SEPTEMBER 2015

AEROSPACE TESTING INTERNATIONAL

ELECTRIC FUTURE

EXCLUSIVE: Why Airbus, NASA and leading universities believe electrical and hybrid aircraft propulsion will shape the future of aircraft development

electric & hybrid aerospace
TECHNOLOGY SYMPOSIUM 2015
FULL PROGRAM INSIDE!

HERVÉ JAMMAYRAC
Meet the chief test pilot for Airbus Helicopters, and the man at the helm during the X³'s world speed record

PRANDTL-M
A revolutionary flying wing design being developed by NASA could help man to land on Mars

CARRIER LAUNCH TRIALS
The first F-35B Lightning II ski jump launches, and the latest from the US Navy's electromagnetic launch system

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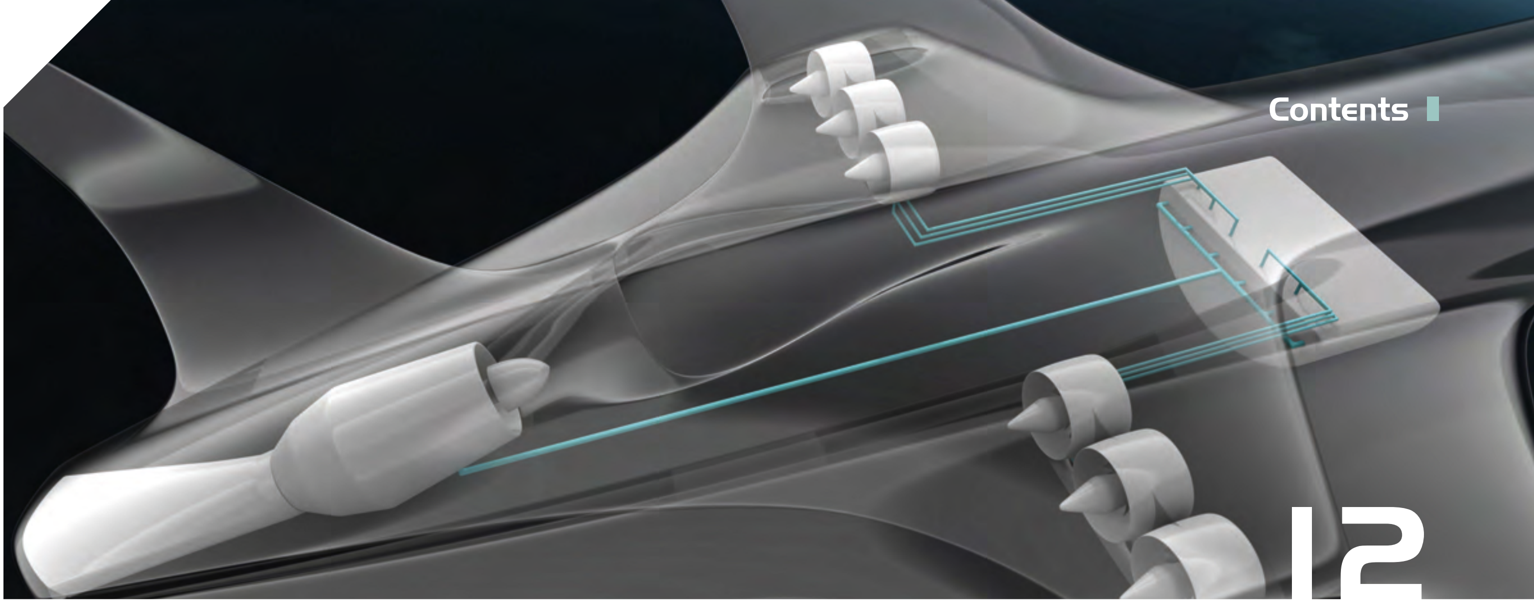

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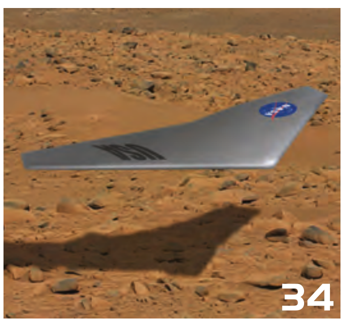

EVENTS

INSPIRATION INFORMATION

September has arrived, hinting at the colder, darker months to follow (at least here in the Northern Hemisphere), and prompting a rather melancholic response in those reluctant to relinquish the warmer, brighter days of summer. However, if you're seeking some inspiration to keep your spirits up, the aerospace sector has much to offer. Just take NASA's research into a flying wing to glide over the surface of Mars, in preparation for a possible landing. It's incredible to think that right now there are teams of scientists and engineers working out how to perfect its design, not to mention how best to reproduce the Martian atmosphere here on Earth for flight testing purposes!

"The aircraft would be part of the ballast that would be ejected from the aeroshell that takes the Mars rover to the planet," explains NASA Armstrong's chief scientist Al Bowers. "It would be able to deploy and fly in the Martian atmosphere and glide down and land. It could overfly some of the proposed landing sites for a future astronaut mission and send back to Earth very detailed high-resolution photographic map images that could tell scientists about the suitability of those landing sites."

