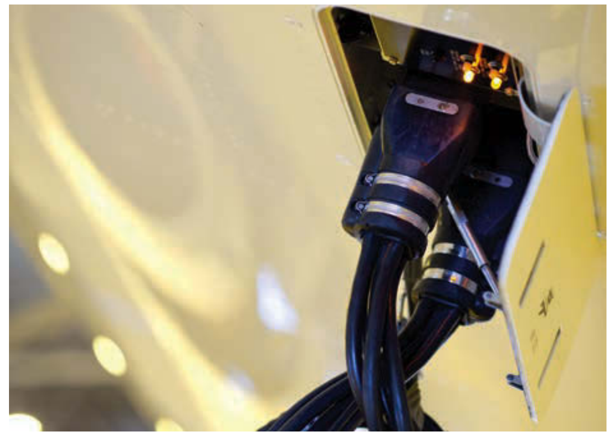
MSN002 (configured with a furnished passenger cabin) and MSN004 should fly in February at the start of programs that call for each aircraft to complete about 400 FH of testing.

Scheduled for three months later, in May, is the first flight of MSN005, another machine equipped with a passenger interior and for which a shorter 300 FH duty is planned. MSN004 and MSN005 carry only light flight test instrumentation, according to van der Stichel. Evrard says that these airframes have been "less difficult" to complete because they have been fitted with less test equipment.

FLUTTER FREE DEMO

The next major milestone in the flight test program is a flutter-free demonstration that will see the A350 being flown at maximum operating speeds (V_{mo}) and Mach numbers (M_{mo}) at moderate to high altitudes. (Mach numbers relate aircraft speed to the local speed of sound, which varies with altitude.)

The tests include acceleration from low to high Mach numbers, as well as establishment of maximum permissible dive speed (V_D) and Mach number (M_D). Another important test exercise, according to van der Stichel, will be flying the A350 in conditions of known icing.



ABOVE: **MSN003 is one of five test aircraft that will participate in the A350 XWB's certification campaign**

BELOW: **MSN003 became the second A350 XWB to join the flight test program, which will include 2,500 hours across five developmental aircraft**

Asked about which maneuvers are most challenging for flight test crews, van der Stichel cites two examples: the establishment of V_{mm} (maximum maneuvering Mach number), which is "difficult because you can go to flight attitudes that were never intended", and flutter-free flight, which can take the aircraft "beyond the edge of the normal flight envelope".

In the extremely unlikely event of something going wrong – Airbus once lost an A330 and its crew while demonstrating the simulated loss of one engine after take-off at an extreme aft center of gravity and with autopilot selected – what provision is made for flight crew escape? Astute observers of the A350 flight test aircraft will notice a panel set in the belly cargo door on the starboard side. This is a 'push-out' escape hatch from which crew members can parachute, and access to which is via a slide from below a special door in the cabin floor.

In parallel with the initial flying, Airbus is continuing work with the static-test airframe, identified as MSN5000. In mid-October, preparation for the ultimate load test was "progressing well", with Evrard declaring himself "very happy" that it would be complete around the end of 2013 or at the beginning of 2014.

With more than 600 FH recorded by the beginning of December, the A350 is almost a quarter of the way through the scheduled flight test program. "Almost exactly a year since we inaugurated the A350 final-assembly line, we have two aircraft flying," said Evrard in late October. "But a program is never finished; we still have great challenges ahead to be processed." ∎

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

FAMOUS FIVE

Airbus will use five A350-900s in the 'relatively standard' flight test program, which for each involves five development- and certification-flying phases, before a buffer period ahead of service entry, according to A350 project test pilot Francis Chapman. The "first several" flights constituted initial development testing, during which the manufacturer analyzed flight characteristics and behavior. Each flight test machine has a dedicated program of activity:

- **MSN001 is the first of a pair of aircraft with 'heavy' flight test instrument (FTI) fits and was earmarked for flight-envelope, powerplant and systems flying, including natural-icing investigation (once Airbus had frozen the aerodynamic configuration) as well as handling-qualities evaluation;**
- **Also heavily instrumented, MSN003 – the second A350 to fly – is being used for high- and low-temperature and high-altitude work in its airworthiness-approval and development flying, which includes engines, performance and systems activity;**
- **One of two lightly instrumented airframes, MSN004 is scheduled for avionics development and certification, and other duties will include external noise measurement and analysis, lightning tests, and pilot training for first customer and maintenance teams;**
- **MSN002, which may fly shortly after MSN004, is to have a medium FTI fit and (with MSN005) will be furnished for passenger-cabin and cabin-systems development and airworthiness approval. It is also planned for partial-evacuation trials and hot- and cold-chamber climatic trials before making early long flights with Airbus employee 'passengers' to assess the design's full-load endurance and ensure cabin 'maturity' at entry;**
- **Otherwise lightly instrumented, MSN005 is to perform route-proving work near the completion of type certification in mid-2014. Essentially cabin-related activities will cover extended-range twin-engine operations (Etops) performance, function and reliability (or 'operability') and training, in addition to initial A350 customer crew training.**

Where no man has gone before

They share many of the same challenges, and use many of the same technologies, but there will always be one key difference between the testing of an unmanned air system (UAS) and a manned aircraft – the pilot stays firmly on the ground

BY PAUL E EDEN

BAE Systems' Taranis drone was unveiled in July 2010 in a formal ceremony held at the anechoic test chamber at Warton

Chat with a Typhoon test pilot, discuss progress on the latest helicopter program with a Eurocopter flight test engineer, or review coverage of the A350's first flight, and datalinking, telemetry, modeling and simulation are soon revealed as key factors in high-technology flight testing. Examine a typical unmanned air system (UAS) test programme and those same factors are again to the fore. The only real difference is that the pilot stays firmly on the ground.

UAS testing follows manned test procedures very closely. The variance and challenges lie in the much higher demands for data transfer of the UAS and the need to create, prove and sometimes challenge nascent regulations governing UAS operations. At the top end of UAS test and experimentation, manufacturers are intricately involved in the process of defining the regulations that will govern the eventual operation of their craft, or at the very least the future applications of the technology.

Asked about approaches to UAS testing, Martin Rowe-Willcocks, head of business development for Future Combat Air Systems at BAE Systems, notes that the company has been building and testing military aircraft for many years and its approach to UAS testing is exactly the same as for a manned aircraft. "Roles and responsibilities that have been defined and matured over decades on Harrier, Tornado, Hawk and Typhoon are just as relevant to the unmanned world. The only real difference is that the person in control of the aeroplane isn't physically sitting in it. It's how you plan and deliver a trial in these circumstances that produces the quirks of unmanned testing, but everything is done under the same governance structure as our military flight testing, under the head of flight operations.

"He's independent of the flight test team and qualifies crews to operate vehicles during the test phase. Some of the crew are test pilots, some are flight test engineers, but all have been through a set of internal assessments to ensure they understand the subtleties of testing an unmanned aeroplane. We also have to make sure they know how airspace works."

For BAE Systems trials, Rowe-Willcocks says that crew experience is essential: "It's important for crews to understand how airspace works, how to fly under air traffic control and how to work with the authority controlling the range and airspace in use," he says. "That's no different from how we run a manned trial."

He also notes that little in UAS test is new, since the company has been doing the work for more than a decade, although only publicly since 2005, when the UK's Defence Capability Plan was published, revealing programs including Raven and Corax.

As far as day-to-day testing is concerned, the major difference in UAS work is that BAE Systems is obliged to work away from its Warton site. This, Rowe-Willcocks says, is down to several factors: "It's the maturity of the

ABOVE: BAE Systems' High Endurance Rapid Technology Insertion (HERTI) UAV

BELOW: HERTI's first flight was in December 2004 at the Australian Woomera test range where much of the test flight programme has been undertaken

RIGHT: BAE Systems Mantis UAV undergoing flight trials in Woomera, South Australia

technology, public acceptability and the use of airspace. We want to be able to fly away from home but we don't always want to do so physically. But we have to be able to do it in a safe, controlled manner. This is one of the reasons we're among the leading lights on the ASTRAEA (Autonomous Systems Technology Related Airborne Evaluation & Assessment) program, where we use a modified, crewed Jetstream 31 as a surrogate UAS, controlled from Warton."

The Royal Air Force began operating the General Atomics MQ-9 Reaper over Afghanistan in 2007, from ground control stations at Creek AFB, Nevada. A second Reaper operating unit went operational in the UK late in 2012 and began flying the aircraft operationally from early 2013. As it continued to expand its remotely piloted air system (RPAS) knowledge, the RAF went on to award wings to its first RPAS-specialist pilots on April 2, 2013. Responding to the author's questions, Squadron Leader Chris Melville echoed Rowe-Willcocks's opinion that airspace restrictions are the major challenge in testing and

7,500	The distance in miles between a pilot in the USA and a UAS flying over Afghanistan
678	The International Institute for Strategic Studies estimates that the US military has at least 678 drones in service, of 18 different types, including the MQ-1B Predator, of which it claims the US has more than 100
$89 billion	Teal Group's 2013 market study estimates UAV spending will total just over US$89 billion in the next 10 years
£62m	The amount contributed by major companies such as AOS, BAE Systems, Cassidian, Cobham, QinetiQ, Rolls-Royce and Thales, as well as 100 smaller organizations, to the ASTRAEA program

expanding UAS capability: "The utilisation of airspace for conducting UAS operations and testing is a known issue, and not just within the UK."

SEPARATE ROLES

All UAS testing involves separate datalink requirements for telemetry and command and control. In the former case there is no difference from a manned test, where an aircraft is telemetered for health and systems monitoring. BAE Systems works with a normal crew that controls and monitors the aircraft in regular flight, just as the pilots in a Typhoon would. A team of flight test engineers then works closely with – but discretely from – the crew, monitoring, analyzing and acting on telemetered data.

The system has considerable advantages, as Rowe-Willcocks explains: "We have a small crew focused on testing the aeroplane, but with the test engineers able to 'look over their shoulders' as the test unfolds. If something unexpected happens there can be a dialogue between crew and engineers, but we ensure that the roles are kept in place. The processes and techniques are essentially those of a manned test, so it's very easy to move engineers between programs."

Of course the teams could be geographically separated, but as Rowe-Willcocks explains, "There's a fine line between having all your experts next to the aeroplane and maybe one or two 'super experts' at the end of a hotline back to the UK. It's driven by the type of test. For example, envelope expansion and communication work require different technicians, so it takes careful planning to make sure all those people are in the right place before and during a test, and for the post-flight debrief."

The earliest of BAE Systems' UAS work involved subscale aircraft, but recent programs have been with larger medium-altitude, long endurance (MALE) type machines, which provide plenty of space for telemetry equipment but are regulated by weight, or at least by the degree of damage that could be caused if they crashed.

Regulators typically look for the aircraft to be demonstrably as safe as a manned machine of similar size and weight. The BAE Systems HERTI (High Endurance Rapid Technology Insertion), for example, was based on a glider, but became increasingly heavy as systems

FANWING OPTS FOR UAS TESTBED

For FanWing, a UK company currently engaged in developing what the *New York Times* describes as "one of the few truly new aircraft since the Wright Brothers", the UAS was the only option for testing its design based on distributed-propulsion vortex-lift technology. The unique FanWing configuration precluded building a manned aircraft test bed, but more importantly, the company's limited budget required a subscale platform that could be modified and tested on a shoestring.

A distributed-propulsion vortex-lift system lends itself well to long-endurance UAS tasks requiring a maneuverable, stable and efficient platform – border surveillance or pipeline survey work for example – although it can also be scaled up to suit a range of manned applications.

Most of the testing to date has been very basic – inventor Pat Peebles built a wind tunnel in the family garage early on in the program, for example, as well as hand-holding models to assess their potential flying characteristics. After many years of demonstration, improvement and struggle, however, Fanwing director Dikla Peebles was delighted to reveal: "On October 1, 2013 we entered into a two-year EU project led by DLR to optimize wingshape and so on." A new era in UAS testing and operation could well be with us.

were added, effectively raising it from EASA's CS-22 category as a powered sailplane, to CS-23. This more demanding certification specification was then used as the reference in setting up the design process and test regime.

Vehicle weight also affects the level of test required for UK military UAS. Release to Service (RTS) testing is overseen by the Military Aviation Authority (MAA), which has different requirements from the Civil Aviation Authority (CAA). "At present," says the RAF's Chris Melville, "a UAS can be operated by a civilian without completing a Kinetic Impact Statement if its dry weight is less than 20kg. However, MAA Regulatory Article 1120 states that a military UAS must be registered if its dry weight is more than or equal to 60g. This means that some micro UAS (weighing less than 2kg) would have to go through the same RTS process as a tactical UAS (weighing between 150 and 600kg) and that the military operates to a more rigorous standard than its civilian counterparts."

GROUND WORK

The flying phase of a UAS test program tends to come toward the end of the

"THE DATALINK BETWEEN THE GROUND CONTROL SYSTEM AND THE VEHICLE, FOR EXAMPLE, MUST BE TESTED AND SHOWN TO BE SAFE AND RELIABLE"

development cycle. Rowe-Willcocks notes: "If you look at the process, we start collecting evidence as we do the design, then test subsystems with the supplier and at our own facility. We do lots of work on mission and interactive rigs, simulators and the aircraft itself, long before we go flying to deliver the final proof of all the testing that's gone before. We find that we don't get that many surprises once flying starts.

"But it's important to remember that the overall test environment is a mix of the equipment, people, training and location. On one of our early HERTI trials in Scotland we sat at Campbeltown airfield with lots of different regulators. Some wanted to see how we tested and qualified the crews, some how we designed and built the aeroplane and others wanted to know how the mission plan was constructed. We had to go through all of those scenarios before they allowed us to do the mission. Now much of that learning process is encapsulated in the CAA's CAP 722 (Unmanned Aircraft System Operations in UK Airspace – Guidance), which has become something of a bible for the industry."

The company also pursues the independent verification and validation of its UAS software, so that as a vehicle comes closer to production standard the regulatory evidence is available to show that it has been designed and tested to industry standards.

As a UAS operator, the RAF takes all its new aircraft types through a further level of RTS testing before they are deemed suitable for service. Melville explains that RTS has been modified for UAS applications: "For manned aviation, the focus of 'release to service' test and evaluation is on the vehicle/vehicle-human interface. In other words, the aircraft and the way the crew interact with it. For UAS test and evaluation, system assurance has to include the ground control station and the air vehicle.

"There are few differences in testing methodology, although because there is a requirement to show the safe operation of the air vehicle, the datalink between the ground control system and the vehicle, for example, must be tested and shown to be safe and reliable.

"Defence Standard 00-970 (Design and Airworthiness Requirements for Service Aircraft) is the source document against which all service aircraft are assessed for safety compliance. Since there are differences between conventional and remotely piloted systems – as there are between fixed and rotary-wing platforms – UAS have their own Defence Standard 00-970."

BELOW: Texas A&M University Corpus Christi's RS-16 UAS

'GO HOME' FUNCTION

Command and control is a crucial aspect of UAS operations and among the systems that must be 100% understood and reliable before flying starts. BAE Systems uses a hardware-in-the-loop setup for command and control tests, simulating a flying environment on the ground, with the crew at their normal stations and with or without the vehicle's engine running. The mission plan is tested and vehicle behavior assessed, but perhaps most

ABOVE: The RS-16 features an HD video camera, as well as ultraviolet and infrared cameras

LONE STAR UAS CENTER OF EXCELLENCE & INNOVATION

Facilities across the USA are awaiting the conclusion of an FAA UAS test-site selection process that will designate six dedicated test sites tasked with the integration of UAS into national airspace and the provision of regulatory data. Somewhat optimistically, the program is scheduled for completion in 2015. Twenty-five prospective sites submitted proposals by the May 2013 deadline and an FAA decision is expected before 31 December.

Among the contenders, Texas A&M University Corpus Christi is already working extensively with UAS in its Lone Star UAS Center of Excellence & Innovation program. Ron George, senior research development officer with the university's Research, Commercialization & Outreach organization, explains: "The university has a certificate of authorisation [COA] to operate a particular type of unmanned aircraft in a specified section of Texas airspace. We're in south Texas where population is sparse and our airspace is over ranchland, the inter-coastal waterway and Padre Island. It extends up to 3,000ft. We operate a small RS-16 aircraft and we've flown more than 20 missions under our COA. We report all our data to the FAA, so it can be sure we're operating safely, and we also report to all the local ATC towers."

The RS-16 is flown in support of the university's geospatial science program and marine science institute, examining the research potential of UAS sensors. Work is also underway on sense-and-avoid techniques and improving communications and control.

As well as fueling lab research, the RS-16 supports a private sector sensor developer, and a typical mission has many goals, not least keeping the operating crew proficient. The aircraft is flown under visual line of sight rules and, using a chase plane and two control centres, it is increasingly being operated to the limits of the airspace. In doing so it yields data that feeds back into FAA rule making.

Should the Lone Star UAS Center of Excellence & Innovation and its wider proposal team – including around 15 organizations and acting on behalf of the Texas governor's office – be chosen as one of the six test sites, its authorised airspace will be expanded to around 6,100 square miles, for testing a wide range of aircraft and at higher altitudes.

However, Ron George says that even if the test-site decision does not go its way, the Lone Star UAS Center of Excellence & Innovation has already invested heavily in development and will continue to work and expand in what it considers a burgeoning sector, with a new command and control center already underway.

importantly, BAE Systems can analyze failure cases and emergency procedures.

A broken communications link, engine failure and unexpected weather conditions are among the most extreme possibilities, and ensuring that the vehicle behaves in a predictable way is essential. The system's possible failure cases are defined within the mission plan in advance of a flight. Depending on where the operation is being conducted, planned responses to a lost communications link can include the vehicle entering a loiter pattern, climbing in an attempt to obtain a stronger signal, initiating an automatic return to base or diverting to an alternative landing site. All these options will have been fully tested in simulated and operational flight trials.

Rowe-Willcocks remembers BAE Systems' first 'go home' test in Australia: "We deliberately turned the comms link off, as planned, with the aircraft 20 minutes out. It came home on its own, as all the engineers had known it would, but the program managers were delighted as it touched down on the runway."

BAE Systems boasts considerable synthetic training and physical testing facilities, with the latter including wind tunnels, radar cross section pole testing facilities and acoustic chambers. Synthetic capabilities allow end-to-end mission testing with real or simulated equipment, and synthetic material is increasingly replaced as development continues. The facility was originally developed for the battle management testing requirements of the Queen Elizabeth II-class aircraft carriers and has proved ideal for modification to UAS testing as well as for analysis of the human interface.