As our exclusive article reveals (p34), the program is also helping to solve an aerodynamic conundrum: "It turns out that flying wings are a rather difficult problem," says Bowers. "But we believe we have figured out how it is that birds are able to maneuver without a vertical tail. We have had some difficulty in convincing the aeronautical community that we have solved this problem. So one of the things we have done is that we have paid for a wind tunnel model and a wind tunnel test at NASA Langley in three weeks' time [at the end of August]. So three weeks from now I will be in a wind tunnel with the engineers and researchers at NASA Langley with one of these designs, and I can have them generate the data for me." A journal article on Bowers' findings is pending.

For further spiritual invigoration, how about a little 'electric shock' treatment? Turn to our cover story on page 12, which details ongoing efforts around the globe to realize a fuel-free aviation future through the development of electrical and hybrid aircraft propulsion systems that would underpin a new generation of quieter, cleaner, greener aircraft.

Skeptical? Hopefully our article will give you some pause for thought: "Current technology levels are enough to develop a commuter aircraft with an electric propulsion and hybrid energy system that outperforms conventional aircraft in the field of noise emission, energy and maintenance costs," says Len Schumann, a senior researcher at the University of Stuttgart's Institute of Aircraft Design.

His optimism is echoed by Dr Detlef Müller-Wiesner, head of Airbus Group's e-aircraft program directorate: "There are many factors, including industry take-up and advances in battery cell development, to consider," he says, "but looking ahead to the next 15 to 30 years, we could potentially see hybrid airplanes with a range of 500-1,000 miles."

For those seeking the strongest dose of inspiration possible, a trip to Bremen this November is in order. Host to the brand-new Electric & Hybrid Aerospace Technology Symposium – the world's first international conference dedicated to the increased electrification of aircraft, as well as the European debut of Space Tech Expo – Bremen Messe will be positively buzzing with inquiring minds and the latest innovations from November 17-19.

If that wasn't enough, Bremen will also host Aerospace Electrical Systems Expo, which includes a dedicated Testing Zone. Turn to our previews on pages 72 and 82 for further information.

It may not be quite as arduous as a trip to Mars, but visiting Bremen this November could also prove to be very rewarding! We hope to see you there.

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COVER IMAGE: EADS eCONCEPT, DEVELOPED IN PARTNERSHIP WITH ROLLS-ROYCE

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WORLD
TEST UPDATE

1 DFA TESTING BEGINS ON ORION

The Orion crew module flown 3,600 miles into space during Exploration Flight Test-1 has arrived at the Lockheed Martin Space Systems company headquarters in Littleton, Colorado, USA. Engineers at the site will now perform final decontamination on the crew module, continue post-flight analyses of select components, and evaluate a new acoustic technology called Direct Field Acoustic (DFA) testing. The team will determine if the method can produce enough energy to simulate the acoustic loads Orion will experience during launch and ascent on the Space Launch System (SLS) rocket.

DFA involves testing with customized, high-energy speakers that use a specific algorithm to control how much energy reaches the vehicle. The speakers will be configured in a circle around the vehicle – the amount of speakers needed for the test will fill up three tractor-trailers. Testing is expected to conclude in early 2016.

If the method proves to be an accurate representation of SLS launch and ascent acoustic loads, it will be used to evaluate and verify Orion's ability to withstand those loads during its next mission, Exploration Mission-1.

Littleton, Colorado, USA

2 BOEING TO TEST 777X FOLDING WINGTIP PROTOTYPE

A revolutionary folding wingtip prototype that will increase wingspan on the Boeing 777X by almost 24ft during flight, yet also allow the aircraft to conform to existing taxiway and gate size restrictions when retracted for ground operations, is undergoing testing at Boeing's Everett, Washington, facility. The tests are designed to analyze operational reliability and any resulting mechanical stress.

Meanwhile, Boeing has also announced the completion of the firm configuration milestone for the 777-9, the first member of the 777X family. This marks the completion of configuration trade studies required to finalize the airplane's capability and basic design. Wind tunnel test results, aerodynamic performance and structural loads have also been evaluated to ensure the airplane meets requirements. The 777X team can now begin detailed design of parts, assemblies and other systems for the airplane. As detailed designs are completed and released, production can begin.

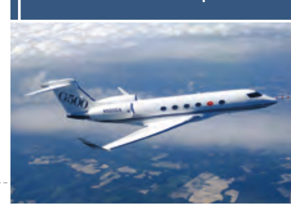
Everett, Washington, USA

3 HIGH FIVES AT GULFSTREAM AS G500 BEGINS FLIGHT TESTING

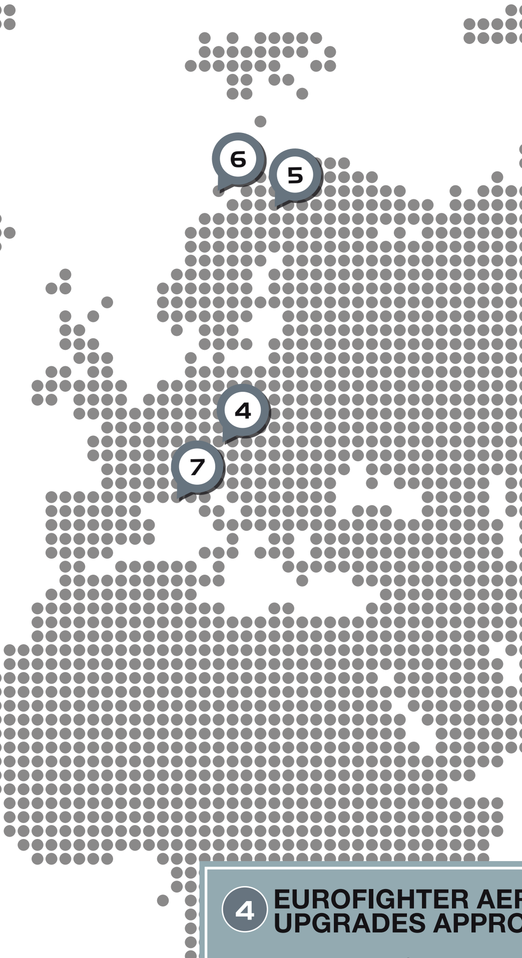
Gulfstream reported in August that the G500 had completed five test flights since it first took to the skies in May. During more than 15 hours of flying, the aircraft achieved a top speed of Mach 0.80 and a maximum altitude of 38,500ft (11,735m). The aircraft's longest flight was more than four hours. "The first five flights exceeded our expectations," said Dan Nale, senior vice president, programs, engineering and test, Gulfstream. "And they demonstrated that our testing facilities on the ground are having very real benefits in the air, allowing us to identify and address issues before they're ever seen in flight."

The first G500 flight test article has since been modified, with flutter vanes fitted to the winglet and tail and a recovery parachute installed in preparation for flutter testing. It has now resumed flying, completing more than 40 hours of flight testing.

Meanwhile two more test articles are preparing to join the program, while a fourth is in production. Additionally, the first G600 flight test aircraft has begun the initial stages of production. Together, the two programs have completed more than 36,000 hours of lab testing, and both the G600 integration test facility (ITF) and the G600 Iron Bird are now operational. Gulfstream anticipates certification of the G500 in 2017, with entry into service in 2018. The G600 certification is slated to follow in 2018, with entry into service in 2019.



Savannah, Georgia, USA



SEE INTERVIEW ON PAGE 46

7 H160 FLIGHT TEST CAMPAIGN LAUNCHED

Airbus Helicopters' highly innovative H160 flew for the first time in Marignane, France, on Saturday, June 13, shortly after beginning its ground runs at the end of May. The aircraft flew for about 40 minutes in ground effect, allowing the flight test team to check the overall behavior of the aircraft and to verify the measurements. "The first flight was very promising in terms of stability, vibrations and sound levels," said Olivier Gensse, the flight test pilot. The flight envelope has since been expanded, with the aircraft reaching 130kts during its second flight on Wednesday, June 17.

In order to complete this final development phase and to ensure the H160's entry into service in 2018, Airbus Helicopters is relying on three dedicated prototypes and two helicopter 'zero integration' test benches on the ground. The first prototype is currently conducting its flight test campaign, including its first hot weather flight tests. The second prototype performed its first power-on on June 12.

Marignane, Marseille, France

6 HYPERSONIC FLIGHT TRIAL

The latest trial of the joint Australia-USA Hypersonic International Flight Research Experimentation (HIFiRE) program was conducted in August at the Andøya Rocket Range in Norway. The flight experiment, known as HIFiRE 7, was designed to determine how scramjet engines start up at high altitudes, and to measure how much thrust the engines produce at lower altitudes, as well as to test the complex systems necessary for the reorientation and control of hypersonic vehicles outside the atmosphere and in the atmosphere at hypersonic speeds.

The scramjet stage of the experiment commenced after completing a suborbital flight and re-entering the atmosphere as the payload accelerated to over seven times the speed of sound, or 2km/s. During atmospheric re-entry, the flight data stream from the payload was lost just 15 seconds before the completion of the flight, possibly due to overheating of the voltage regulator in the telemetry system. However, data received in the early part of the flight showed that the test vehicle was functioning perfectly, the flight was proceeding on the correct trajectory, the flight control system performed flawlessly, and supersonic airflow was established in the combustor.

The next two flights in the HIFiRE program will be conducted at the Woomera Test Range in South Australia during 2015 and 2016.

Andøya Rocket Range, Norway

4 EUROFIGHTER AERODYNAMIC UPGRADES APPROVED

Airbus Defence and Space has successfully completed flight testing of a package of aerodynamic upgrades to the Eurofighter Typhoon swing-role fighter. The Aerodynamic Modification Kit (AMK) is part of a wider Eurofighter Enhanced Maneuverability (EFEM) program, and sees the addition of fuselage strakes and leading-edge root extensions, which increase the maximum lift created by the wing by 25%, resulting in an increased turn rate, tighter turning radius, and improved nose-pointing ability at low speed – all critical in air-to-air combat.

Eurofighter project pilot, Germany, Raffaele Beltrame said, "We saw angle of attack values around 45% greater than on the standard aircraft, and roll rates up to 100% higher, all leading to increased agility. The handling qualities appeared to be markedly improved, providing more maneuverability, agility and precision while performing tasks representative of in-service operations."