Paul E Eden is a UK-based writer and editor specializing in the aviation industry

Development on a diet

Smaller, lighter aircraft within the light and very light jet sectors require a fresh approach to aerospace testing, and one that is completed on a much smaller budget

BY JOHN CHALLEN

The very light jet (VLJ) sector has suffered a difficult few years, but is slowly bouncing back to command a greater share of the market. Increased demand is seeing a lot more companies enter the market with new models, each of which demands a development program that delivers on performance, reliability and robustness, but also has one eye on keeping down costs. Quite a challenge for many aviation businesses in the sector, which may not have the resources of more mainstream manufacturers.

As part of a four-year development, Stratos Aircraft has been using the latest testing techniques to bring its 714 to life. Early on, much of the time on the project was spent on aerodynamics, the chief aerodynamicist's work being confirmed and validated in an intensive wind tunnel test program in 2011. Since then, there has been a shift in focus to the aircraft's structure, concentrating on proving the strength of components such as the wing assembly and main fuselage.

The man responsible for the Stratos 714's structure is Richard Abbott of Abbott Aerospace. The airframe design is almost complete, but there is work remaining on the vertical tail and parts of the fuselage. The airframe design is expected to be finished by the end of the year, with project completion expected mid-2014.

The desire to save weight from the aircraft was a key consideration, with a number of specific materials investigated that could ensure not only that weight is kept as low as possible, but also that the necessary structural attributes are maintained. "The 714 airframe is predominantly constructed from carbon fiber prepreg, which is well-proven technology, with numerous aircraft types already certified and thousands in service," explains Abbot. Advantages realized on the 714 program over traditional aircraft with a metal construction include weight savings, improved fatigue characteristics and the ability to produce any shape.

The majority of the aircraft typically consists of individual parts that are bonded and/or mechanically fastened together; however, the pressure vessel is a single co-cured part. "The 714 has a relatively high-pressure differential, and the co-cured pressure vessel reduces weight and simplifies manufacturing," says Abbot.

Prior to the prototype 714 taking to the skies, the airframe will undergo 30 different load tests, confirms Abbot. "During the certification process, several airframes will be dedicated to structures and flight testing to cover all the certification requirements. There will also be a complete airframe used for fatigue testing to prove the airframe's structural integrity based on hours and cycles in service."

Developing the 714 is a shared responsibility between Stratos and a number of other specialists


PHENOM 100

from the aerospace industry. "The landing gear is being designed by landing gear specialists, and the concept is complete and detailed analysis is currently underway," explains Michael Lemaire, CEO of Stratos Aircraft. "Two sets of the gear will be built initially, one for testing and the other for the prototype aircraft."

In addition, Air Management Technologies has been working on environmental control systems, Pacific Precision Products is working on a complete oxygen system, and Composites Universal Group is producing the airplanes' tooling. "The tools for the prototype program are a mix of temporary and permanent tooling," explains Lemaire. "All larger molds are production-quality carbon-fiber tools, and some of the smaller tools are lower-cost tools designed to produce only a small number of parts. These tools will be upgraded to production-quality tools in the next phase of the program." Lemaire confirms that Composites Universal Group is also making the composite parts for the prototype, together with the static test articles.

THE EMBRAER EXPERIENCE

Traditionally concerned with larger jets, Embraer made its move into the VLJ market back in 2005, when work on the design of the cabin commenced – with the help of BMW Group Designworks USA – and names for the company's new, smaller, jets were announced: Phenom 100 and 300.

In terms of development, the 100 was the subject of a relatively short test program, with initial runs on the engine (a Pratt & Whitney PW617F) being made in June 2006, before the first flight of the aircraft just 12 months later.

CESSNA'S STORY

One of the more recognized manufacturers in the jet market, Cessna, has recently completed the first flight of the first production unit of its latest business jet – the Citation M2. According to Michael Thacker, senior vice president of engineering at Cessna, the development journey to the inaugural two-hour flight was relatively straightforward – testament to the company's history in a wide range of aircraft.

"For structural testing, we have a physical test organization that does static and cycle fatigue testing on our products," explains Thacker. "Light jets are certified to FAA Part 23 regulations, so we treated the M2 like we would any other light jet, and put it through the same test process to ensure reliability and performance. Large commercial aircraft are all FAA Part 25-certified and, while there are some different standards, we make sure many processes are common on the structural testing side."

The SVP admits that only composite parts are used on the airplane, for areas such as the fairings and control surfaces; instead the M2 retains a bonded metal construction that is seen on the majority of the Cessna portfolio. Light weight is not an issue on the aircraft, however, nor is performance, thanks to the use of two Williams FJ44 engines, which offer a cruising speed of 460mph.

"There were no new tests on the structural side, but there are elements of the electrical component evaluations that continue to move and advance," says Thacker. "We continue to develop methods and test techniques for high- frequency radiation and lightning effects, and it is part of an ongoing project, to stay ahead of the competition."

BELOW: Testing of the SportJet II is now 80% complete; development has included an engine upgrade from the first iteration of the VLJ

RIGHT: How the final product will appear when the project concludes

VLJ RIP CORD

One of the most important elements of light aircraft is safety – both inside and outside the cockpit. As such, there is a number of systems designed to help prevent accidents, or at least lessen their severity. One company involved in this area is BRS Aviation, a provider of ballistic recovery systems that serve a number of sectors including UAVs, sports aircraft, general aviation and military airplanes.

Effectively like a large parachute, it is a major investment, but essentially seen as a small price to pay. "For certified airplanes, we spend more than US$1m just on an STC [supplemental type certificate] – a certification process that we need to get approval from," explains Boris Popov, founder of BRS Aviation. "In that process we carry out a number of tests, such as in-air deployments, structural analysis, static pull testing, and static deployment on the ground. We also do fuselage testing with anthropomorphic dummies to see what spinal loading they would see."

Previously, Popov says that the development team had to carry out up to 30 tests of the structure, and the canopy on the specific model the system was being fitted to, in order to comply with FAA requirements, but things have changed. "With the Cessna 150, we had to do around 30 tests, but nowadays we've proved we can do testing from a safety standard that the FAA requires, and it now allows us to do comparison and technical analysis on models with similar characteristics – high wing, common gross weight and speed," reveals Popov. "That has been a big factor in offering the product at a more reasonable price than it was being sold at."

For the future, Popov says he is looking at a number of different solutions, such as GPS-steered canopies. "We have been doing some testing on deploying a parachute and having it steered by GPS needs. If you have an area the parachute needs to land in order to drop off supplies, for example, we'll be able to control it by GPS. Future technology will demand a pre-determined GPS coordinate, and a program can be written that steers the canopy into a safe location with no risk to the aircraft or its occupants."

Starting one month after the engine first ran, the 100's wind tunnel test program used a 1:6 scale model of the VLJ. There were three phases of test, the first at the University of Washington's Aeronautical Laboratory (UWAL), before moving to Embraer's homeland of Brazil, at the General Command for Aerospace Technology. The third phase saw evaluations in Russia's Central Aerohydrodynamic Institute (TsAGI). The decision to use these locations was based largely on successful evaluations with previous Embraer jets, according to Henrique Langenegger, senior program manager for the Phenom 100 and 300 jets. "TsAGI wind tunnels have proved to be very precise for the Embraer 170 and 190 aircraft, where results have come within 1% of flight test numbers," he said at the time of the tests. "The Phenom 100 wind tunnel results give us a high degree of confidence that its projected range, maximum speed and field performance will be met."

The program was completed on time, however some early owners experienced problems with the brake-by-wire system, flap computer and air-conditioning unit, suggesting that a little more time and attention to detail was needed in development.

These issues were swiftly resolved, but the experience signaled a re-evaluation of the company's approach to testing. By the time Embraer started working on the larger Legacy 500, testing of all of its products – not just VLJs – had changed dramatically at the Brazil-based company. Based on the experiences on the Phenom 100/300 program, a bespoke engineering office was built for the Legacy 450/500 project, housing 200 engineers from Embraer and its partners. The team worked alongside test pilots, systems/powerplant/avionics/interior/manufacturing engineers and supply chain specialists. As a company that offers, according to Alexandre Figueiredo, VP of ground and flight tests, almost one aircraft in every part of the market, Embraer had to adapt its programs to meet the specific demands of its customers. The company's development phases are now more akin to those of a typical commercial aircraft testing regime, which is helping the overall efficiency of test programs.

"With Legacy 500 we integrated ground and flight test activities more than before," Figueiredo, explains. "We had a full Iron Bird, with the hydraulic system, avionics, electrical system, fuel and air-conditioning being tested on the ground before flying. We are doing Iron Bird and more, typically flying earlier – with the rig as a bigger part of the integration. We have done flight tests with many more airplanes than we are doing now.

"The cost of the test campaign was reduced as we cut the number of

"STARTING ONE MONTH AFTER THE ENGINE FIRST RAN THE 100'S WIND TUNNEL PROGRAM USED A 1:6 SCALE MODEL OF THE VLJ"

Wind tunnel testing at Stratos for the 714

"ONE PRIMARY OBJECTIVE FOR THE SPORTJET TEAM AT THE MOMENT IS TO OPTIMIZE A NEW INTAKE DUCT SYSTEM"

LEFT: The Stratos 714 has a length of just 38ft, take-off on a runway of only 600m, but can still fly at 415kts

BELOW: The test team for the Legacy 500 learned a great deal from the Phenom 100/200 program using broader tests and a more diverse but specialist team

flights that we make, as well as the number of prototype airplanes," Figueiredo continues. "The most important improvement was being able to discover integration and development issues much earlier – before flying the airplane. This meant we could reduce the development cycle because when we discovered an important issue that we needed to act on, we could do it right there, instead of waiting to get the results of the flight test, and work on the relevant components straightaway."

Reducing the number of prototypes was also a key element of working toward a more efficient test program. For Legacy 500, just three test airplanes were used, when normally five would be the norm. A smaller prototype fleet was achieved by more instrumentation being used on the program. "In total we had 40,000 recorded parameters, about five times the number we would normally have," states Figueiredo. "We also increased the flight rate – we typically fly 2,000 hours, but in order to meet all the regulations, we needed to increase it by 40%."

SPORTJET

At the smaller end of the market, the test program for the SportJet II has been long – but with good reason. "We judge a program by how many flight test hours are done in the first calendar month. In the case of SportJet II, we didn't test in the afternoon because the air was too unstable and turbulent, so we were limited to one hour in the morning," explains Bob Bornhofen, founder and CEO of SportJet.

Given the limited time every day, it is fair to say the development program was difficult to schedule. "What we did in that hour depended on what happened the previous day," says Bornhofen. "If we had a landing gear issue – maybe if it wasn't tucking up tight enough (indicated by sensors) – we would check the hydraulics, and then fly again the next day to verify our changes. We didn't want to change too much at one time, especially if the alterations were inter-related. If you have different non-coupled options, one flight could go through three or four fixes.

Although operating on limited resources, the development team for SportJet II – the test phase of which is 80% complete, according to Bornhofen – had the previous SportJet to work from. A lot of lessons were learned from the first aircraft, but one major change has actually seen weight added, as opposed to cut. "We changed the engine from a Williams FJ 33, and now we have a Pratt & Whitney JT15D," explains the SportJet founder. "It was

80	The maximum amount of flight minutes decided by manufacturers for a VLJ that did not need a lavatory
1,000	The minimum length in meters for a VLJ runway
US$4m	The approximate cost of the most expensive VLJ, the Spectrum S.33
US$900,000	The cost of the cheapest, the Maverick SMARTjet
450	The Teal Group's forecast for VLJ deliveries through 2013

done for financial reasons, but adds an extra 200 lb to the aircraft. Obviously we wanted more air going through it, so we've got almost the same plane with a slightly bigger wing because of the extra weight (SportJet II weighs 250 lb more than the original)."

One primary objective for the SportJet team at the moment is to optimize a new intake duct system, says Bornhofen. "We've got a 5ft exhaust block extension, which has to be engineered to meet criteria of exhaust ducts. There might be one more iteration of the ducts and one on the exhaust ducts, he predicts. Even then, however, the development will not be completed – a situation unheard of in a commercial aerospace development. "There will always be tweaks and revisions of the airplane," admits Bornhofen. "No matter what we design, we'll probably change it after the next 15 airplanes – but that is the scenario when you have such a wide range of customers. We've got weekend pilots with 400 hours, and some with 4,000, then commercial pilots, some that do general aviation, and we have to appease all of them." ∎

John Challen is a freelance aviation and automotive journalist

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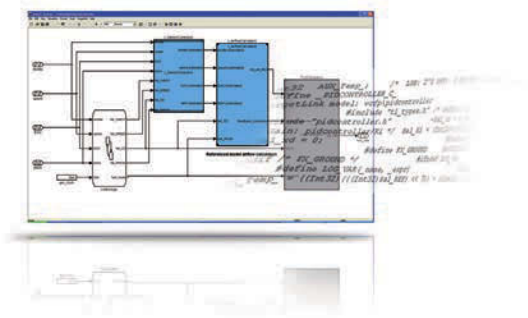

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Sikorsky

Part-time pilots

By 2025 the number of unmanned aerial vehicles in use is predicted to have risen substantially. With new regulations, will they be able to be unmanned at all times or will an OPV be more economically and tactically viable?

BY DAVID OLIVER

The Sikorsky Autonomous Research Aircraft (SARA), an S-76 OPV

The US FAA is predicting that there will be an astonishing 10,000 unmanned aerial vehicles (UAV) by 2017 and 30,000 by 2025. However, due to the emerging new roles envisioned for the UAV and the requirement for many of them to operate in civilian airspace, not all of them will be unmanned all of the time. This is illustrated by the number of aerospace companies developing rotary-wing and fixed-wing optionally piloted vehicles (OPV).

Using a combination of proven airframes and UAV technologies such as flight control systems (FCS) and autonomous GPS waypoint navigation as a starting point for these hybrid aircraft may well prove to be a cost-effective solution for both civil and military applications. These range from surveillance and cargo resupply for the military to research and implementation of UAV integration in unrestricted airspace.

THE EC145 PROGRAM

Eurocopter proved its ability to integrate unmanned flight capabilities into its helicopter family when it revealed its OPV demonstration program earlier this year, using an EC145 medium twin-engined helicopter to fly routes that included deployment of an external sling load and a representative observation mission. The OPV was developed in an internally funded Eurocopter program coordinated by a team at the company's Donauwörth facility in Germany. A series of 20 short initial flight tests with a monitoring pilot aboard the EC145 were flown from Donauwörth before the series of three unmanned flights were conducted at the French Air Force base in Istres in April.

The unmanned demonstrations used a four-dimensional flight plan that was uploaded to the helicopter, with its starting and completion points situated on the Istres Runway 15/33. After an automatic take-off, the EC145 flew the circuit via multiple pre-programmed waypoints, during which the helicopter performed a mid-route hover to deploy a load from the external sling. It continued on a return route segment representing a typical observation mission, followed by an automatic landing.

For delivery of the external load, the helicopter entered a planned hover – enabling the ground station controller to provide flight control inputs in orienting the EC145 over the drop point. The ground controller then transmitted a command to release the load once the helicopter and load were correctly positioned. The system included an automatic hover-to-land capability in case of major system failure.

The EC145 testbed helicopter was fitted with an enhanced dual-duplex four-axis automatic flight control system (AFCS) and the latest navigation systems. In addition, the helicopter is fitted with a 70 lb (32kg) plug-in OPV avionics rack and datalink subsystems in its cabin behind the pilot seats.

A forward-pointing onboard camera plus an external gimbaled camera on the helicopter provided the ground-based pilot's eye view during the EC145's unmanned flights for infrared and daylight mission imaging.

Eurocopter's head of EC145 commercial programs, Romed Schweizer, told *Aerospace Testing International* that predicted applications for the OPV included cargo supply and disaster surveillance and support, and that the company was discussing customer requirements prior to marketing the capability.

The OPV may be offered by EADS North America as a contender for the US Army's Armed Aerial Scout (AAS) competition.

SIKORSKY PROGRAM

Working to a similar target, Sikorsky Aircraft has also unveiled a major research program designated Matrix Technology to develop test and field systems to improve the capability, reliability and safety of flight of optionally piloted helicopters.

"VTOL pilots will increasingly become mission managers, either on the aircraft or when monitoring from the ground via datalink, because they will feel comfortable letting the aircraft fly itself," said Mark Miller, Sikorsky's vice president of Research and Engineering.

An S-76 commercial helicopter with FBW controls, called the Sikorsky Autonomous Research Aircraft (SARA), will be used to enable rapid flight testing of software and hardware, including multispectral sensors. When not in flight, SARA can be configured as its own simulator to develop and test autonomy software and hardware.

At the end of 2014, Sikorsky will test and refine the software applications and complex algorithms to demonstrate safe flight in obstacle rich environments, shipboard and brownout condition landings, and cargo transport using an optionally piloted JUH-60A Rotorcraft Aircrew Systems Concept Airborne Laboratory (RASCAL) Black Hawk helicopter to develop optionally manned aircraft and manned/unmanned teaming (MUM-T).

TMUAS PROGRAM

Playing catch-up in the fielding of a capable maritime UAV, the UK's MoD is looking into equipping the Royal Navy with its first Tactical Maritime Unmanned Air System (TMUAS), announcing in July 2013 that it has contracted AgustaWestland to develop a capability concept demonstrator (CCD) program to explore the prospects of utilizing a rotary-wing unmanned aerial system (RWUAS), inspired by the US Navy's MQ-8B Fire Scout.

AgustaWestland is planning to use the optionally manned variant

Eurocopter

ABOVE: Inside the unmanned EC145 during its flight demonstration

"VTOL PILOTS WILL INCREASINGLY BECOME MISSION MANAGERS, EITHER ON THE AIRCRAFT OR WHEN MONITORING FROM THE GROUND"

PELICAN BRIEF

The US Center for Interdisciplinary Remotely-Piloted Aircraft Studies (CIRPAS) is a research center at the Naval Postgraduate School in Monterey, California.

The Center operates manned, instrumented research aircraft in support of the science community. The Pelican is a highly-modified and adapted Cessna 337, O2, Skymaster originally developed by the Office of Naval Research for low-altitude, long-endurance atmospheric and oceanographic sampling.

Through an SBIR program between Zivko Aeronautics and GA, the air vehicle was configured to operate as a true Predator UAV surrogate for the US Navy.

ABOVE: The ground station where controllers enter flight commands to the EC145 OPV

of the PZL-Swidnik SW-4 Solo helicopter as a basis of the CCD to develop and test the system and its sensors by mid-2015, in what, according a statement from an MoD spokesperson, "will inform future maritime UAS requirements, potentially leading to an acquisition program in the second decade".