The flight trials followed some five years of studies. Eurofighter test pilots, joined in the latter stages by operational pilots from Germany, Italy and the UK, completed 36 sorties from Manching, Germany, on the IPA7 Instrumented Production Aircraft.

Manching, Germany

5 D-SEND#2 SECOND PHASE TEST RESULTS

Japan Aerospace Exploration Agency (JAXA) conducted the second phase test of the 'Drop test for the Simplified Evaluation of Non-symmetrically Distributed sonic boom' project (D-SEND#2) at the Esrange Space Center in Sweden on July 24, 2015. The supersonic experimental airplane successfully flew over the boom measurement system (BMS), with the booms generated from the airplane measured by multiple microphones. The BMS uses multiple aerial microphones tethered to a blimp to measure sonic boom without being affected by atmospheric turbulence near the ground.

During the test, the Supersonic Experimental Airplane (S-cube Concept Model, or S3CM) was separated from a balloon at 30km altitude. Accelerating into supersonic speed during its free-fall, at Mach 1.3 with flight path angle of 50°, the airplane glided over the BMS, with the resulting boom measured for further analysis. JAXA reports that the experimental airplane flew normally and was terminated safely within the test area.

Esrange Space Center, Sweden

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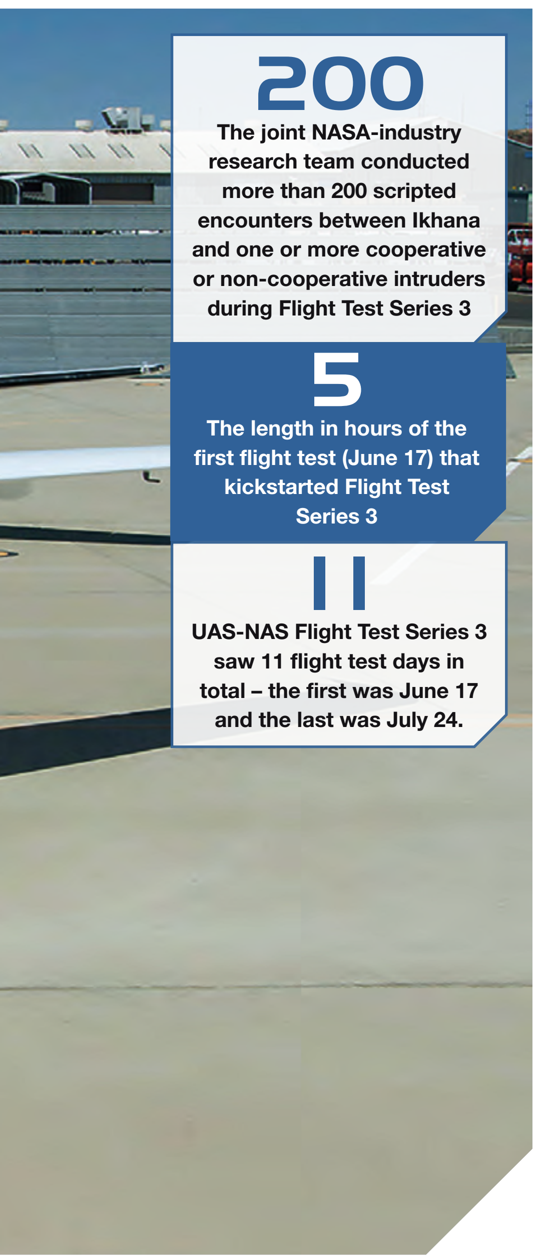
AEROSPACE TESTING INTERNATIONAL NEWS EXCLUSIVE

NASA TESTS SENSE-AND-AVOID SYSTEM FOR UNMANNED AIRCRAFT

NASA, working with government and industry partners, continues to test a system that will make it possible for unmanned aircraft to fly routine operations in US airspace. "This system is very close in technical performance to the minimum operational performance standard being developed by RTCA SC-228," explained a NASA spokesperson.

Through the agency's Unmanned Aircraft Systems Integration in the National Airspace System (UAS-NAS) project, NASA, General Atomics Aeronautical Systems Inc (GA-ASI) and Honeywell International flew a series of tests beginning on June 17 and continuing through July at NASA's Armstrong Flight Research Center at Edwards Air Force Base, in California, USA.

"We are excited to continue our partnership with GA-ASI and Honeywell to collect flight test data that will aid the development of standards necessary to safely integrate these aircraft into the National Airspace System," said Laurie Grindle, UAS-NAS project



200

The joint NASA-industry research team conducted more than 200 scripted encounters between Ikhana and one or more cooperative or non-cooperative intruders during Flight Test Series 3

5

The length in hours of the first flight test (June 17) that kickstarted Flight Test Series 3

11

UAS-NAS Flight Test Series 3 saw 11 flight test days in total – the first was June 17 and the last was July 24.

manager at Armstrong, speaking at the time of the tests.