CENTAUR PROGRAM

Leading fixed-wing OPV development is Aurora Flight Sciences, which is offering its Centaur Optionally Piloted Aircraft (OPA) to customers as a capable cost-effective intelligence, surveillance and reconnaissance (ISR) data gathering and research platform. The Centaur OPA operates in a manned or unmanned configuration and provides access to all airspace with up to 24 hours of endurance and reduced logistics requirements.

ABOVE: Aurora Flight Sciences Centaur OPA based on the Austrian Diamond DA42NG

BELOW: Eurocopter's EC146 OPV completed a test program at Istres earlier this year

Centaur is based on the incredibly versatile Diamond Aircraft DA42MNG Twin Star, a four-seat twin diesel-engined aircraft of composite construction that has made Austria a leading aerospace manufacturer, having sold over 500 DA42s in less than a decade.

Capable of flying from Europe to North America non-stop carrying an 880 lb (400kg) payload, Twin Star has been adopted by more than a dozen air forces as an ISR aircraft, while unmanned and optionally manned aircraft variants have been developed to take full advantage of its 24-hour endurance.

880	The payload weight in pounds that can be carried by the Twin Star ISR aircraft
165kts	The maximum design speed of the Pelican developed by CIRPAS
US$6m	The estimated cost to US taxpayers of training a fighter pilot for the USAF
2,000	Maximum range (nautical miles) of the Centaur with a 200 lb payload

With avionics integrated by Rockwell Collins, the Centaur OPA system is compatible with NATO STANAG 4586, the standard for other existing unmanned systems, and is the world's first OPA to retain its FAA and EASA Normal Category Airworthiness Certification in the manned flight mode with the ability to provide its full functionality for unmanned flight. The conversion between manned and unmanned flight modes takes only four hours. Centaur is able to carry its own ground control station, making it the world's first self-deployable unmanned aircraft system.

The DA42 Optional Piloted Aircraft, Long Range (OPALE), developed in conjunction with Rheinmetall Defense Electronics, features a nose-mounted gyro-stabilized UOMZ SON 112 system; microwave LOS broadband downlink; satellite uplink for command, control and payload data; and variety of task-specific sensors. It has been used in several NATO exercises. During contractor test flights, the OPALE has been used to test the reconnaissance, wireless data transmission and live videos of the Rheinmetall KZO and IAI Harop UAVs for the German armed forces.

As a pure research platform, Centaur has been sold to Armasuisse, the official procurement agency of the Swiss Department of Defence, which has its own flight test center and will use Centaur as a flying test bed for new sensors and sense-and-avoid equipment required to operate unmanned aircraft systems (UAS) in the entire Swiss National Air Space. Based in Emmen, Switzerland, Centaur will only be operated by Armasuisse and it will not become an operational system of the Swiss Air Force.

"Reliability, safety, efficiency and low noise are essential features of Centaur," said Armasuisse program manager Roland Ledermann. "This hybrid aircraft is uniquely suited to the needs of customers who seek the advantages

RIGHT: **At the sharp end of optionally piloted development is an OPA variant of the Saab Gripen fighter**

David Oliver)

"ADAPTING THE GRIPEN SO THAT IT CAN BE FLOWN BY REMOTE CONTROL REPRESENTS AN ATTRACTIVE OPTION TO CASH-STRAPPED GOVERNMENTS"

of a remotely piloted aircraft but must also operate in crowded skies."

Following the installation of specialist equipment and its integration with the aircraft's ground control station, unmanned flight trials commenced in April of this year.

In addition to its sale to Switzerland, Centaur OPA has been selected for the US Navy's Autonomous Aerial Cargo/Utility Systems (AACUS) program to explore advanced autonomous capabilities for reliable resupply/retrograde and, in the long term, casualty evacuation by a UAV, and by DARPA and Raytheon for the Persistent Close Air Support (PCAS) program.

BELOW: **Armasuisse's Centaur is being used to test UAV integration in non-segregated Swiss airspace**

Armasuisse

SAAB PROGRAM

Among the potential developments of the Saab Gripen E fourth-generation multirole fighter announced at this year's Paris Air Show was an optionally manned version. According to Saab CEO Håkan Buskhe, "Adapting the Gripen so that it can be flown by remote control represents an attractive option to cash-strapped governments thinking about their next-generation combat aircraft. So-called 'optionally piloted' fighters could fly in formation accompanied by one or two piloted planes. The Saab concept will also reduce the cost of adding a new type of aircraft to air force fleets. If you create a new platform for everything you do, the logistics footprint cost will kill your possibility to fly."

The program to adapt the Gripen design to unmanned operation could see results relatively quickly. "It's not such a big step," Buskhe says, although there will be an extra cost that Saab will recover from sales.

Following 10 years' experience of developing UASs, including the Sharc, Skeldar V-200 and, most recently, the European Neuron experimental UCAV, an optionally piloted Gripen is on Saab's horizon. Saab senior executive vice president, head of aeronautics Lennart Sindahl, told *Air Traffic Technology International* that a future Optionally Manned Gripen was prompted by the Swedish Air Force's experience during Operation Unified Protector over Libya in 2011. The primary role of the Swedish Gripens was reconnaissance, but their reach was limited by the range of NATO's combat search and rescue (CSAR) assets. This meant that large areas of the country, which is twice the size of France, could not be reached by manned coalition aerial reconnaissance aircraft, but an unmanned aircraft would have no such constraints. The aircraft could overfly countries en route to a conflict zone with a pilot aboard before being operated as an unmanned aircraft.

Sindahl said that development would begin with altitude hold and waypoint navigation, already fitted in the Gripen NG, followed by basic air traffic maneuvers, take-off and landing, formation with manned leader aircraft, aerobatic maneuvers, tactical turns, and BVR combat maneuvers that include crank, beam and pump.

This is a Saab initiative and will have to wait for a prospective customer before the concept is fully developed, but according to Sindahl, the future battlespace will require close cooperation between manned and unmanned systems. In the future, all options are open. ∎

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

Next giant leap...

The largest rocket ever designed by NASA recently passed a key stage in its wind tunnel tests, with a launch set for 2017. *Aerospace Testing* speaks to the lead aerodynamic test engineer for the program, which will eventually see a human step onto the surface of Mars

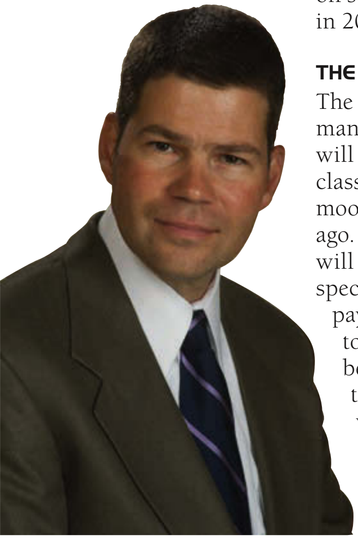
BY GEORGE COUPE

RIGHT: **The 4% scale model of the SLS in NASA's transonic wind tunnel at Langley Research Center, Virginia**

BELOW: **John Blevins, lead engineer for aerodynamics on NASA's Space Launch System**

The cause of manned space exploration took another crucial step forward in November with the completion of a series of aerodynamic tests on the scale models of what will eventually become the largest and most powerful rocket the world has ever seen.

John Blevins, the lead engineer for aerodynamics on NASA's Space Launch System (SLS), told *Aerospace Testing International* that a major part of his work was now "virtually complete". The results of the static-aerodynamic wind tunnel tests, or force and moment testing, are a major addition to the progress the project has made this year. After passing the crucial preliminary design review in July, and with the finalization of the outer mold line (OML), the SLS program is on schedule for its a first test launch in 2017.



THE SLS PROGRAM

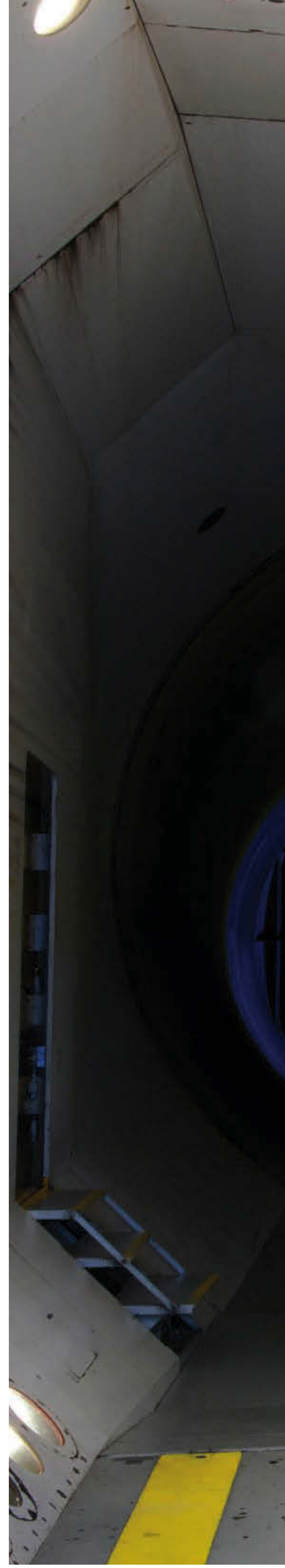
The SLS is key to NASA's plans for the manned exploration of deep space; it will be the agency's first exploration-class rocket since the Saturn V of the moon missions, more than 40 years ago. The new heavy-lift launch vehicle will be capable, in a variety of mission-specific configurations, of lifting payloads ranging from 70-130 metric tons into low Earth orbit and beyond. One such payload will be the Orion multipurpose crew vehicle (MPCV), which will carry humans to deep-space destinations including near-Earth asteroids, Lagrange points, the moon and ultimately to Mars.

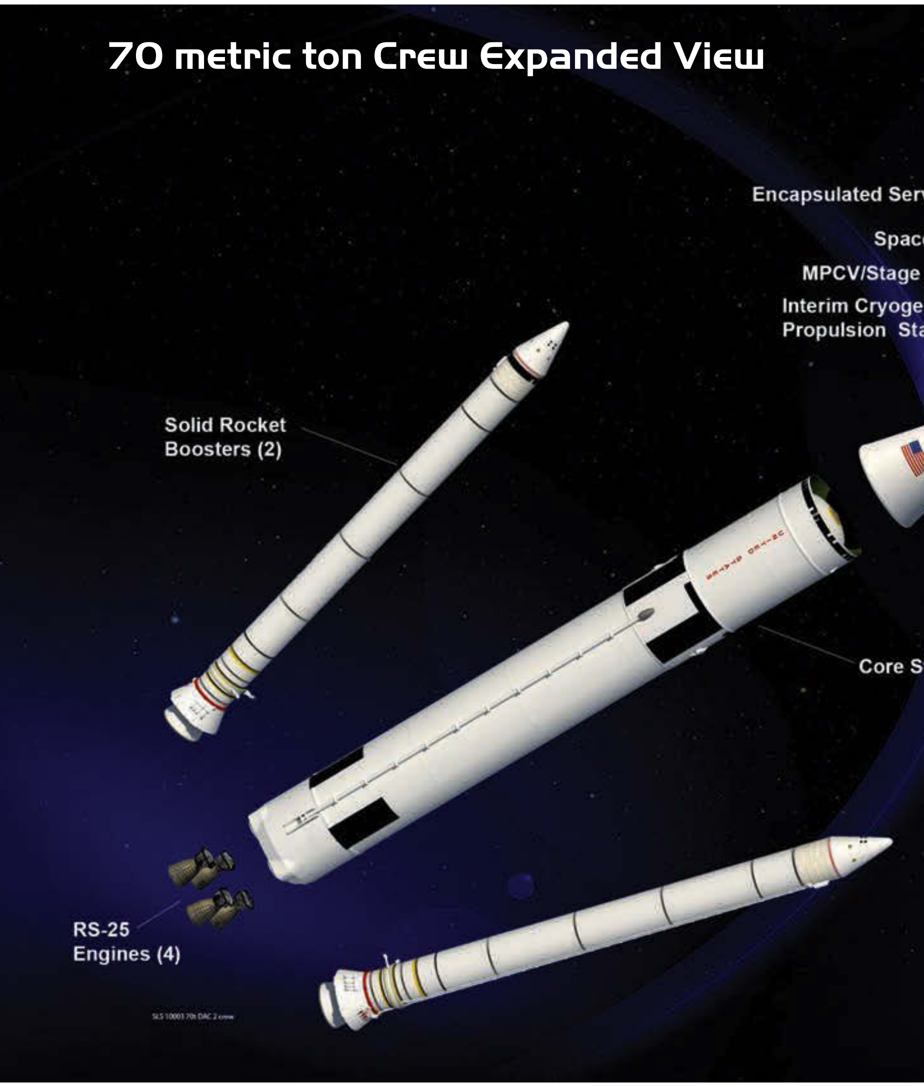
For Exploration Mission 1, set for 2017, the initial configuration will include the 200ft core stage, developed by Boeing, equipped with four RS-25 Shuttle main engines, and two five-segment solid rocket boosters, built by ATK. On top of the core stage will be the Launch Vehicle Adapter, and then the Interim Cryogenic Propulsion stage, which will sit beneath an uncrewed Orion MPCV.

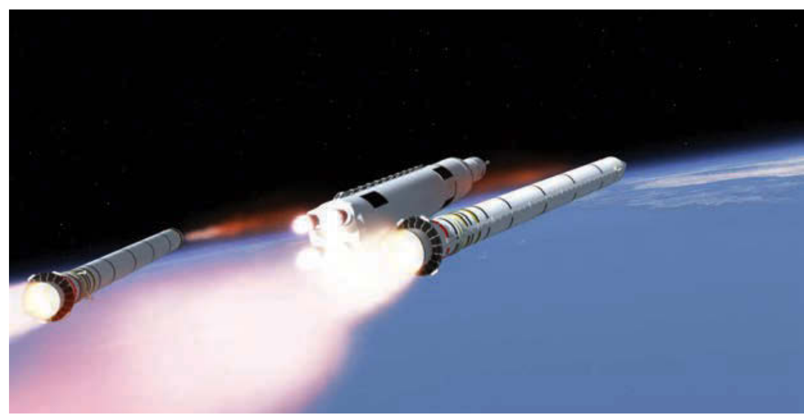
The mission is to place the empty crew vehicle in an orbit around the moon to test the performance of the integrated system. Exploration Mission 2, scheduled for 2021, will do the same, but with a crew of up to four astronauts.

The fully evolved 130 metric ton configuration will be the most powerful launch vehicle in history, according to NASA. It will stand 384ft tall and generate 9,200,000 lb of thrust at lift-off. It will use the same core stage, but will require advanced, high-acceleration rocket boosters, for which NASA is gathering industry proposals. This version of the rocket will also include an upper stage, also built by Boeing, to provide the additional power needed to travel to deep space.

But what exactly is going to happen when the engines are lit for the first time, and the monster rocket lifts off and accelerates to Mach 5 as it climbs through the atmosphere? How will the SLS actually respond to the massive loadings and vibrations generated at those speeds? Finding the answers to that is the responsibility of Blevins' team at the Marshall Spaceflight Center in Huntsville, Alabama.







TOP: SLS breakaway graphic

ABOVE: Solid rocket boosters detach from the core stage of the SLS. The aerodynamics of their re-entry must also be tested

THE TESTING HAS BEGUN

Marshall is NASA's lead design center for rockets; the aerodynamics team consists of experts from across the agency and draws on their experience of former programs, such as the Shuttle. This expertise and the unique facilities at NASA mean other aircraft and rocket manufacturers regularly undertake part of their aerodynamic testing with the agency and also consult Blevins' team.

Describing his work to date on the SLS, Blevins breaks the program into two halves: static aerodynamic tests and unsteady aerodynamic – or buffet – testing.

"When a lot of people visualize wind tunnel testing, they think of force and moment testing, or what we call static aerodynamic testing. That is indeed a big part of what we do, and we break it down by phase of flight," says Blevins. Using the various wind tunnel facilities around the agency, including Marshall, the Langley Research Center and the Ames Research Center tunnels, the team has simulated the changing conditions during all stages of the mission.

The first is the ground wind loads on the vehicle, even those experienced when on the mobile launcher and moving to the pad. The next phase is lift-off – a unique environment due to the high angles of attack, caused by ground winds traversing the vehicle at the very beginning of flight, and is a condition that is reproduced in the wind tunnel. The next phase is ascent, during which the vehicle accelerates to Mach 5, producing a range of extreme forces on the rocket.

Among the other events to occur during ascent is separation of the boosters and then of the core stage from the crew or cargo capsule. This happens at highly supersonic speeds and NASA must manage the disposal of these components, which requires an understanding of their aerodynamics on re-entry.

"For every phase of flight, ground roll-out, lift off, ascent, separations and other orientations, we do wind tunnel testing for the aerodynamics," says Blevins. "We support the data with select computational fluid dynamics, but generally testing is our mainstay for that static aero portion and most of that testing has been completed."

After the OML was confirmed earlier this year, the team updated the models and did some additional tests, culminating in a large model test.

"So we have finished the ascent flight static aero testing, with the exception that we do reserve the right to go back and do a transonic test at the end of this phase of flight. It's the one phase of flight that is more

BALANCING CFD AND WIND TRIALS

Wind tunnel testing is a crucial part of rocket development. When the Germans built the V2 to attack London, they used a wind tunnel. "I don't know of a single rocket, including the commercial ones, many of which have come and tested here, that have flown without wind tunnel testing," says Blevins.

Over time, advances in technologies – computational fluid dynamics (CFD), for example – have changed the way these facilities are used. "We can accurately predict the static aerodynamic characteristics of the vehicle very well with CFD," explains Blevins, "but what we haven't achieved is cost effectiveness. It's actually cheaper for me to build a reasonably sized model and go to a wind tunnel and test it for three weeks. But this does change our thinking, because what we will do is analyze some critical validation points in CFD."

challenging for control due to the shocks moving and so forth. But otherwise our static aero testing is virtually complete."

AERO-ACOUSTICS

Alongside the static aerodynamic tests, the rocket is also subjected to a regime of aero-acoustic tests, otherwise known as the unsteady aerodynamic tests, which at this stage are not nearly so complete.

"The program includes the same phases of flight and is focused on the engine-driven acoustics. Those tests are longer lead items and require more instrumentation. We are about 50% through that test program," explains Blevins.

The tests focus initially on lift-off, specifically the moment when the core stage liquid engines are lit, followed by the ignition of the rocket boosters, which is when the rocket lifts away. "This produces an aero-acoustic environment all of its own," says Blevins, as part of that energy is reflected back at the rocket by the launch pad. These tests are conducted in the open with scaled-down versions of the engines.

The rocket experiences another period of highly unsteady forces during ascent, as it approaches Mach 1 and then breaks through the sound barrier. "This is really the only other phase that has any design issues. Within it is the transonic phase, which generally characterizes environments people call buffet," says Blevins.