This was the third series of tests that builds on the success of similar experiments conducted late last year that demonstrated a proof-of-concept sense-and-avoid (SAA) system. NASA planned and executed the flight test series with input from partners GA-ASI and Honeywell, who both provided the necessary hardware. Tests were conducted in restricted airspace near NASA Armstrong Flight Research Center at Edwards Air Force Base in California, USA.

SIMULTANEOUS TESTING

The tests engage the core air traffic infrastructure and supporting software components through a live and virtual environment to demonstrate how a remotely piloted aircraft interacts with air traffic controllers and other air traffic. "This is the first time that we are flight testing all the technology developments from the project at the same time," Grindle added.

This series of tests is made up of two phases. The first is focused on validation of sensor, trajectory and other simulation models using live data. Some of the tests were flown with an Ikhana aircraft, based at Armstrong, that has been equipped with an updated SAA system as well as other advanced software from Honeywell International.

Other tests involved an S-3B plane from NASA's Glenn Research Center in Cleveland, Ohio, serving as a high-speed piloted surrogate aircraft. Both tests used other aircraft following scripted flight paths to intrude on the flight path flown by the remotely piloted craft, prompting it either to issue an alert or maneuver out of the other aircraft's path. These flights also saw the first full test of the traffic alert and collision avoidance system (TCAS II) on a remotely piloted aircraft.

During the June 17 test, which lasted a little more than five hours, the team accomplished 14 encounters using the Ikhana aircraft and a Honeywell-owned Beechcraft C90 King Air acting as the intruder. A second test was flown the following day, with a total of 23 encounters. The project team flew more than 200 encounters throughout the first phase of the test series.

"Our researchers and project engineers have gathered a substantial amount of data to validate their pilot maneuver guidance and alerting logic, which has previously only been evaluated in simulations," said Heather Maliska, Armstrong Flight Research Center's UAS-NAS deputy project manager.

The second phase of the third test series, which began in August, will include a T-34 plane equipped with a proof-of-concept control and non-payload communications system. It will evaluate how well the systems work together so that the aircraft pilots itself, interacts with air traffic controllers and remains well clear of other aircraft while executing its operational mission. The aircraft, which will have an onboard safety pilot, will fly an operationally representative mission in a virtual airspace sector complete with air traffic control and live and virtual traffic.

While the previous flight test series (FT2) in 2014 was a proof-of-concept demonstration, FT3 is a full performance flight test of a prototype detect-and-avoid (DAA) system that included legacy TCAS II and the engineering development model Due Regard Radar developed by GA-ASI.

NASA's Flight Test Series 4 is scheduled for the first quarter of 2016. GA-ASI is currently preparing to flight test the DAA system that will eventually be integrated onto on Ikhana aircraft for FT4.

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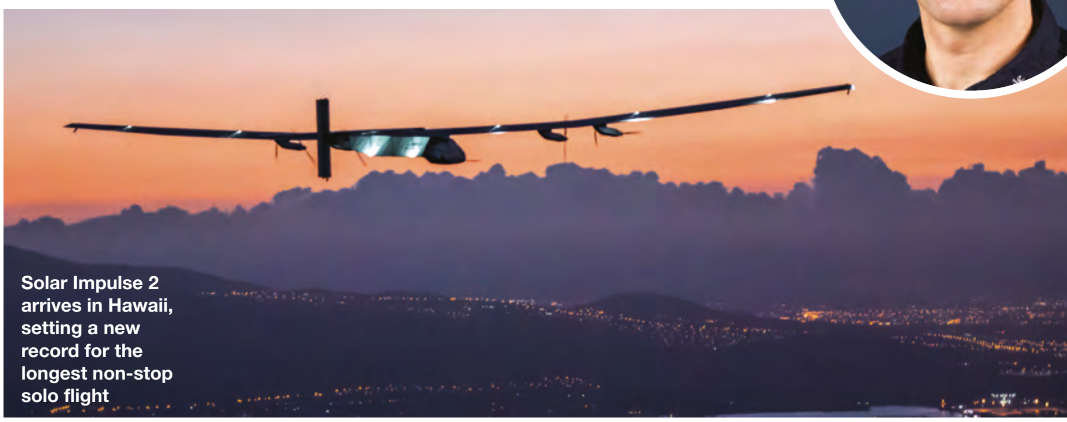
CHRISTOPH SCHLETTIG

Flight director/flight test engineer, Solar Impulse, Switzerland



Solar Impulse 2 arrives in Hawaii, setting a new record for the longest non-stop solo flight

electric & hybrid aerospace
TECHNOLOGY SYMPOSIUM 2015

Christoph Schlettig will present a paper entitled 'Solar Impulse – the first human-carrying aircraft capable of perpetual flight' on Day 1 of the Electric & Hybrid Aerospace Technology Symposium

See the full program on p72

In a new series, *Aerospace Testing International* talks to the individuals involved in the most interesting and innovative testing and research programs currently running. We start with Christoph Schlettig and the Solar Impulse 2, which recently completed the first-ever oceanic crossing by a solar aircraft, from Japan to Hawaii, before being grounded by battery failure.

HOW DID YOU FIRST GET INTO AEROSPACE, AND MORE SPECIFICALLY, TESTING?