The transition from subsonic to supersonic is recreated in the wind tunnel with a highly sophisticated model, the largest of its kind ever built by NASA, equipped with 360 unsteady pressure microphones. It is subjected to simulated acceleration from Mach 0.7 to Mach 1.2.

"This is our largest integrated model, a 4% model. You'll have to indulge me, but it's very beautiful," confesses Blevins. By comparison, the models used in the static tests are very simple, he adds. "These only have a balance embedded in them and are pinned so that you can measure the six degrees of freedom. But for the unsteady tests, the models will usually have a main strut that is load-bearing and a 'wagon-wheel' design spiraling off at various stations of the rocket. We attach outer panels to that, and the outer panels will carry the transducers and amplifiers."

The transducers measure the unsteady airflow on the surface of the model, which applies rapidly changing forces to the vehicle during the transonic phase of flight.

Manufacturers have their own wind tunnel facilities, but none are capable of this type of unsteady aerodynamic test, which is crucial in the development of many types of aircraft, from passenger jets that fly into the transonic range and most rotor aircraft. As such, they will regularly use the NASA technology and expertise. Indeed, Blevins says the wind tunnels now operate as production facilities. His team are the experts when it comes to rocket development and will advise on other rocket projects.

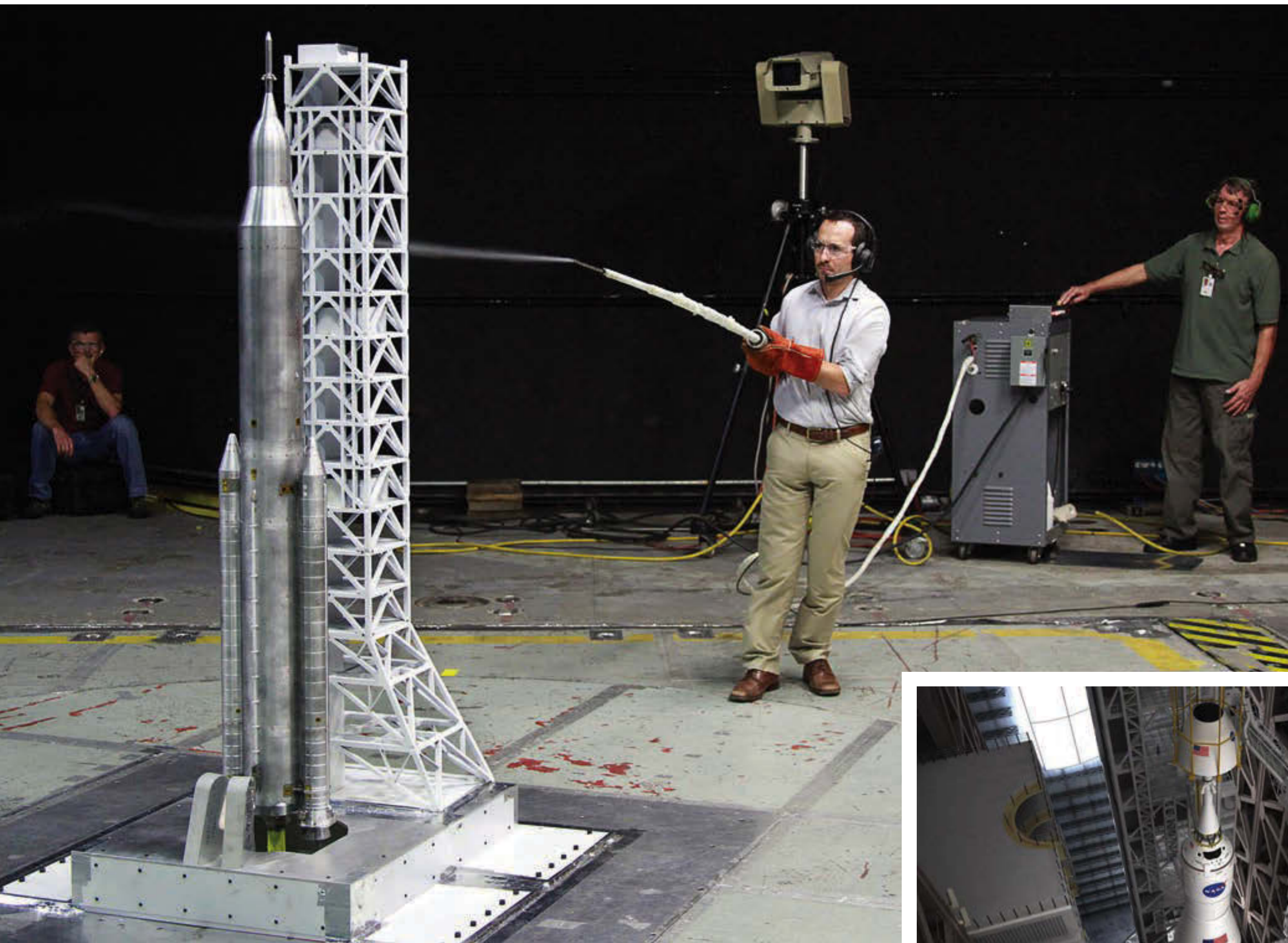
NASA achieves the unsteady aerodynamic tests through a technique that accurately simulates the viscous effects, or forces, created by the air on the surface of the rocket at transonic speeds.

This is done by using a high-density gas in the wind tunnel to match the Reynolds number of the test model with that of the actual rocket. The Reynolds number is used to determine the similarity between two cases of fluid dynamics at different scales.

"When we run the transonic tests, we are unique among facilities because we change the working fluid of the transonic wind tunnel at Langley to Argon 34a, instead of air, so that we can match the Reynolds number,"

LEFT: SLS lifts off with the Orion crew vehicle. This phase of flight creates a unique aero-acoustic environment

8,400,000	Pounds in thrust needed at the moment of lift-off
20%	The extra thrust generated on take-off by the larger second configuration versus Saturn V
40	The number of years that a liquid hydrogen/oxygen rocket has been developed to carry humans
250ft	The height of the core stage rocket that will be fed by the boosters
6,500,000	The weight in pounds of the SLS second configuration



LEFT: **Engineers simulate changing ground wind conditions on a large-scale model of the SLS**

ABOVE: **Assembly of the 70 metric ton configuration of the SLS. The rocket will eventually carry a payload of up to 130 metric tons**

explains Blevins. "When you are looking at the boundary layer effect, if you are looking at the fluid flow that is right on the surface, the slower you get, the more the viscous forces on the vehicle matter. Unsteady aerodynamics is a function of 'compressibility', which is the Mach number, but it is also a function of the boundary layer and the viscous effects."

USING THE DATA

The data from the static aerodynamic tests is used for navigation and control purposes, for example to determine how to respond to changing conditions such as a wind gust, which might change the angle of attack by one or two degrees. In those circumstances the rocket nozzle will be gimbaled to account for it.

"The guy who is designing the control for how to address the nozzle needs to know those forces and moments, and what the center of pressure of that rocket is in order to make that correction," notes Blevins.

The unsteady aerodynamic data is used to answer weighty questions of load. For example, will the rocket survive the violent shaking it will receive, right down to its last bolt? "These are both local and integrated vehicle loads, what people call the buffet. The unsteady pressure that you realize on the vehicle is transmitted to all the structures and parts of the vehicle."

Among these parts are the attachment points between the solid rocket boosters and the core stage. It has been reported that canted nose cones are under consideration for the boosters to reduce these effects. But Blevins is clear that so far none of the configurations to be tested have included the Ariane-style booster caps: "Different companies propose a lot of different things. We evaluate all kinds of designs that are within and without the purview of SLS. Every program looks at different things, but on the 2017 flight and the 2021 flight there will be no canted nose caps."

Blevins says that for 10,000 datapoints in the wind tunnel, he will do 300 in CFD. This has led to a small reduction in the use of wind tunnel testing for static aerodynamic environments, but CFD was at least two orders of magnitude away from being able to replace those tests altogether. Unsteady aerodynamic testing with CFD is a different story. "We simply cannot calculate those environments. For one, there is just not enough computational space to do it.

"But what has really improved are the electronics and the ability to put more sensors on board and more channels in our wind tunnel models, and to run them for longer durations and get more accurate results for each Mach number."

So far, then, the SLS has been making steady progress through its preflight paces, with "no major problems or surprises", says Blevins. There have been no heroics, he insists, no pushing of the boundaries, everything is just much bigger than before – bigger models, more tests and much more data to deal with. But then we must remember that, ultimately, this is all about the big one – putting a human being on Mars. ∎

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

Fly and report

The US Army Aviation Flight Test Directorate gives program managers and other paying customers independent test services to define the true capabilities of their aircraft and systems

BY FRANK COLUCCI

AFTD was part of the combined government/industry test team for the Block III Apache Longbow and now flies an on-loan AH-64E Guardian

As part of the US Army Redstone Test Center (RTC) outside Huntsville, Alabama, the Aviation Flight Test Directorate (AFTD) flies a range of aircraft and aviation systems to document safety, performance and reliability.

AFTD pilots last year logged more than 5,500 flight hours in some 2,000 test events, most on behalf of acquisition managers in the co-located Program Executive Office, Aviation. This summer, they began development testing of the OH-58F cockpit and sensor upgrade (CASUP) of the Kiowa Warrior.

Other ongoing efforts include test-flying technology development models of competing common infrared countermeasures (CIRCM) systems for the project manager, aircraft survivability equipment. AFTD generates final reports for its paying customers, according to chief aviation engineer Carvil Chalk. "There are some instrumentation development projects funded from other, separate funding, but predominantly tasks come from Program Executive Office, Aviation." He adds, "We do conduct select projects for commercial test entities, test capabilities that are unique to our organization and not available in the commercial realm."

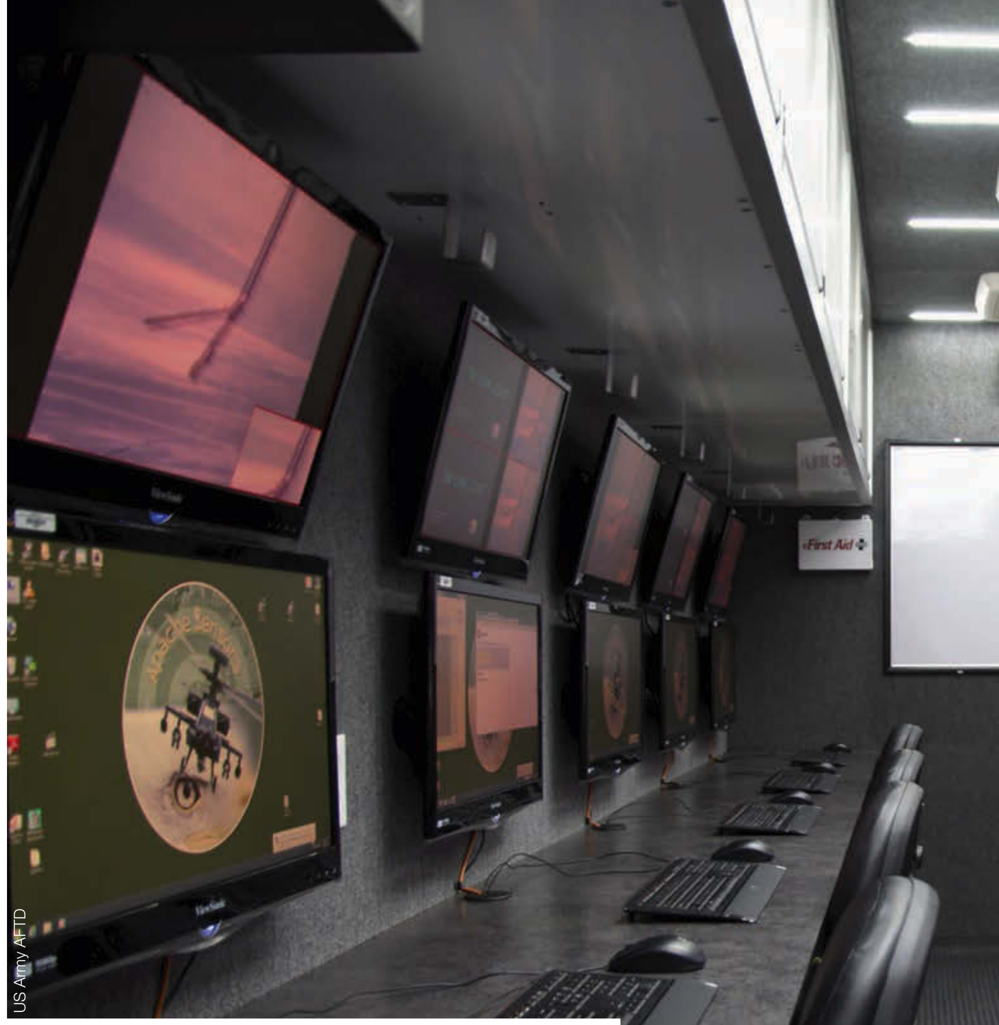
AFTD tested the Iraqi Armed Bell 407 for the Armed Scout Helicopter project office and fly-by-wire flight controls on the UH-60M upgrade for the project manager of utility helicopters. The directorate occasionally takes assignments from other US armed services and industry customers. In 2010, Redstone pilots flew a US Army Black Hawk on a 50:50 mix of JP-8 and coal-derived fuel for a US Air Force alternative fuel demonstration. AFTD personnel and aircraft also supported government and contractor testing on the BAE advanced threat infrared countermeasures (ATIRCM) suite.

ENGINEERING TECHNIQUES

In every case, AFTD provides independent measures of technical performance and system safety using established engineering test techniques and data analysis methods. Directorate engineers and pilots, for example, formulated the test program for the new sensor and avionics architecture integrated on the veteran Kiowa Warrior armed scout helicopter. The OH-58F/KW CASUP test and evaluation masterplan, detailed system specification and airworthiness qualification plan, plus historical flight test reports and methodologies, are all used to schedule and score test events.

To support the test program, the Kiowa Warrior product manager first gave the Redstone testers a risk reduction/structural loads aircraft with the systems of the current OH-58D and the airframe changes incorporated in the OH-58F, including structures to support a new nose-mounted sensor. The risk-reduction helicopter will conduct a flight load survey and expand the flight test envelope for two OH-58F/CASUP engineering and manufacturing development and demonstration helicopters with OH-58F systems, and the four

Aviation Flight Test Directorate



ABOVE: AFTD pilots completed fly-by-wire flight control development on the UH-60M upgrade at the Sikorsky flight test center near West Palm Beach, Florida

RIGHT MAIN: AFTD and PM Apache developed the Mobile Apache Sensors Telemetry Trailer to test AH-64 sensors in different environments away from specific test ranges

RIGHT INSET: AFTD used a permanently assigned CH-47D to test the advanced threat infrared countermeasures system

subsequent production qualification aircraft used for development testing.

OH-58F plans call for about 450 hours of development testing, including 300 hours in the engineering manufacturing development phase, most to be flown at RTC, but with some testing at Eglin Air Force Base, Florida. Another 150 hours in the production development phase will be flown by AFTD pilots primarily at RTC, with some testing at Yuma Proving Grounds, Arizona; Patuxent River, Maryland; and Eglin.

TESTING CENTER

RTC falls under the US Army Test and Evaluation Command and AFTD shares ranges and facilities with RTC systems engineering, technology, missile and sensors, and environmental component and test directorates. RTC last year added a new climatic multichamber test facility, aircraft parking area, aviation parts storage and other facilities. AFTD itself occupies a new rotary-wing center with workshops, offices and hangar space for a mixed helicopter fleet.

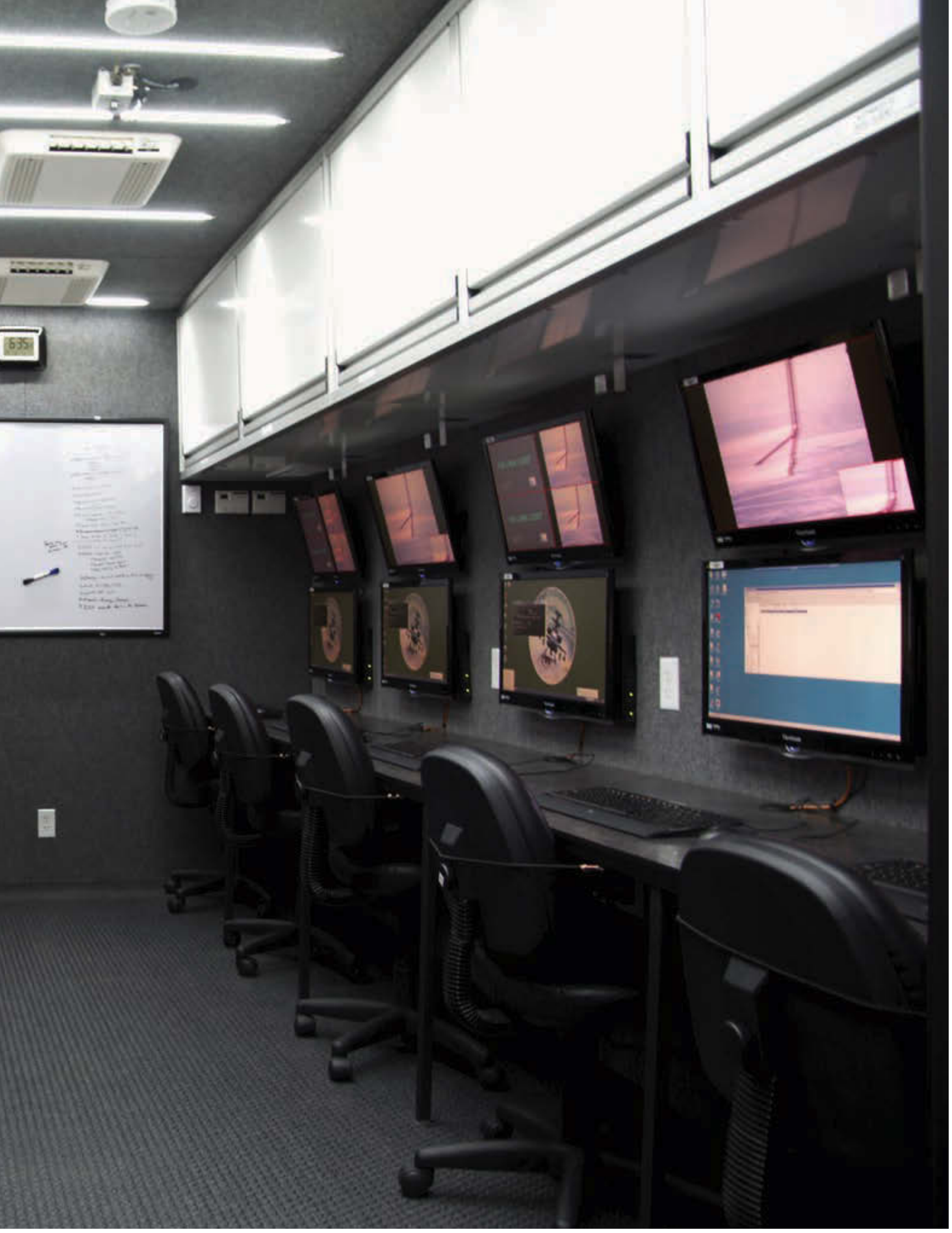
Under congressionally mandated base realignment and closure actions, AFTD consolidated flight testing once divided between Redstone and Fort Rucker, Alabama, by the previous Army Aviation Technical Test Center. It finished merging the army flight test activities at RTC in 2012. AFTD maintains 55 to 60 aircraft at a time at Redstone, and last year provided more than 350,000 maintenance man-hours for the mixed fleet.