My interest in aerospace was sparked as a boy. Initially I was into radio-controlled model airplanes, which I modified all the time. My 'experimental hangar' held canards, blended wings, negative swept wings and quadruple wing models. Most of them impressed with their ridiculous design rather than their flying qualities. After my graduation from university, I was offered a position as flight test engineer on a business jet project with Grob Aerospace in Germany. I was privileged to work with some very experienced flight test engineers and test pilots who taught me the basics, and within a short time I was the FTE in charge for aircraft performance and auto flight.

WHAT BATTERY TECHNOLOGY DOES Si2 USE, AND WHAT WENT WRONG?

Si2 uses four identical, custom-built lithium polymer batteries. Each battery contains 70 individual cells supplied by KOKAM; the housing and battery box has been developed by Solar Impulse. We care a lot about the batteries and keeping them at peak performance. During flights, we monitor hundreds of battery cell parameters in real time and have strict pilot procedures should we reach any of the limits.

However, during the first ascent on Day 1 of the flight from Nagoya to Hawaii, we had to fly an unusual altitude profile, which resulted in increased battery temperature. While the flight profile for the subsequent days was modified as much as possible, there was no way to decrease the temperature for the remaining days.

The damage to the batteries is not a technical failure or a weakness in the technology, but rather an evaluation error in terms of the profile of the mission and the cooling design specifications of the batteries. The temperature of the batteries during non-standard ascent/descent in tropical climates was not properly anticipated.

WHAT WERE SOME OF THE KEY TECHNOLOGY UPGRADES YOU MADE BETWEEN Si I AND Si2?

Our first aircraft, Si1, was designed as a highly experimental proof of concept intended to be operated over land and up to a flight time of 24 hours maximum. The main upgrades for Si2 include a special autopilot, which allows the pilot to sleep during flights of up to 120 hours. The cockpit does includes a lie-down seat with an enclosed toilet, storage space for food, water and personal belongings, as well as pilot rescue equipment like parachute, life raft, locator beacon and a dry suit. During the design of Si2, a complete system safety analysis was performed. Compared with Si1, the Si2 system design is much more robust and failure tolerant, enabling the pilot to successfully complete flights of up to five days, even with multiple failures.

WHAT ROLE DO YOU FEEL SOLAR-POWERED AIRCRAFT COULD PLAY IN THE FUTURE?

Everybody agrees that Formula 1 race cars are unsuitable for weekend shopping. Still, technologies like carbon-ceramic brakes or dual-clutch transmissions have found an application in normal cars. Given the current capability of batteries and the solar constant being about 1,300W/m^2 at best, it is clear that solar-powered aircraft are very restricted. However, improvements in battery and electric propulsion technology are enormous. I am convinced that we will soon see very interesting developments, most likely in the area of unmanned solar-powered high-altitude platforms. In a sense, solar aviation should be understood like Formula 1. Lightweight structures and energy savings are major topics everywhere. Solar-powered aircraft will have found their place, once their concepts and ideas find their way in other branches of aviation.

WHICH PART OF THE Si2 TESTING PROGRAM HAS PROVED THE MOST CHALLENGING?

During the first flights of Si2, we encountered a vibration phenomenon originating from the propellers in non-perpendicular airflow (AoA and/or AoS). Our engineers immediately started to work on a technical solution, but the modification would not be available for a few weeks. Because Si2 required near-perfect meteo conditions for test flights, we knew that we would only have three or four suitable weather windows per month. With time limited, it was not easy to develop an alternative test program within a confined aircraft envelope that still allowed overall project progress. So the most interesting challenge was the flight test management, not a particular technical problem.

WHAT NEXT FOR Si2?

The University of Hawaii is currently hosting the aircraft in its hangar at Kalaeloa Airport, while we repair the batteries. Post maintenance check, flights will start in 2016 to test the new battery heating and cooling systems. ▮

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GARNET RIDGWAY

ERROR PRONE?

A spate of recent air accidents has been attributed to human factors. Is this an emerging trend or simply history repeating itself?

SOPHIE ROBINSON

Human factors (HF) as a contributory cause of air accidents is as old as aviation itself, although admittedly it gained its moniker only relatively recently. It can therefore be argued that the 'recent trend' of HF-related accidents is, in fact, simply the continuation of a problem that has never been fully understood.

During World War I, the British Royal Flying Corps concluded that 90% of fatalities among pilots were caused by "their own deficiencies". Today, the majority of this percentage would certainly be classified as HF-related (insufficient training, fatigue, excessive workload), giving a proportion comparable to that of modern aviation accidents.

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 the period following World War I, efforts were made to improve the accommodation of human physiology into military aircraft in the hope of reducing accident rates. While some progress was made (the advent of closed cockpits, for example), the psychological aspects of HF were still poorly understood. By way of demonstration of this lack of understanding, consider the world's first widely adopted flight simulator, the Link Trainer.

Despite its name, the Link Trainer was actually envisaged as a device for the selection of pilots "most suitable for instrument flying". This backward approach of attempting to tailor the users to the requirements of the machine, rather than vice versa, is indicative of the attitude prevalent for much of the 20th century, and lingers to this day. Additionally, causes of accidents resulting from these psychological subtleties are far more difficult to identify after the event; this resulted in further misidentification of HF-related accidents as "pilot error" or other such catch-all phrases.