The directorate has at least one of each US Army design-series, either assigned permanently to the aviation unit or on loan from the specific program manager. It currently flies an AH-64E Guardian on loan from the attack helicopter project manager. This July, AFTD took delivery of three new UH-72A Lakotas from the product office for light utility helicopters, aircraft permanently assigned for test and general support missions. AFTD does not operate the MQ-1C Gray Eagle unmanned aircraft system (UAS) now teamed with the AH-64E, but it partnered with the PM UAS Rapid Integration and Acceptance Center at Dugway Proving, Utah, to provide independent government oversight and verify system safety for the Gray Eagle Quick Reaction Capability and UAS production program.

FLEXIBILITY

Aircraft directly assigned to AFTD give the testers added flexibility. For example, the CH-47D Chinook used to test the common missile warning system and ATIRCM is assigned directly to the testers. Test managers need not coordinate its use with the project manager for cargo helicopters. The AFTD Chinook flew the laser-based ATIRCM against captive missiles on the White Sands Missile Range sled track.

The Redstone testers also still fly a one-of-a-kind JCH-47D with the helicopter icing spray system (HISS) to test ice protection technologies on aircraft trailing in formation, usually in winter around Duluth, Minnesota. The HISS entered service on a CH-47C in 1973 and has since been used to test anti-icing systems on different aircraft, including commercial Sikorsky S-92 and AgustaWestland AW139 helicopters. PEO-STRI (the Army Program Executive Office Simulation, Training and Instrumentation) plans to replace the spray system in 2016 with an objective HISS (OHISS) palletized to fly on any new CH-47F. The Battelle research and development organization is developing a 2,000-gallon OHISS with improved droplet and cloud control, and expects to fly the new spray rig in early 2014, with acceptance testing in 2015. Better



"A NEW TEST CONTROL CENTER ENABLES AFTD ENGINEERS ON THE GROUND TO TRACK AND MONITOR TELEMETRY FROM TWO FLIGHT TESTS SIMULTANEOUSLY"

spray control will eliminate the fixed-wing C-12 aircraft currently required to calibrate the icing cloud.

AFTD technicians routinely develop and install their own aircraft instrumentation. Some of the more complex instrument suites today collect three to four times the number of parameters collected by previous testing hardware. For the OH-58F test program, AFTD developed a patent-pending wireless sensor package to collect rotor blade and drivetrain data without traditional slip rings and associated harnesses. Without slip rings to seize, the wireless system enhances test safety.

A new Redstone Flight Test Control Center, finished last year, enables AFTD engineers on the ground to track and monitor telemetry from two flight tests simultaneously. The directorate also runs comprehensive test programs away from RTC. The Special Operations MH-60M with common

KIOWA WARRIOR DELTA TO FOX

Digitized, armed and otherwise modernized in stages, the Bell Kiowa Warrior became the most heavily used combat helicopter in the US Army. OH-58Ds in Afghanistan and Iraq averaged 75 flight hours per aircraft per month, with surges to 110 hours a month – five times peacetime utilization – with about 85% availability. The OH-58F cockpit and sensor upgrade (CASUP) aims to improve reliability and cut support costs of the veteran scout with a new nose-mounted sensor and the latest iteration of the Honeywell cockpit display system, CDS-4. The OH-58F CASUP aims to keep 368 Kiowa Warriors in the US Army beyond 2025.

The CASUP hardware integrator is the US Army Aviation and Missile Research Development and Engineering Center (AMRDEC) Prototype Integration Facility at Redstone Arsenal, Alabama. Schedules call for an OH-58F 'first unit equipped' by September 2016, with initial operational capability in 2017. Redstone engineers are working with Corpus Christ Army Depot (CCAD) in Texas to finalize production conversion plans. CCAD full-rate production deliveries of 368 OH-58Fs should stretch through 2025.

The Raytheon common sensor payload (CSP) under the OH-58F nose replaces the distinctive mast-mounted sight (MMS) of today's Kiowa Warrior. Without the dampening effects of the MMS, the OH-58F fuselage needs new side and transverse beams to preserve structural life. New, higher landing gear provides more ground clearance for the nose-mounted sensors. The CSP sensor gimbal and wiring harnesses shaved 160 lb from the first engineering manufacturing development and demonstration aircraft (EMDD-1) – the equivalent of 30-40 minutes of fuel, or a Hellfire missile plus three more rockets.

In support of the OH-58F design and test effort, AMRDEC Aeroflightdynamics Directorate engineers at Langley Research Center, Virginia, ran wind tunnel tests of a 37.7% scale model Kiowa Warrior with the CSP to quantify OH-58F drag reductions.

The powered scale model was sized to fit Langley's 14 x 22ft wind tunnel. The outer mold line of the model was developed using a laser scan of an actual OH-58D aircraft carried out by the Redstone Prototype Integration Facility.

More than 100 configurations were tested to provide a detailed drag breakdown of the OH-58F with different weapons loads, aerodynamic interactions and potential drag reduction changes, and to validate computational fluid dynamics tools.

The accuracy of the drag measures was impossible to match with actual flight testing.

US Army AFTD

ABOVE: AFTD pilots have begun development testing of the OH-58F cockpit and sensor upgrade at Redstone Test Center – a wireless instrumentation system collects rotor and drivetrain data during testing

avionics architecture system cockpit, YT-706-GE-700 engines, APN-174B multimode radar and other unique mission equipment, underwent testing at the Lexington Blue Grass Army Depot in Kentucky, where the aircraft was integrated.

M-TADS

Based on a telemetry trailer built for the Special Operations program, AFTD engineers and the Apache project office integrated a Mobile Apache Sensors Telemetry Trailer to test AH-64 sensors in different environments away from the usual test ranges. The trailer was used in 2012 to test the Lockheed Martin Modernized Target Acquisition Designation Sight (M-TADS) in the high Colorado Rockies, humid Fort Rucker, and Arizona's dry Yuma Proving Ground. Trailer workstations enabled 10 AFTD and/or contractor engineers to see real-time data from the test aircraft, including M-TADS, M-PNVS (modified pilot night vision sensor), or Longbow radar displays selected by the pilot. Engineers in the trailer could also access any parameter on the aircraft databus, including data unavailable to the Apache pilots.

The telemetry trailer accompanied an Apache to Eglin Air Force Base, Florida, for live fire missile tests. Win Miller, assistant division chief for the AFTD Attack/Recon Division, explains, "The real point of the test was to allow the Lockheed Martin engineers, the engineers who actually write the code for the M-TADS, to see the video in actual flight and hear the experimental test pilots tell them what's good or bad with the M-TADS software."

The mobile facility made it possible to turn modified software around quickly, typically in less than 24 hours.

"In the end, it's lower cost to the project manager and quicker turnaround to the soldier in the field with better software," notes Miller. The Apache trailer can be modified for other test programs, but has yet to be used with other aircraft.

FINAL REPORTERS

AFTD headcount hovers around 400 people, including support contractors. "It fluctuates slightly over a given year," says Chalk. Within the total are about 50 test pilots and 40 flight test engineers. "Our cadre of experimental test pilots are predominantly graduates of the Navy Test Pilot School at Patuxent River, either active military or Department of the Army civilians. Most of them show up with combat time as aviators."

AFTD pilots and engineers are organized along program lines. "We have a cargo/utility, attack/recon, and a special projects division we use to serve Special Operations," explains Chalk. "We have an integrated systems test division that looks at those systems used across different platforms such as the common missile warning system, radio communications equipment and human factors engineering."

AFTD pilots supported the Army Aeroflightdynamics Directorate at Moffett Field, California, developing fly-by-wire control laws for the UH-60M upgrade. Laws refined on the JUH-60L rotorcraft aircrew systems concepts laboratory (RASCAL) reduced flight time needed on the UH-60MU. AFTD pilots nevertheless logged more than 200 flight hours on UH-60MU test aircraft at the Sikorsky development center in West Palm Beach, Florida, tocomplete fly-by-wire qualification. The Black Hawk upgrade has been shelved by the army.

Other Redstone pilots filled temporary duty assignments at Boeing facilities in Philadelphia, Wilmington and Delaware during CH-47F development. The Block III Apache Longbow, now the AH-64E Guardian, put AFTD pilots on permanent change of station to Boeing in Mesa, Arizona, as part of the combined government-contractor test team.

AFTD is flying technology development models of the competing Northrop Grumman and BAE CIRCMs. CIRCM ties a laser jamming head to missile warning receivers to defeat infrared missile threats. The army project manager for aircraft survivability equipment in Aberdeen, Maryland, awarded two CIRCM technology development contracts in January 2012, and AFTD will test the palletized systems at RTC on an HH-60M Black Hawk. ∎

"OUR CADRE OF EXPERIMENTAL TEST PILOTS ARE PREDOMINANTLY GRADUATES OF THE NAVY TEST PILOT SCHOOL AT PATUXENT RIVER"

Frank Colucci specializes in writing about rotorcraft design, civil and military operations, test programs, materials and avionics integration

Take the strain

Metal fatigue has long been a major challenge for aircraft designers and aviation safety authorities. How is aircraft structural integrity testing adapting to the latest technological developments?

BY TIM RIPLEY

During the spring of 1954, two De Havilland Comet airliners crashed in mysterious circumstances with the loss of 56 passengers and crew. At the time, the Comet was the first operational all-jet powered airliner and the hopes of the British aircraft industry rested on its success. It was as if an Airbus A380 or Boeing 787 had been lost today. The subsequent investigation proved a milestone in air crash investigation as well as in the diagnosis of metal fatigue in aircraft. It gave birth to the modern science of aircraft structural integrity and, due to the advances made since then, it is now very rare for an aircraft to be lost through structural failure.

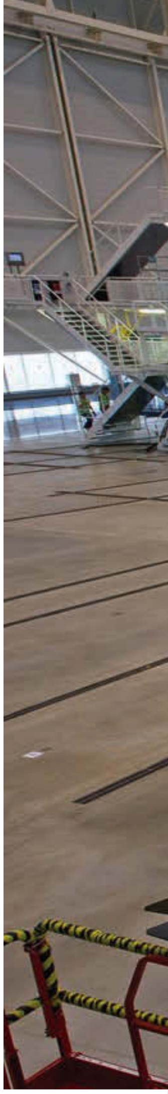
The Comet crashes have entered aviation folklore, with the incidents and subsequent investigations telling us a lot about metal fatigue and how to prevent it. Initial examination of the wreckage suggested that the Comets had suffered catastrophic structural failure in flight and it was thought that a bomb had ripped the aircraft fuselage apart.

Metal fatigue was initially discounted because the aircraft had been designed to withstand cabin pressures in excess of air safety requirements of the time. Investigators from the Royal Aircraft Establishment went back to basics and decided to subject another Comet airframe to a regime of systematic fatigue testing. The airframe was submerged in a water tank and water was repeatedly pumped into the cabin to simulate some 3,000 pressurization and depressurization cycles, to see how the metal structure responded to the stresses placed on it during these processes.

Eventually a fatal failure occurred in a small fiberglass window in the roof of the aircraft used as an aperture for two radio antenna. This then propagated rapidly across the aircraft, causing the fuselage to break apart. The window's supports were found to have been incorrectly fitted, punch riveting caused defect cracks to occur, and sharp-cornered windows exacerbated the problem and made the fatal cracks grow rapidly. Future jet airliners would feature windows with rounded corners to eliminate stress concentration.

MOVING ON UP

Since then, metal fatigue linked to crashes of F-111 combat jets, Boeing 707 and Boeing 737 airliners have all led to similar dramatic advances in the understanding of structural integrity and how to mitigate problems affecting it. Dr Russell Wanhill, principal research scientist (emeritus) at



National Aerospace Laboratory (NLR) in Apeldoorn, the Netherlands, says, "The lessons learned from these accidents, and others, have greatly influenced and improved our knowledge and perception of the problems involved in ensuring safety and durability."

Fast-forward to today and the science of structural integrity has moved on considerably. Aircraft are designed to have specific fatigue lives and fail-safe features; damage tolerance analysis is commonplace to minimise the hazardous effects of component failure, and 'inspectability' is incorporated into aircraft designs to enable critical components to be easily and regularly inspected for fatigue or damage.

Technology is also being incorporated into aircraft to enable structural integrity to be monitored during flight so that a crew can understand the stresses their aircraft is undergoing and detect unsafe vibrations in key components. Health-usage monitoring systems are now very common in helicopters to ensure key components, particularly the dynamic elements in rotor assemblies and gear boxes, are operating within safe design parameters. Unusual vibration, for example, is often a sign that critical component failure is approaching in a helicopter.

SYNCHRONIZED TEST CONTROL

With the recent introduction of MTS FlexDAC 20 data acquisition (DAC) systems, the company MTS resolved a major source of uncertainty in aerospace structural testing: unacceptable data skew caused by insufficient test system integration.

System integration problems typically stem from mixing DAC units and system controllers that employ different internal clocks, which will necessarily yield data that contains some degree of skew. Typical aerospace systems can be off by 25-50ms and it is not always apparent.

If data from the system controller and DAC units are not synchronized, simultaneous events can appear to have happened at different times, introducing ambiguity into test results. Until now, minimizing data skew meant oversampling, which required more processing power and repeated adjustment of time stamps between the system controller and DAC data sources, which in turn introduced jitter.

To overcome the uncertainties caused by data skew, new FlexDAC units are designed to integrate seamlessly with MTS FlexTest controllers, employing the same clock source and the same trigger source. With such a truly synchronized system, test engineers can be absolutely certain that the time stamps of every sample will align with zero milliseconds of skew, enabling them to spend time analyzing the results rather than questioning their accuracy.

TESTING REGIMES

Structural integrity testing philosophies and technologies are now embedded across the aviation industry, from initial design to in-service maintenance. Modern aircraft designers use this huge industry-wide corporate knowledge of structural integrity to try to design fatigue out of their products, as well as ensure aircraft remain safe if failures do occur or they are accidentally damaged.

Aviation safety authorities have long required that complete airframes and major components be subjected to realistic testing to prove the ability of aircraft to perform as required. This usually involves a representative airframe being installed in a fatigue rig and then subjected to a simulated lifetime of flight cycles. Fuselage cabins are repeatedly pressurised and depressurized, and wings are bent and unbent. This is designed to find any point of failure and give researchers real data, but often results in the destruction of the test items. Given the cost of modern aircraft it is an expensive business, but no aviation safety authority has yet considered doing away with this type of testing and replacing it totally with computer modeling.

Loris Molent, head of structural integrity (Combat and Trainer Aircraft) at the Australian Defence Science and Technology Organisation's (DSTO) Air Vehicles Division, says, "Despite better design and analysis tools being available in recent years, the highly optimized nature of modern aircraft, coupled with increased operational requirements, will likely lead to surprises in the form of structural failures that are better discovered in the test laboratory than through accident investigation."

Many in the aviation industry now talk about a structural integrity triangle or pyramid as a means of ensuring the safety of aircraft in an affordable manner. So even before an airframe is subjected to whole-aircraft testing, all the components have undergone rigorous testing and their characteristics are known quantities. The heart of this has been advances in non-destructive testing to enable the integrity of material, compounds, fastening devices and complete aircraft to be assessed throughout their life, as well as during the design and manufacturing process.

It starts at what is termed the coupon level, when the material used is tested to ensure that it has been manufactured to the required standard. Then the elements and subcomponents, such as weight-bearing struts or windows, are tested to make sure they retain their qualities when brought

Boeing

LEFT: **Destructive testing of 787 wing**

Airbus

Airbus

ABOVE: A350 XWB wing being prepared for fatigue testing

RIGHT: A350 XWB static test

together as finished products. Next to be tested are major components, such as wings, undercarriage assembles and flaps, to see if they meet the required standard. Finally, the whole completed airframe is assessed to make sure that it reacts as predicted to the stresses and strains of flight.

AIRBUS TEST RIG

Aviation safety authorities around the world have different requirements for who conducts structural integrity testing. Most civil aviation authorities now require that original equipment manufacturers conduct real stress testing during the certification process for new aircraft and that the authorities conduct regular inspections of this live testing, as well as reviewing documentation and other evidence, to ensure its validity.

In December 2012, the first Airbus A350 XWB was transferred to the L34 static test hall in Airbus's Toulouse facility. It was integrated into a test rig for a campaign that submitted it to nearly a year of evaluations, including limit load and ultimate load validations, along with residual strength and margin research. The L34 static test hall covers an area of 10,000m^2 and is supported by 200 workers during peak testing activity. It houses a rig that incorporates 2,500 tons of steel and 240 jacks/loading lines, which are used to induce structural loads. The testing is recorded by 12,000 sensors.

Although modern structural integrity testing is now very advanced it is not yet foolproof. Speaking after cracks were discovered in the wing ribs of its A380 Superjumbo airliner, Airbus executive vice president for programs Tom Williams admitted that fatigue testing cannot take into account every variation of the environment to which the aircraft will be subjected in service.

He said that, during ground testing of the A380 airframe, the company had made "assumptions" on the material used in the wing ribs because it had been used in other programs. The linear, finite-element modeling used to model some ribs on the aircraft assumed that adjacent ribs would behave in the same way. Some non-linear modeling tools, which might have helped the analysis, were not available at the time, he said.

Military safety authorities run different testing regimes because they often use aircraft for purposes other than those intended by the manufacturers. They like to conduct their own testing to ensure that aircraft meet their specific requirements or to inform life-extension programmes designed to keep their airframes in the air longer. The Australian DSTO runs a fatigue test regime on all aircraft used

FUTURE TESTING

The science of aircraft structural integrity is advancing at a rapid pace and as understanding of it changes, testing requirements will evolve. The accelerating development of new materials for use in aircraft has to be met by the necessary testing methodology and technology. So far, testing technology is perceived as keeping pace with these new materials. There has not been a catastrophic accident of a modern airliner that has been attributed to the failure of composite material. This has been a major success for the structural integrity testing community.