So, what is the way forward? Ironically, the most effective (and often final) layer of mitigation for HF errors in design or maintenance is a human operator – an ability to cope well with sudden, unexpected changes has been instilled by millennia of evolution. However, this must be facilitated by good, user-centric system design and comprehensive HF assessment at the test and evaluation phase. Finally, there must be an acceptance that HF is, in fact, a real issue that causes fatal air accidents.

The role that the human element can play in air safety has recently been put in to sharp focus by a spate of accidents caused by HF – Virgin Galactic, TransAsia Flight 235 and the Lynx Mk9A crash in Afghanistan being just a few examples from recent months.

What could be causing this apparent surge of human-induced accidents? The increased maturity of all areas of aircraft design is partly to blame; engines are more reliable, airframes stronger and materials more durable, meaning accidents resulting from mechanical or manufacturing failures are becoming rarer. As a result, the proportion of HF-related accidents has increased.

While technological advances have improved safety in some areas, advances in other areas have created new safety issues. For example, as the sophistication of avionic systems (autopilots, navigation, radios, and so on) in aircraft has increased, so too has the cognitive effort required to fly modern aircraft. This can result in a dangerously high workload for the pilots, and combined with the high-pressure nature of aviation jobs, can lead to mistakes being made that can have deadly consequences. This was not the case for the relatively simple aircraft and relaxed duty cycles of yesteryear.

The increasingly automated cockpit environment can also lead to low crew arousal: according to a 2013 survey by the British Airline Pilots' Association, more than half of pilots have fallen asleep in the cockpit. The poll showed that of the 56% who admitted to taking an impromptu nap, 29% said they had awoken to find the other pilot asleep. This certainly wouldn't happen if piloting an aircraft required the full attention of the crew for the duration of the flight!

Sophie Robinson works at the front line of aerospace testing as a rotary-wing performance and flying qualities engineer for a leading UK-based aircraft test organization. She also holds a PhD in aerospace engineering from the University of Liverpool

As aircraft continue to become more complex, and testing schedules remain tight, HF issues have the potential to be missed during the design, manufacturing and testing stages of the product lifecycle. As the proportion of accidents attributed to HF continues to increase, it is logical to increase proportionally the attention paid to HF-related issues during aircraft evaluation. While HF can never be eradicated, there certainly remains scope for improvement.

For opinion, videos and more: AerospaceTestingInternational.com

MAIN: Airbus Group's two-seater E-Fan 2.0 will be a fully electric training aircraft powered only by batteries

Electric dreams

Aerospace Testing International talks to Airbus, NASA and leading universities about the future of electric and hybrid flight and the challenges ahead

BY JAMES GORDON

Electric-powered flight on a grand scale may seem like a distant dream, but when you listen to Dr Detlef Müller-Wiesner, who heads Airbus Group's E-Aircraft Program Directorate, you begin to realize that, although in itself quite small, the E-Fan demonstrator aircraft that recently flew across the English Channel (see sidebar, overleaf) is part of something far, far bigger.

"We believe electrical and hybrid aircraft propulsion has the potential to become a game-changer in aircraft in the future," says the Airbus man. "The E-Fan project is important because if we are to pave the way for an electrical hybrid aircraft propulsion future, we realized that we would need to start at a low certification level, which means light sports aircraft. It is easier to certify electrical propulsion elements with this size of aircraft, too, because the system complexity is less challenging than for bigger aircraft," he says.