There is a huge repository of expertise and capability for structural integrity testing in private industry and academia. Southwest Research Institute, for example, is an independent, non-profit, applied engineering and physical sciences research and development organization in San Antonio, Texas, and provides more than 2,000,000ft^2 of laboratories, test facilities, workshops and offices for more than 3,100 employees who perform contract work for industry and government clients. This involves computer-aided design, production and installation drawings, finite element stress analysis, dynamic and aero-elastic analysis, fracture mechanics/crack growth analysis, stress intensity factors, crack growth models, cycle-by-cycle crack growth analysis and residual strength.

ABOVE: JSF fatigue testing

INSET: Aloha Airlines Flight 243 fatigue damage

by the Royal Australian Air Force (RAAF), even though they are usually purchased from foreign companies and have been subject to testing in the aircraft's country of origin.

The benefits of this approach were demonstrated in 2008 when the DSTO, working with the UK company QinetiQ, completed an airframe analysis program on a proposal by the Australian Defence Material Organisation to extend the life of the RAAF's Boeing F/A-18 Hornet aircraft fleet.

Originally up to 49 of the RAAF's F/A-18 Hornet aircraft were scheduled to undergo expensive structural refurbishment that would have included the replacement of the entire main load-bearing fuselage center barrel, which carries all loads from the wings. The DSTO conducted full-scale fatigue testing of ex-service aircraft center fuselages to establish a more accurate assessment of their fatigue life. Using data obtained from the tests, QinetiQ experts determined that only 10 of the aircraft needed the upgrade immediately, resulting in a saving of around A$400m being made and deferment of the remainder of the upgrades could wait for two years.

In the days of the original Comet inquiry, large contingents of scientists and engineers conducted these full aircraft fatigue tests. Today many of these tests have been automated and computerised, so highly complex experiments can be conducted.

To allow through-life structural inspection of aircraft, a wide variety of non-destructive testing technologies are available. They include liquid penetration, magnetic particle, eddy current, ultrasonic, radiography with x-ray or gamma rays, visual or optical, sonic resonance and infrared thermography tests.

A whole new industry sector has developed to provide structural integrity testing and inspection of composite materials, which are now accounting for more than 50% of some aircraft. New aluminum alloys with lower density and welding suitability, the extension of the application of titanium alloys, high-strength magnesium alloys as well as the application of carbon fiber reinforced plastic (CFRP) materials, all have new design, inspection and testing demands.

Sabine Goldbach, of the leading European testing company IMA Dresden, says, "Implementation of new materials for fuselages requires a large number of tests and validations. The spectrum of investigations reaches from a simple material specimen through coupons to a complete fuselage. It is important to be aware of the damage tolerance behavior of the fuselage structures. The design of further fuselages is strongly influenced by new materials and joining technologies."

Her colleague Rainer Franke adds, "For CFRP material, riveting is not the only way to combine structural parts. The behavior of bonded structural parts and the material properties after impact damage or under cyclic conditions are of major interest. Everything from simple parts to whole CFRP panels with complex joints between several materials and structural parts can be inspected." ∎

Tim Ripley is an international aviation journalist and writer

TECHNOLOGY BEHIND THE STRUCTURE

The equipment used for structural integrity testing is now multifaceted and involves a variety of technologies. Testing of finished components and whole airframes requires very different equipment. As is expected, it very much requires brute strength to bend and stress metal.

Full aircraft test rigs usually incorporate a selection of hydraulic actuators to push and bend wings, tails, fuselages and other components. The airframes themselves need to be rigged up with strain gauges and other sensors so that the loads being applied can be monitored and recorded.

The Canadian National Research Council's aerospace division in Ottawa has a typical test rig with uniaxial servo-hydraulic test frames that are computer-controlled and can be used for customized static and cyclic tests. Each system includes data acquisition for monitoring load, strain and stroke. Environmental chambers can be mounted for testing under temperatures from -70°C to 1,000°C. For cruciform specimens, the test frame is rated for 225kN along both axes. Using a phase-shift controller, tests can be carried out with tension on one axis and compression on the other.

10,000	The area in square meters of the L34 static test hall used to test the A350 XWB
12,000	The number of sensors used to test the A350 XWB
26	The number of months the A380 went through structural fatigue tests
47,500	The number of test flight cycles the A380 passed through – 2.5 times the number an aircraft would have in a 25-year career

Supersonic B2B

The latest flight tests by Aerion and NASA using an F-15B research aircraft have confirmed manufacturing tolerances for future supersonic business jets

BY JASON MATISHECK

MAIN: **The 11 flights featured a 40 x 80in Aerion phase-two test article mounted under the centerline position of NASA's F-15B research aircraft**

Phase 2 of a cooperative aerodynamic test program with NASA Dryden Flight Research Center has been completed by Aerion Corporation. The company has developed technology to optimize aircraft configurations for natural laminar flow in transonic and supersonic flight conditions. The technology is being used to develop an efficient supersonic civil aircraft, initially as an 8- to 12-passenger business jet. Previous tests have demonstrated the ability to achieve large extents of laminar flow, beyond a 30 million chord Reynolds number, for more efficient cruise than is possible with conventional wings. The recent work at Dryden focused on the next level of detail.

The tests were performed on NASA's F-15B research testbed. Aerion developed a 'strongback' support system that attaches to the F-15's specially modified Centerline Instrumented Pylon (CLIP). Various aerodynamic surfaces can then be mounted to the strongback. This modular arrangement allows the testing of different thin-wing experiments, while keeping a common structural element and instrumentation package.

Phase 1 of the test program, conducted in 2010, consisted of calibrating the flowfield under the F-15. A flat plate containing an array of static pressure ports was mounted to the strongback. A series of five-hole pitot probes was arranged near the leading edge of the flat plate to capture flow angularity. This experiment was then flown at altitudes from 35,000 to 50,000ft and up to Mach 2.0. The data from these tests were used to design the Phase 2 test article.

The purpose of the Phase 2 test was to look at surface quality criteria for a supersonic laminar flow wing. The test surface was reverse-designed to cancel out, as much as possible, the flow irregularities under the F-15 and simulate the pressure distribution on a laminar flow supersonic wing.

Surface irregularities above a critical size will move the location of laminar to turbulent transition forward, or in the worst case trip the flow, causing immediate transition. There are theories for determining this critical size on subsonic laminar flow surfaces. It was not known whether these theories would apply to supersonic flow, as they had not been tested at those conditions. There were two kinds of surface irregularities of interest in this test. One type is called discrete roughness, which is an isolated bump such as a rivet head or insect remains. The other is a two-dimensional step more or less transverse to the flow direction like a joint line between the leading edge and the wing structural box.

THE PHASE ARTICLE

The Phase 2 test article consisted of a 40 x 80in slab of aluminum, CNC-machined on one side to represent an airfoil section plus the adjustments for the F-15 flowfield. The back side was flat to mate to the strongback. The test surface was coated with a layer of epoxy syntactic foam for insulation, then painted with flat black epoxy paint and carefully polished to a semi-gloss finish. The article was fabricated by TriModels in Huntington Beach, California.

The primary instrumentation system was a digital infrared camera housed in a pod mounted in place of the F-15's forward right missile launcher. The camera looked slightly back and down at the test surface. Laminar and turbulent boundary layers have different heat transfer rates. As the aircraft accelerates and decelerates, the different boundary layers heat or cool the test article at different rates. This temperature differential shows up in the infrared video and provides a global picture of the boundary layer state on the test article. It is important for the test surface to have good IR emissivity and for it to be fairly well insulated for good IR response.

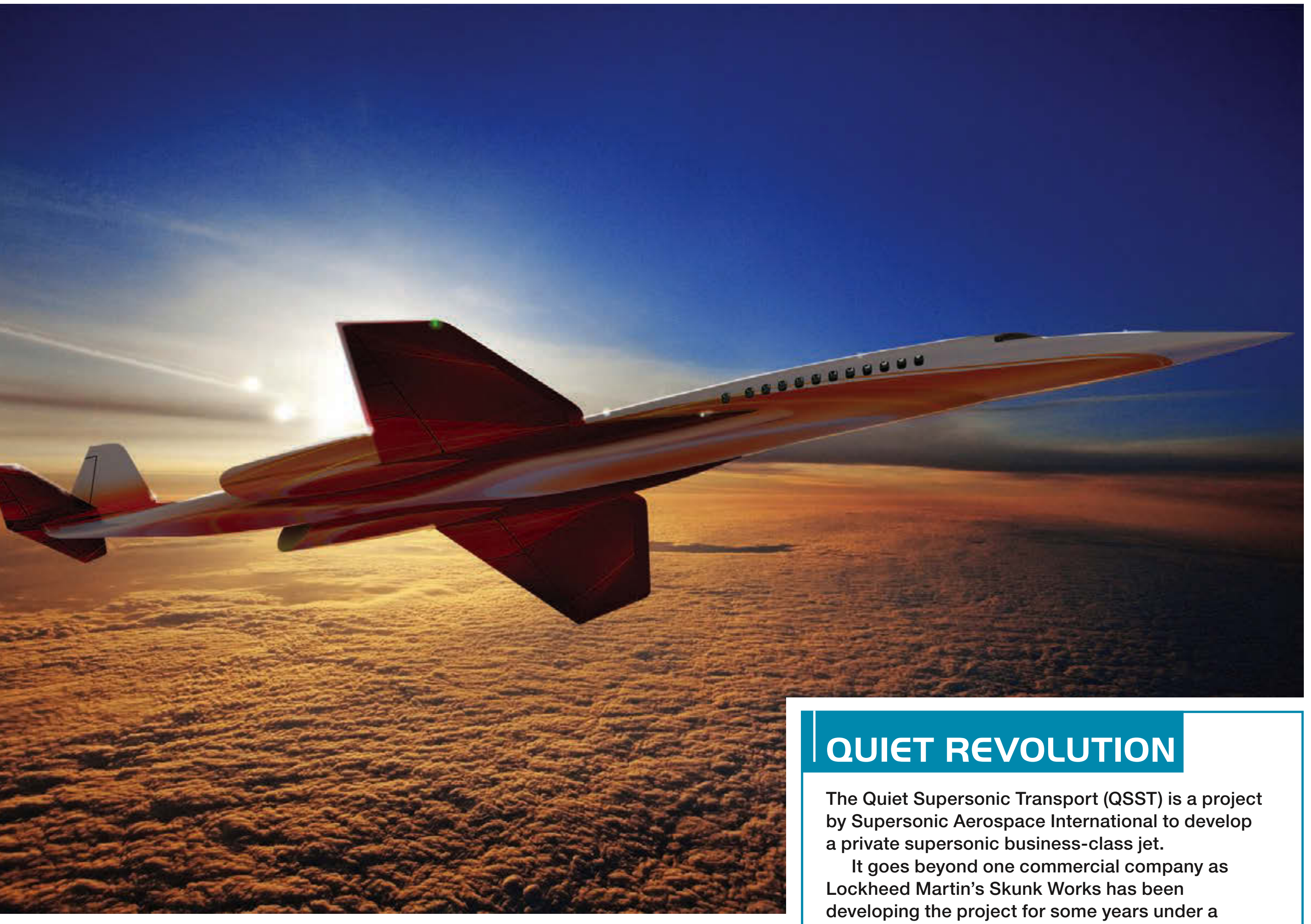
Each flight featured a different configuration of dots and/or steps. The dots were made by punching out

NEARLY THERE...

The latest Citation X will boast a maximum speed of Mach 0.935, outpacing the Gulfstream G650's Mach 0.925 and making it the fastest operational civilian aircraft in the world.

It also claims to have a maximum cruising speed of 527kts (606mph). Cessna expects it to have the same maximum altitude of its predecessor at 51,000ft, allowing it to fly above commercial air traffic and adverse weather.


836
NASA
N836NA



QUIET REVOLUTION

The Quiet Supersonic Transport (QSST) is a project by Supersonic Aerospace International to develop a private supersonic business-class jet.

It goes beyond one commercial company as Lockheed Martin's Skunk Works has been developing the project for some years under a US$25m contract from SAI. Designed to fly between Mach 1.6 and 1.8 (1,056-1,188mph), the two-engine gull-wing aircraft would leave a sonic wake that is reported to be only 100th the strength of the Mach 2 Concorde.

various thicknesses of Kapton or aluminum tape. The dots were arranged on the test surface to systematically look at different element heights at different chord-wise positions. Further aft chord-wise position corresponded to a thicker boundary layer. Two-dimensional steps of different heights were created by building up layers of vinyl film that is commonly used in graphic wraps for cars. The film is remarkable in that it is off-the-shelf with a pressure-activated adhesive that is rated from -65°F to +225°F and is removable. It is also designed to stretch over contours and easily remove air bubbles, perfect for high-altitude supersonic flight testing.

THE EDWARDS CORRIDOR

All testing was conducted in the Edwards high-altitude supersonic corridor. Two test profiles were used. One profile was simply a constant altitude acceleration and deceleration. This was used for initial envelope clearance and to look for hysteresis between the acceleration and deceleration conditions. During acceleration the article is relatively cooler than the airflow, while during deceleration it is relatively warmer. These 'hot wall' and 'cold wall' conditions can affect boundary layer stability. The main test profile consisted of a level acceleration at 49,500ft to Mach 1.7. (Some runs to Mach 2.0 were made.) Then, a constant Mach descent to about 31,000ft was performed. This increased the Reynolds number, which reduced the critical roughness height for transition.

Watching the IR video, the test team could observe the roughness elements begin to cause turbulent flow as the Reynolds number increased. In total, 12 data flights were performed for the Phase 2 testing during the first half of 2013.

Results from the testing supported the idea that supersonic aircraft do not require more demanding surface tolerances than subsonic jets. In general, the aesthetic requirements for modern vehicle fit and finish are often higher than what the flow demands. Perhaps the most surprising results were from the transonic Mach 0.9 to 1.0 portions of the flight. At these conditions, the flow over the article was often nearly all laminar, even surviving both the forward and aft-facing steps from the leading and trailing edges of the 2D test patches.

Aerion and NASA are now evaluating ways to extend their mutually beneficial relationship. As the two organizations gain more knowledge of transonic and supersonic flow physics, they contribute to the shared body of aerodynamics knowledge and intend to foster more efficient high-speed flight in the future. ∎

ABOVE: **It is hoped that Aerion's next-generation aircraft will be certified by the FAA and be in the air by 2015**

Jason Matisheck is the test manager for Aerion Corporation, which is based in Reno, Nevada, USA

Scramble for space

It was the hypersonic flight experiment that was over before it began. Scramspace project director Prof Russell Boyce gives a personal account of the ill-fated launch, and reflects on how it could never extinguish three years of success and the development of Australia's space future

BY RUSSELL BOYCE

MAIN: Scramspace lifts off, boosted by a two-stage S30/improved Orion sounding rocket (Photo: Janelle Kirkland, The University of Queensland)

September 18, 2013: T minus two minutes. The final moments of the choreographed scurry before the rocket launch of the Scramspace hypersonic scramjet flight experiment, far above the Arctic Circle at Norway's Andøya Rocket Range.

Among spectacular mountains rising up from white sand and a very cold ocean, under a crisp blue sky that would later give way to stars and magical displays from the Northern Aurora, the tension was peaking. Three -and-a-half years of intense effort by a small team of young scientists and engineers, supported by and adding value to the capabilities of several Australian and international partners, had gone into this moment. Millions of dollars of investment were at stake. By way of the media and the internet, the international aerospace community and the broader public were watching in anticipation.

"Science Lead, are we Go?"

"SL is Go."

"Inertial Measurement Unit, are we Go?"

"IMU is Go."

"GPS, are we Go?"

"GPS is Go… Telemetry is Go…"

"Mission Manager, this is Payload Technical Lead, Scramspace status is Go… 4 – 3 – 2 – 1 – 0…"

The perfectly functioning Scramspace science experiment had launched, with data from almost 200 onboard sensors already feeding into the rocket range science room via the telemetry stream.

I had seen three such sounding rocket launches before, during the UQ-led HyShot program at Woomera that blazed the trail of affordable hypersonic science flight experiments for which Australia enjoys a world-leading reputation. So when I raced out of the building and looked skyward to see an unfortunately familiar corkscrew smoke trail from the lower stage rocket motor, I knew instantly that the experiment was over before it had begun.

Disappointment and dismay, for myself and many of the team and others around me, quickly turned to disbelief. What had been one chaotic smoke trail turned into two – the upper stage motor was now firing at the same time. One insane minute later, the 150kg scramjet payload dived at 700km/h into the water a few kilometers from the launch range. By the grace of God, for which I will forever be thankful, nobody had been hurt.

Three-and-a-half years of effort, millions of dollars, a complex scientific payload that oozed technological sophistication… was the project a failure? As shock set in, as the enormity of the near-miss played over and over in our minds, as tears inevitably flowed, the apparent failure of the flagship of the Scramspace program weighed down on us. Was it a failure? Absolutely not. Despite the loss of precious scientific data for high Mach number scramjet combustion processes, the project and flight experiment had been an amazing success.

TO UNDERSTAND, WE NEED TO BACK-TRACK A FEW YEARS…

The primary reason for the development of the Scramspace program was to build a human talent pool – the capability and capacity to support an awakening Australian space sector – coupled with international credibility, and to do so by pursuing an ambitious combination of fundamental ground-based and flight-based science.

So, in 2010 the core Scramspace flight team began to assemble at University of Queensland (UQ). Initially it was just myself as scientific lead, Dr Sandy Tirtey as technical lead, and an intern student, Johannes Riemer, from Germany, and we set about defining the scientific requirements of the flight experiment and making a preliminary cut at packaging the key components and systems needed to fly a stable free-flying scramjet flowpath. The plan was to minimize risk and manage a fast-tracked (three year) schedule by employing aspects of the generic flowpath of a captive-carry (scramjet captive to rocket booster) flight experiment under development by our partner Defence Science & Technology Organisation (DSTO) on the Australia/USA HIFiRE program. Advice and assistance was provided by DSTO in the process, and within six months the core team had grown to include Dr Melrose Brown (aerothermodynamics and propulsion simulations) and Dr Michael Creagh (navigation and control), and was ready for a Conceptual Design Review provided by the HIFiRE program.

A Preliminary Design Review and a Critical Design Review followed in 2011 and 2012 respectively, and along the way the team grew to respond to the needs of the payload development as they unfolded, and to manage the ambitious schedule. The talents of recent UQ electronics engineering graduate, Igor Dimitrijevic, enabled the complex flight avionics needs to be implemented.

THE TEAM GROWS

Through combining existing DSTO systems, off-the-shelf components, and developing new electronic subsystems, the Scramspace avionics and instrumentation requirements were met. Experienced aerospace engineer and UQ PhD student Paul Van Staden provided the skills and stubbornness to turn innovative conceptual designs into operational and flightworthy mechanical CAD assemblies. Brad Sharp, former satellite telemetry expert, joined the team to define and develop the telemetry stream for the 8.3Mb/sec of data from almost 200 onboard sensors. Dr Bianca Capra provided sophisticated thermal analyses, coupling 3D finite element simulations with computational fluid dynamics to underpin the design of the various hot structures on the vehicle. Adrian Pudsey – RAAF engineer and UQ PhD student – contributed additional numerical simulations. Among all this, Sandy Tirtey led the payload team and managed the interfacing between the various aspects of the design

Meanwhile, Melrose Brown and Michael Creagh were hard at work making two critical contributions. Melrose successfully brought supercomputing horsepower to bear to design and validate a set of fins for the payload and strakes for the upper stage rocket, that would ensure stability of the combined payload and rocket motor stack on the ascent phase of the flight, and at the same time ensure stability of the free-flying scramjet on the descent phase – two conflicting requirements. The approach challenged conventional wisdom that avoids the destabilising effect of lifting surfaces on the payload of sounding rocket flights, and was successfully achieved and verified by independent simulations from partner the German Aerospace Center (DLR).

Creagh, on the other hand, developed a 'reaction control system' for exo-atmospheric re-orientation of the payload and for assisting stability by damping vehicle motion in the upper parts of the atmosphere, underpinned by an elegant control law. Subsequent Hardware-and-Software-in-the-Loop testing of the payload by partner BAE Systems (Australia) demonstrated Creagh's system to be extremely robust.

So by late 2012, following two years of intense effort, a rather weary but nevertheless committed and enthusiastic and increasingly skilled team set out to turn a detailed design into the most sophisticated hypersonics flight experiment Australia has ever flown.

PUTTING IT TOGETHER

A steady flow of drawings sent out in batches turned into high-precision mechanical components – the inlet and combustion chamber, external panels, bulkheads, and so on. Meanwhile partner Teakle Composites wound the carbon-phenolic thrust nozzle; DLR manufactured the carbon-carbon silicon carbide (CC SiC) fins; and the Italian Aerospace Research Center (CIRA) provided its ultra-high-temperature ceramic winglets for a piggyback experiment. Similarly, the University of New South Wales (UNSW) manufactured and provided its diode laser flight instrument experiment for installation into the scramjet inlet.

Fast response surface pressure sensors and thermocouples were mounted to the internal flowpath, and the complex network of flight computers, power switching boards, batteries, data acquisition electronics, GPS and IMU, and other avionics components was assembled. Two pneumatic systems were assembled: one controlling the pulsing of hydrogen fuel from two 230 bar carbon-fiber tanks; the other supplying nitrogen from another two such tanks for the RCS and inlet starting systems.

By mid-2013, the scramjet payload was assembled and moved into the shake-and-bake stage – the exhaustive series of pre-flight tests to ensure that the experiment was functioning properly and ready to fly. These included thermal cycling, vibration in all axes, bend testing, spin balancing, and pneumatic system calibration. The tests were mostly performed at and assisted by DSTO, where the team had assembled the payload.

In parallel, the flight code had to be written. Building on code developed by DSTO for earlier flights, some 13,000 lines of C and C++ had been written to enable the flight computers to be communicated with during the ground phase of the launch and for the flight computers to control the onboard systems, acquire and package data, and deliver it to the telemetry stream. The most complex part of this was the use

"A STEADY FLOW OF DRAWINGS SENT OUT IN BATCHES TURNED INTO HIGH-PRECISION MECHANICAL COMPONENTS"

of the RCS thrusters to control roll, pitch and yaw, re-orient the payload prior to re-entry, and stabilize it during the early re-entry stage.

Scheduling of the pulsed fuel system for maintaining a fixed fuel-lean mixture was also a key aspect of the code. Throughout the development of the flight code, a continual process of testing the logic and detail of the algorithms was conducted – firstly against virtual input; then in connection with elements of the hardware such as the RCS thrusters; eventually on a dummy payload of identical flight computers receiving input from virtual hardware; and finally on the fully assembled scramjet.

The latter part of this 4.5-month effort was underpinned by partner BAE Systems' sophisticated aerospace Hardware-and-Software-in-the-Loop test capability that was purpose-built for high-speed applications and tuned for Scramspace.

LEFT: **Corkscrew exhaust trail from the failed lower stage rocket**

BELOW: **Scramspace (blue) and rocket motor stack on the launch rail (Matthew Taylor, The University of Queensland)**

BELOW INSET: **Some of the complex avionics and pneumatics obscuring the scramjet flowpath**

THE END RESULT

The result? Despite the inevitable teething problems and bugs along the way, the hardware and software for a free-flying scramjet science experiment was ready for flight. So by the end of August 2013, a shipment of payload and support equipment was winging its way to Norway, followed in the week or so after by the core UQ Scramspace flight team; several personnel from DSTO who were supporting and managing the campaign under the banner of a Defense Trial; as well as staff from UNSW, BAE and CIRA. DLR's Mobile Rocket Base arrived to assemble and launch the stack of rocket motors (Brazilian S30 and American Improved Orion) and payload, supported by the professionalism of the Norwegian rocket range staff.

On September 18, 2013, Scramspace took to the air, with the broader team of some 20 post-doctoral researchers and PhD students who performed the extensive ground-based research alongside the flight developments, as well as staff from across the 13 Scramspace partners, the international hypersonics community, the media, and more than 1,000 Facebook followers, waiting in anticipation.

Did we fail? Again, absolutely not. Our experience was an unforgettable example of the reality that if something is hard to do, when you are pushing the boundaries in pursuit of new knowledge and innovation, then there is a real risk of something going dramatically wrong. It is in that situation that the lessons learned and experience gained are the most valuable.

We missed out on a few seconds of scramjet flight data but, despite withstanding incredible aerodynamic forces, the scramjet functioned perfectly all the way from launch to splashdown, a tribute to the quality of the payload that the team had designed and built. The engineering was a success; the research that surrounded it was, too, and continues to bring advances and new insight into hypersonics science and technology; but above all, the talent pool that assembled and grew in skills and know-how, and the international credibility and partnerships and friendships that have resulted from that, has been a huge success.

So where to from here? Scramspace has been but one chapter in the proud history of UQ and Australian hypersonics research. Indeed, it is by no means the only chapter being written or to be written in the future. Ongoing funding for the Scramspace capability has not been possible. The Scramspace flight team is already beginning to disperse to other opportunities that have arisen from the project. Yet hypersonics research in Australia remains strong and can continue to hold its place as a world leader in hypersonics through the ongoing work of colleagues at UQ and partner organizations, and at least in part enabled by the platform of knowledge and innovation provided by the Scramspace project. ∎

Professor Russell Boyce is the director and overall scientific lead for the international UQ-led Scramspace program

VICTORIOUS VITO

Swiss Air Racing Team pilot Vito Wyprächtiger scores a victory in the Formula 1 class at the 2013 Reno Air Races

To successfully participate in Reno, USA, a pilot must fly in an aircraft designed using the best flying material and possess outstanding skills, and be a true flying addict. In the 2013 race, Swiss pilot Vito Wyprächtiger won the Formula 1 class and proved that he has all of these things. He even made history by being the first European to win this prestigious trophy in the 50 years of the race. This exceptional accomplishment was achieved after he appeared in the competition for the first time in 2010, when he finished second.

TACTICS AND TECHNOLOGY

On the pylon course at Reno/Stead Airport, clever tactics in close proximity to the ground are required in order to succeed. Vito's triumph over his strong opponents was largely due to his excellent flying skills, but technological improvements on his airplane also played a major role.

The victorious aircraft was Scarlet Screamer, a Cassutt IIIM kit plane, which originally featured plywood wings and a steel tube frame covered with fabric. This simplicity in construction comes at the cost of reduced structural and aerodynamic efficiency. In recent years, successful competitor aircraft have often profited from the technological advantages of composite monocoques and advanced aerodynamics. In order to overtake its competitors, the Swiss Air Racing Team recognized the need for drastic improvements with similar technology on their base aircraft.

REDESIGNING THE TURTLE DECK

In partnership with RUAG Aviation's aerodynamics department, several options for enhancing the basic performance of the Scarlet Screamer were studied and a step-by-step development plan was put together. The turtle deck was identified as being most promising for short-term improvements. This structure on the upper fuselage essentially comprises the cockpit canopy and its downstream aerodynamic fairing.

The aerodynamicists at RUAG's wind tunnel facility in Emmen, Switzerland, analyzed and finally optimized its shape under the constraints of the rule books. This largely reduced its contribution to the aircraft's overall drag. Integrating the vertical stabilizer into the new turtle deck further helped to optimize the aircraft. Implementing the design in carbon composite provided increased stiffness at a low weight.

NEW COMPOSITE PARTS

With the aerodynamic shape fixed, the structural design and fabrication tools (molds) needed to be completed in preparation for manufacturing. The turtle deck was then fabricated in the RUAG wind tunnel model workshop.

The RUAG team specializes in prototype components and low production rate parts in support of internal or external wind tunnel tests and flight activities (repair and modification kits for payload integration, for example). The short communication paths within RUAG's aerodynamics department and the sterling efforts of the workshop ensured that the tight delivery schedule was adhered to. Following the integration of the RUAG turtle deck and a new canopy in the USA, test flights confirmed the benefits of the design changes and set the way for Vito's outstanding victory. Preparations for the next race have already begun! ▮

ABOVE: The all-new turtle deck before leaving the wind tunnel composite workshop

ABOVE: Swiss Air Racing Team pilot Vito Wyprächtiger with the new Scarlet Screamer at Reno Stead Airport (Photo: Swiss Air Racing Team)

FURTHER INFORMATION

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or go to online enquiry card 101

WHAT'S IN THE BOX?

USB and Ethernet-based databus interfaces are becoming more popular as flexible systems need to separate data from the control station

Open, flexible and modular system architectures for test, simulation, maintenance and other applications are becoming more of a trend.

One important feature for flexibility is the ability to separate databus interfaces from their control stations. This eliminates some problems that have been identified in the past with the obsolescence of PC platforms, form factors and supported backplanes. This is reflected by the growing popularity of USB and Ethernet-based databus interfaces, such as those offered by AIM. Both USB and Ethernet are available on almost every PC, and a missing Ethernet interface on the PC side can be simply implemented via corresponding USB adapters. However, it should be noted that this separation implies other challenges concerning data communication to and from the databus interface device, so the well-known form factors/backplanes like PCI/PCIe/PXI/VME still hold their position.

When opting for a solution that places the interfaces external to the PC, due to its openness and great flexibility Ethernet is the choice over USB, as the latter always requires OS-dependent device driver support on the controller side. Wireless Ethernet, which is more or less transparent to the communication partners, provides further possibilities.

The flexibility mentioned so far applies to the physical implementation of modular systems. However, flexibility must also be addressed by software support, which is an important factor when considering the physical separation of databus interface and controller.

Rapidly acquiring incoming data from the interface so as to be able to react and update outgoing data quickly is a real challenge due to the processing times of the related software layers. The onboard processing capability of an Ethernet-based interface is a key feature in order to offer flexibility with regard to the implementation of the application.

Hardware-based real-time bus-protocol tasks need to be performed at the interface level to guarantee proper handling of the datalink layer of the corresponding bus protocol. However, getting the more application-specific parts of the software down to the interface level offers more possibilities for scalable system approaches, not limited to one Ethernet-based interface.

This design has open and flexible processing capabilities implemented within the AIM ANET family of interfaces. It has a system-on-chip (SOC) processor available for the application support processor (ASP) operating in the background and for the Bus Interface Unit (BIU). It also offers connection to the outside world via Ethernet.

Furthermore, a general purpose USB 2.0 host port is available. Being a host port means it can 'host' USB devices rather than simply operating as a connection to a host. With its own RAM and flash memory it is basically an autonomous processor at the interface level, which is independently operated from the real-time BIU processor.

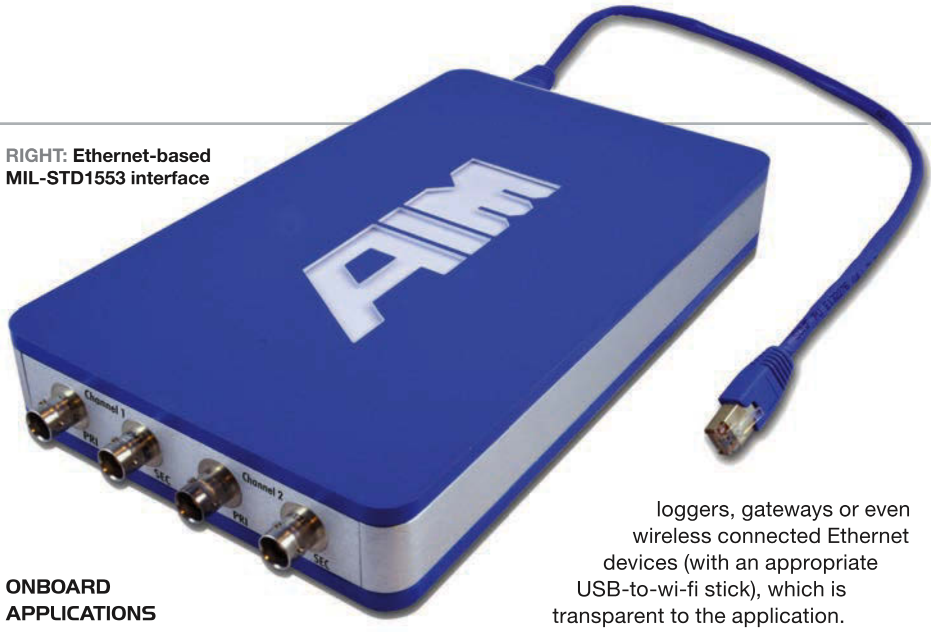
ADVANCED SOFTWARE

To realize the full benefits of the architecture and to maximize flexibility, an additional and advanced software capability is embedded in the dedicated ASP processor. Various approaches for embedded OSs have been implemented in the past and are still available.

However for the above type of interfaces an onboard LINUX OS with a real-time extension has been chosen for several reasons. When having a look at the software architecture shown in the figure opposite, far right, the traditional layering with a device driver and an application programming interface (API) has been retained. Furthermore, the core code of the onboard driver and API has been easily migrated from LINUX to standard PC platforms, which normally host other interface form factors like PCI/PCIe/USB.

Therefore, for writing onboard applications executed by the application support processor, programmers do not have to familiarise themselves with a new API. Even the migration of existing code, written and executed on host PCs, becomes possible in an efficient way. This means migration tasks and developments of new onboard applications can be focused on application-specific aspects rather than a new API. Also the platform-handling knowledge for standard LINUX systems is applicable due to the ability to work via SSH (Secure Shell). Furthermore, and due to the onboard API commonality and compatibility with the standard APIs for PC hosts, application prototyping can be performed on standard PC hosts without going 'embedded' in the first instance.

LEFT: Using an Ethernet-based interface wireless from a tablet



RIGHT: **Ethernet-based MIL-STD1553 interface**

ONBOARD APPLICATIONS

Software flexibility has also been envisaged by offering different ways for the implementation of onboard applications, which can be written in C/C++ with a cross-development toolset for compiled executable programs, or simple Python scripts using the built-in Python support. Both are based on the common API layer as shown in the figure bottom right.

Both methods can use the available ASP resources and implement an application-specific uplink using a TCP/UDP socket connection for maximum flexibility or integration into existing architecture and systems. The onboard LINUX built-in support for mass data-storage devices and other standard USB interfaces (e.g. host USB-to-serial converters) allow further autonomous operation as standalone data loggers, gateways or even wireless connected Ethernet devices (with an appropriate USB-to-wi-fi stick), which is transparent to the application.

So far the use of the ASP for customer/system-specific applications 'from scratch' has been outlined, either by a compiled executable or a Python script. However, another reason to go with an onboard LINUX OS is that even existing application software for LINUX can be efficiently rehosted onboard due to the common software architecture. So as a further step an existing software application framework has been entirely migrated to the interface level, offering another level of flexibility and application implementation.

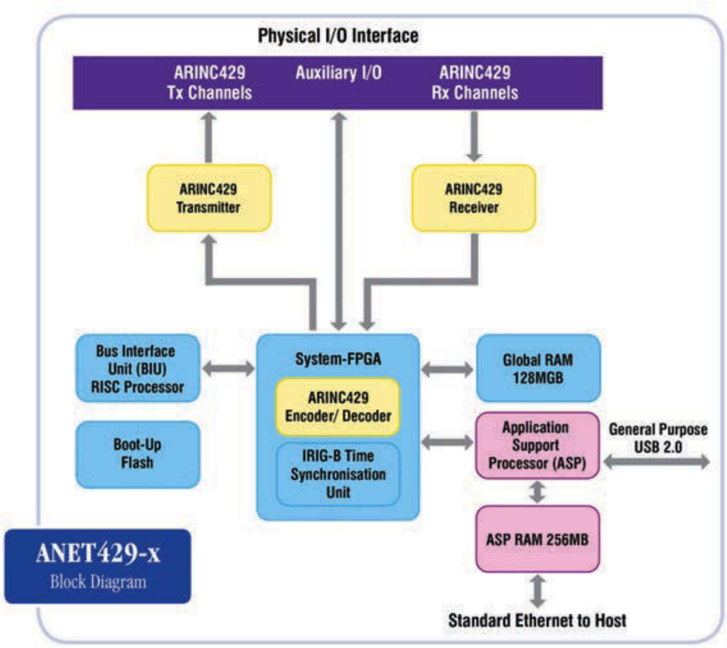
THE SYSTEM SOFTWARE

AIM's PBA.pro Test & Analysis application has been migrated to the ASP in the form of the PBA.pro Engine, offering all functionality but without the graphical user interface. Communication from a host is performed via a 'string' oriented remote-control interface over TCP sockets, which offers access from any OS via a raw socket terminal.

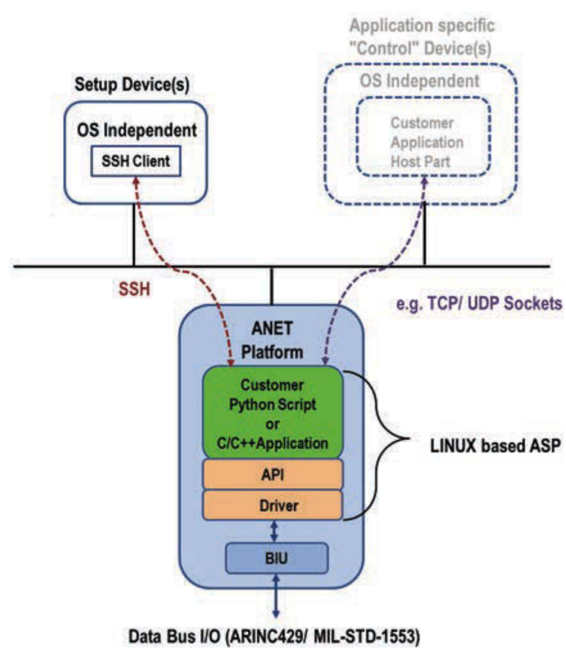
The API in this case is the higher level oriented remote-control interface with commands such as initialization of the bus interface, setting up a message and set/read the data, etc. It also allows the uploading of existing or predefined project and database files to the PBA.pro Engine, which is hosted on the interface. The application study shown in the figure on the opposite page combines the wireless communication capability with higher-level API access via the PBA.pro remote-control interface as an excellent example of the flexibility of the Ethernet-based ANET devices in such a configuration.

Finally, the setup and maintenance of the Ethernet-based interface is achieved using any standard web browser to access the onboard web server running the corresponding configuration front end for IP address setup, onboard software updates, etc.

In conclusion, this profile has addressed the flexible and open concept and capabilities for further customisation and integration of ANET Ethernet-based interfaces. It should be noted that ANET products can also be operated like all other AIM interfaces (PCI, PCIe, PXI, USB, ExpressCards, etc) just as an interface from any host PC over wired or wireless Ethernet, but with all the above mentioned capabilities for a maximum of flexibility and scalability. ▮



ABOVE: **Block diagram of the Ethernet-based ARINC429 interface**



ABOVE: **Software architecture of the Ethernet-based interface**

FURTHER INFORMATION

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HOT TO HANDLE

A piezoelectric accelerometer is ideal for measuring aerospace systems in a high-temperature environment

Shock and vibration testing performed on jet engines, propulsion systems and power generators requires transducers that can withstand the high temperatures in very demanding applications. In test environments over 200°C, the best choice is a piezoelectric accelerometer. Below 200°C, several models in the Isotron (IEPE) family are available.

There are some specific advantages in using Isotron accelerometers, including a low-impedance output with better noise immunity. But these potential benefits should be evaluated based on the application requirements. The downside of using Isotron devices, however, is imposing the temperature environment on the internal amplifier, which would otherwise be sitting outside at room temperature. The consequences of exposing the electronics to high temperature are shorter operating life, reduced electrical performance and lower meantime between failure (MTBF).

Selection considerations in high-temperature applications include:

Survivability – temperatures as high as 400°C and above are common for engine vibration monitoring. The accelerometer should be able to survive and operate under these conditions continuously without degradation in sensitivity or resonance characteristics;

Temperature response – the performance of a transducer at its temperature limits must be well defined. It is important that the sensitivities at the higher temperatures be repeatable and without hysteresis. Some piezoelectric models feature special output sensitivity compensation over a defined range of temperature, resulting in a fairly 'flat' temperature response. Most piezoelectric transducers show a drastic drop in internal resistance at very high temperature, rendering the signal conditioner (charge amplifier) inoperable; and

Cable survivability – along with the accelerometer itself, the connector and cable assemblies must be able to survive the hot environment. The output cable must have a similar temperature rating as the transducer. Most high-temperature, hardline cables use ceramics as their dielectric, which is typically brittle and not very flexible. The Endevco 3075M6 cable assembly has a temperature rating of +482°C (+900°F) and is constructed with an Inconel center pin and MgO insulation to provide a bend radius of 0.75in.

The Endevco 65HTLPF-10-XX miniature triaxial ISOTRON accelerometer with integral two-pole, low-pass filtering is the latest innovation in the model 65HT series. This low-impedance transducer is designed for test and measurement applications requiring high-temperature operation; resonance suppression; and the effective attenuation of high-frequency, high-*g* signals which can otherwise obscure required low-frequency data and saturate electronics. The model suffix 'XX' denotes the customer designated low-pass filter corner frequency at -3dB. Of the two available standard options, the Endevco 65HTLPF-10-02 features a 2kHz corner frequency; while the Endevco 65HTLPF-10-10 features a 10kHz corner frequency. Other frequencies are available upon request.

Offering a 10mV/*g* sensitivity, the Endevco 65HTLPF-10-XX offers high-reliability vibration and acceleration measurements across three orthogonal axes in continuous temperatures of up to +175°C (+347°F) without requirement for a separate charge amplifier. Units are packaged within a 10mm welded titanium cube with interface via a robust four-pin Microtech connector, for a compact and lightweight footprint that weighs just 5g. The Endevco 65HTLPF-10 incorporates Meggitt's proprietary piezoelectric sensing elements for high performance and stability, with excellent amplitude and phase frequency response. Constant current accelerometer power travels through the same pins as the low-impedance output signals. Temporary petro-wax adhesive and a 10ft cable assembly with BNC connectors are provided as standard accessories, with an optional mounting block sold separately.

The Endevco 2280 is a hermetically sealed, triaxial, piezoelectric, charge-output accelerometer with high-temperature operation to +482˚C (+900˚F). With its small package, the 2280 is ideally suited for vibration measurements across three orthogonal axes on aircraft engines, aerospace components, ground-based turbine engines, power plant equipment, and other machinery that operates at high temperatures. It shares the same piezoelectric charge sensor system as the popular single-axis 2248 family with 15 years of field-proven performance. Offered with a sensitivity of 3pC/*g*, the 2280 features Meggitt's proprietary piezoelectric elements and patented Isobase construction, to provide mechanical isolation of the sensing assembly from the mounting surface and minimize base strain.

The Endevco 2280 is 1.35in (35mm) square and weighs less than 0.6 lb (270g). It has three 10-32 side connectors and is mounted with two 8-32 bolts. The unit is hermetically sealed and signal ground is isolated from the outer case of the unit. Three 10ft Endevco 3075M6-120 high-temperature cable assemblies are supplied with the unit for error-free operation, along with two mounting screws. Recommended optional accessories include the 2771C remote charge converter.

ABOVE: The 2280 is a hermetically sealed, triaxial, piezoelectric, charge-output accelerometer designed for high-temperature operations

RIGHT: The model 65HTLPF-10-XX miniature, triaxial, Isotron accelerometer is a low-impedance transducer designed for high-temperature operation, resonance suppression and attenuation of high-frequency, high-*g* signals

FURTHER INFORMATION

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or go to online enquiry card 103

CONTRACT AWARDED FOR ELECTROHYDRAULIC TEST RIG

Micro Movements, a subsidiary of Electroservices (Midlands) of Telford, UK, has recently been awarded a contract valued in excess of US$1m for the design, development, manufacture, installation and commissioning of an electrohydraulic aerospace test rig. The system will be installed in a UK manufacturing facility of a large multinational aerospace company.

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

For over 40 years, Micro Movements has supplied signal conditioning and recording systems to a wide range of industries, from automotive, power generation and government (including infrastructure and defence) to rail and aerospace. During this time the company has developed a number of test systems to suit its customers' needs. Recently Micro Movements has added to this capability, enabling it to design, develop and manufacture complete test stands to meet precise customer specifications.

FURTHER INFORMATION

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COMPONENT TESTING AND SIMULATION

Osram Sylvania provides a wide range of standard and custom high temperature and pressure in-line electric air heaters for aircraft component testing and simulation. Sylvania Specialty Flanged Inline heaters reach an amazing 900°C on 1,000+ PSI compressed air streams with industry-leading speed, compactness and temperature stability. That means that the company's heaters are not just hot stuff, they are your best choice for any kind of aerospace testing. Systems range from 18kW to multi-megawatt and include standard and custom control panels.

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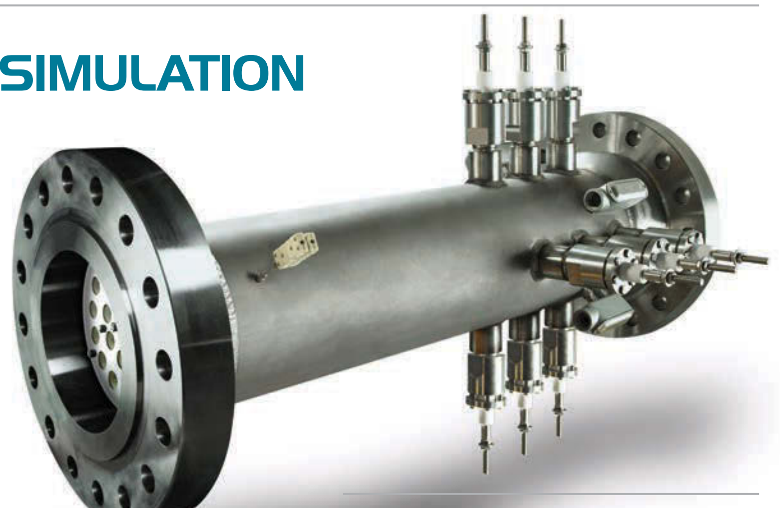
Improve the efficiency of your overall development process from design to testing with practice-proven air heaters from Osram Sylvania, and benefit from the company's comprehensive services.



FURTHER INFORMATION

Osram Sylvania
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LOAD CELLS FOR AEROSPACE APPLICATIONS

PCB Load & Torque, a wholly owned subsidiary of PCB Piezotronics, manufactures a wide range of high-accuracy, strain-gage load cells for aerospace applications.

Series 1400 includes a dual-output feature that offers sensor redundancy and the ability to provide control feedback from one sensor while the other is used for data acquisition. These load cells are available in multiple ranges and have a NIST traceable, A2LA accredited calibration to ISO 17025, in both tension and compression directions. Additional features include low deflection, high accuracy and repeatability, thermal compensation and moment compensation. Fatigue-rated load cells are specifically designed for durability testing machine manufacturers and users, or any application where high cyclic loads are present. Applications include material testing, component life testing and structural testing. All fatigue-rated load cells are guaranteed against fatigue failure for 100 million fully reversed cycles.

As with all PCB Load & Torque manufactured instrumentation, this equipment is complemented with toll-free application assistance, 24-hour customer support, and a commitment to total customer satisfaction.

FURTHER INFORMATION

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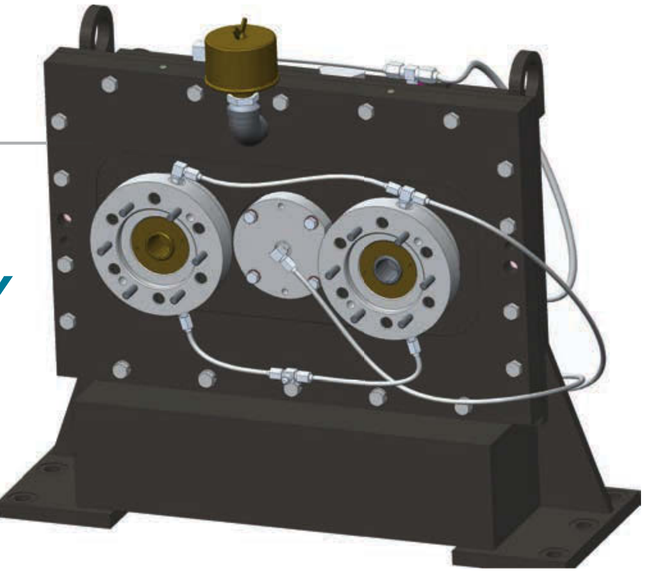
or go to online enquiry card 106



HIGH-SPEED TRANSMISSION FOR MAXIMUM TEST STAND FLEXIBILITY

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

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

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

FURTHER INFORMATION

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or go to online enquiry card 107

AIRBUS APPROVAL FOR THE WALICLEAN TROLLEY

Waliclean, the innovative waste line cleaning system developed by Austria's Test-Fuchs, has achieved an important milestone in its success story. During Inter Airport Europe in Munich in October this year, Airbus and Test-Fuchs signed an agreement for Airbus's approval of the Waliclean trolley. The aim is to include Waliclean in Airbus's technical publications, such as the Tool and Equipment Manual (TEM) and the Aircraft Maintenance Manual (AMM) for the A320 family, A330/340, A380 and A350XWB aircraft.

Following completion of the approval, Airbus customers will benefit enormously from the Waliclean process no longer requiring personal or airline approval, as a Waliclean task will be included as standard in the Airbus AMM, under Chapter 38.

Until now airlines were forced to spend huge amounts of money to solve problems with clogged toilet systems, using expensive and aggressive chemicals for prevention, or time-consuming disassembly of the waste lines. The Waliclean technique is surprisingly simple and at the same time also extremely environmentally friendly. A solution of citric acid and warm water circulates through the aircraft's waste line with system compatible negative pressure. Afterward the cleaning solution can be disposed of in the normal sewage systems. Therefore, the cost savings for the airlines are enormous, with savings in chemicals, working hours and, in the long run, kerosene, since less weight in the waste lines means less consumption of fuel.

As well as being environmentally friendly, this system is also surprisingly easy to handle. The operator clicks the 'start' button and the process starts, automatically stopping when finished. For safety reasons the Waliclean also performs a leakage check of the waste-line system. There is no need to monitor the cleaning process, which takes only five hours and can easily be performed overnight.

FURTHER INFORMATION

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or go to online enquiry card 108

STATIC ANALOG AND DIGITAL DATA

Aerospace testing is not 'monochrome' – there are signals in multiple domains that all need to be recorded and displayed in real time. Dewetron systems record dynamic and static analog data plus digital signals (discrete and rotary pulse types) in perfect sync with hundreds of parameters from the ARINC-429 and 1553 databuses plus video data streams, PCM data from bit and frame synchronizers, chapter 10 data and more. All data is already synchronized at the time of recording. The systems are capable of performing all the different testing paradigms simultaneously and in sync with each other, as well as synchronized to external time reference such as IRIG time code or the UTC code from GPS.

All these vastly different parameters can be recorded using one single Dewetron system with Sync-Clock technology, the DEWE2-A4. All information can be displayed and monitored in real time throughout the test.

Dewetron systems are used in both military and civilian aerospace, either in the air for recording during flight tests or for a range of tests on the ground, in the hangar or in test chambers – including important component burn-in, NVH, satellite and wind tunnel testing.

FURTHER INFORMATION

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INDEX TO ADVERTISERS

Dogfight with flutter

New Zealand-based company The Vintage Aviator Ltd (TVAL) aims to build World War I aircraft, engines and propellers to the same exacting standards to which they were originally made over 90 years ago. The Albatros D.Va is one example that has faced a few problems

BY GENE DeMARCO

MAIN: Albatros airframe set up for ground vibration testing with accelerometers in place

INSET: Albatros D.Va with author and production manager Gene DeMarco

One of the most prolific aircraft manufacturers during World War I was Albatros, which created a series of single-seat fighters that were in service longer than all the Fokker fighters combined. The Albatros D.III introduced the distinctive 'V' strut-braced sesquiplane arrangement borrowed from the French Nieuport scouts.

Throughout 1917, Albatros D.IIIs enjoyed sustained success over the front and production of this model continued until early 1918. Structural problems encountered by the D.III persisted with the latter D.V and D.Va models, despite the D.V types having heavier spars and visible steel tube braces between the lower front strut and the leading edge of the lower wing. The D.III, D.V and D.Va's lower wing had only one spar and employed the distinctive V-strut, greatly reducing its rigidity and permitting substantial torsional movement. Now recognized as flutter, this was a strong contributor to failure.

Aware of several lower wing failures on Albatros aircraft during World War I, TVAL insisted on carrying out additional flight testing, including flutter analysis, on this machine to improve its safety or at least identify its deficiencies. In one instance where the structure failed in flight, the pilot survived and the wreckage was photographed, raising concerns as to the airworthiness of the design and also pointing to a potential design flaw.

> The Albatros D.Va was a fighter used by the Luftstreitkräfte (Imperial German Air Service) during World War I. A total of 1,612 D.Va aircraft were built before production halted in early 1918

Pilots who survive crashes due to the rapid and violent effects of flutter consistently describe the wing breaking away downward after only a few cycles. Lt Von Hippel is one pilot who would probably have described the lower wing of his D.Va breaking away downward during a dive. Wreckage of his crashed fighter provided very strong evidence to this effect, showing that the V-strut was still attached to the upper mainplane. This is entirely consistent with the hypothesis presented. A lower wing breaking away in a downward motion could very easily have left the remaining structure untouched. In the case of the Albatros D.Va, a contributing factor would be the V-strut attachment itself, which lacks rotational and hence torsional rigidity.

TVAL completely modeled this aircraft in CAD, which allowed specific aircraft data to be used during the flutter analysis. This information included the aircraft geometry, fuel tank volume and location, mass and center of gravity of all components, and design of the flight control system – to name just a portion of what was required for the ground vibration testing to be carried out.

For the test setup, electromechanical exciters are attached to the airframe to get the vibration started at different frequencies. Up to 64 accelerometers measure the response of the structure. The test equipment records the results, which are used to calculate damping and critical speeds. Typically, the characteristics are tested without fuel and full fuel, and control surfaces fixed and free.

The resulting test report shows plots of damping over airspeed for different frequencies. Based on these plots, it can be proved that a proper margin of damping exists at V_d (maximum design speed) and that there is no rapid reduction in damping as V_d is approached. These results are then validated by flight test. If low damping is forecast at speeds below V_d, recommendations for design modifications can be made (decrease of control surface mass or hinge moments, increase in structural stiffness, or even mass damping of the structure).

A ground vibration test is more reliable in identifying issues based on analysis of structural models, because it covers real-world issues such as play in the control system, flexibility of mounting hard points, etc. Another benefit of analysis is the determination of the type of flutter – hard or soft – that may occur. Simply speaking, when hard flutter occurs, the amplitude of vibration of the wing rapidly increases and there is little to no observable oscillation before the critical flutter speed. In soft flutter, oscillations are observed as the critical flutter speed is approached. Once the critical flutter speed has been exceeded, the oscillations increase in magnitude until failure occurs. The onset of hard flutter would provide no time for a pilot to react or recover from the event.

TVAL arrived at an estimate of the critical flutter speed, which lay just outside the flight envelope of the Albatros D.Va. It is worth noting that the predicted speed is very likely achievable in a dive, which is where flutter was observed historically, and that flutter may be induced at a lower speed in high turbulence. Modifications were made to the structure to increase the margin of damping, which moved the critical flutter speed further outside the normal flight envelope of the aircraft. ∎

Gene DeMarco is production manager with TVAL, based in New Zealand

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