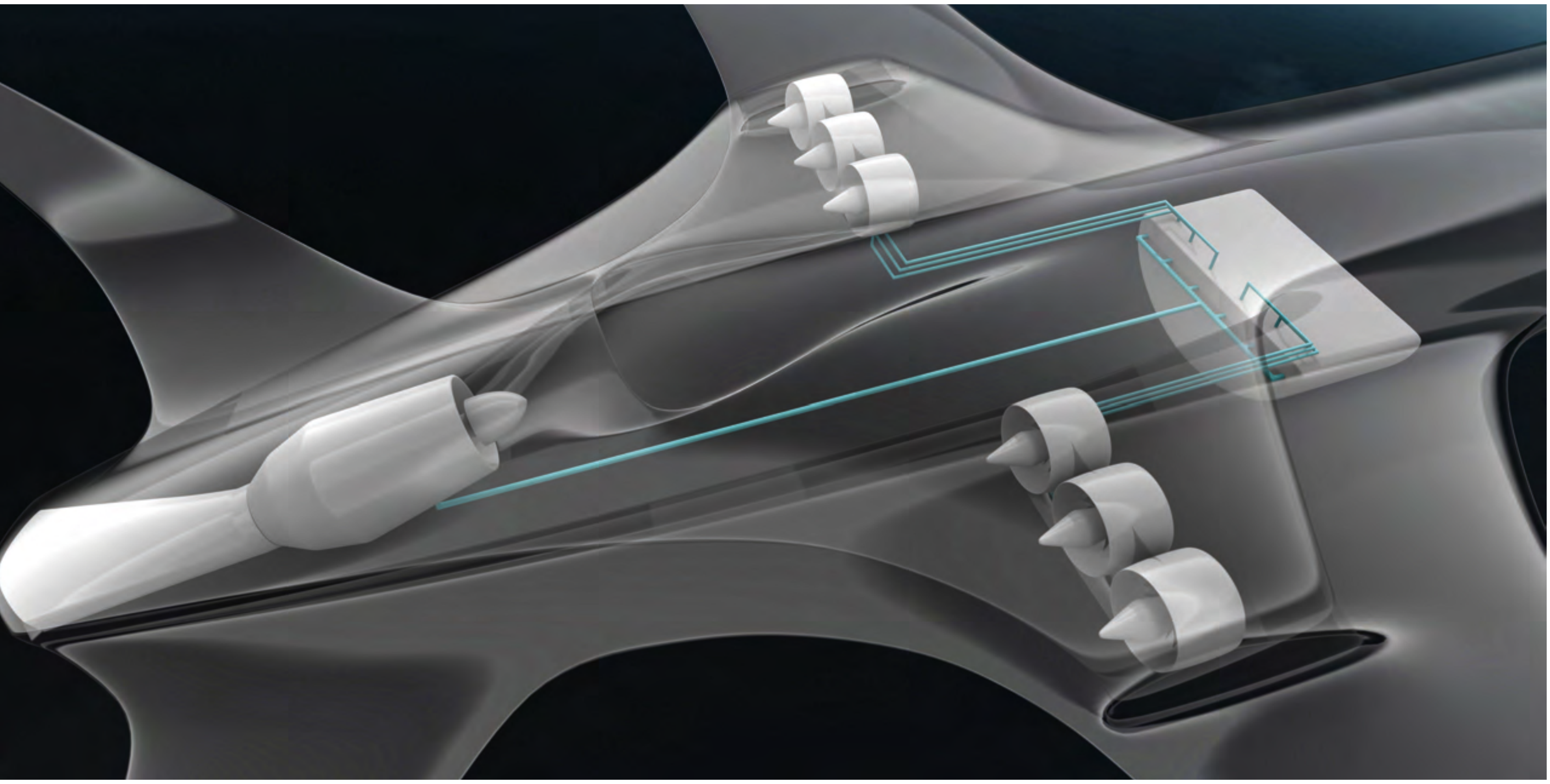
The testing focus so far has been on the characterization and verification of the EPU (electrical propulsion unit) with respect to the intended mission profile, explains Müller-Wiesner. "In particular, the mechanical, thermal and electrical behavior of all elements [engines, batteries, power electronics software and the e-FADEC – the fully digital electrical aircraft energy management system], and their interaction with other systems, has been a focus of our testing of the E-Fan technology demonstrator."

The demonstrator is fitted with a telemetry system transmitting data such as battery charge, rate of discharge and temperatures of the batteries, controller and motors, as well as conventional performance-related flight data such as speed and altitude. Data from every single flight is relayed, supervised on the ground and recorded.

FUEL-FREE FUTURE

The E-Fan technology demonstrator is the first of a series of aircraft that the company is developing to realize the dream of a fuel-free aviation future. Airbus Group thinks that developing a less-polluting hybrid-electric version for commercial purposes is achievable in the next 30 years or so.

But one step at a time. The next stage is the construction of the E-Fan 2.0 – a two-seater all-electric aircraft that will be used for basic pilot training and is slated for delivery at the end of 2017. "The two-seater E-Fan 2.0 is the industrialized version of the E-Fan demonstrator," says Müller-Wiesner,



"where a pilot is seated beside the instructor and not behind him."

The batteries will store more than 25kWh, meaning that the aircraft can remain in the air for about 90 minutes. The lithium battery system, powered today by batteries containing Panasonic cells, will be fully charged in the future in 90 minutes or less.

"There is no testing of E-Fan 2.0 yet, as the design is not finalized and production of the first aircraft has not started," says Müller-Wiesner.

The E-Fan 2.0 will be followed by the 4.0, a hybrid four-seater light aircraft, which is expected to enter service shortly after the E-Fan 2.0. This airplane, which is also being aimed at pilot training schools, will contain a thermal engine, which will provide electrical energy as part of a genset to the batteries and engines during cruise, allowing the airplane to remain airborne for longer.

Of course, these aircraft, many of which will be flown from small airfields surrounded by large urban populations, will be considerably quieter than their kerosene-powered counterparts: "I can say that the noise measurement tests we have carried out on our small demonstrator aircraft so far are in the range of a noise reduction of -5dB to -10dB, which equates to half or a quarter of the noise from an existing piston engine airplane in comparison," says Müller-Wiesner. "It could be that these airplanes enable airports with flying schools to extend their operating times."

ACROSS THE ATLANTIC

NASA, too, is keen to do its part to breathe life into small airports. It has set its Aeronautics Research Mission Directorate the task of overhauling a conventional four-seater light aircraft by adding as many as 20 small electric propeller engines to new wings.

Sean Clarke, a senior systems development engineer at NASA's Armstrong Flight Research Center in Southern California, explains the reasons behind the US$15m Leading Edge Asynchronous Propeller Technology (LEAPTech) project, which will come to fruition in 2017.

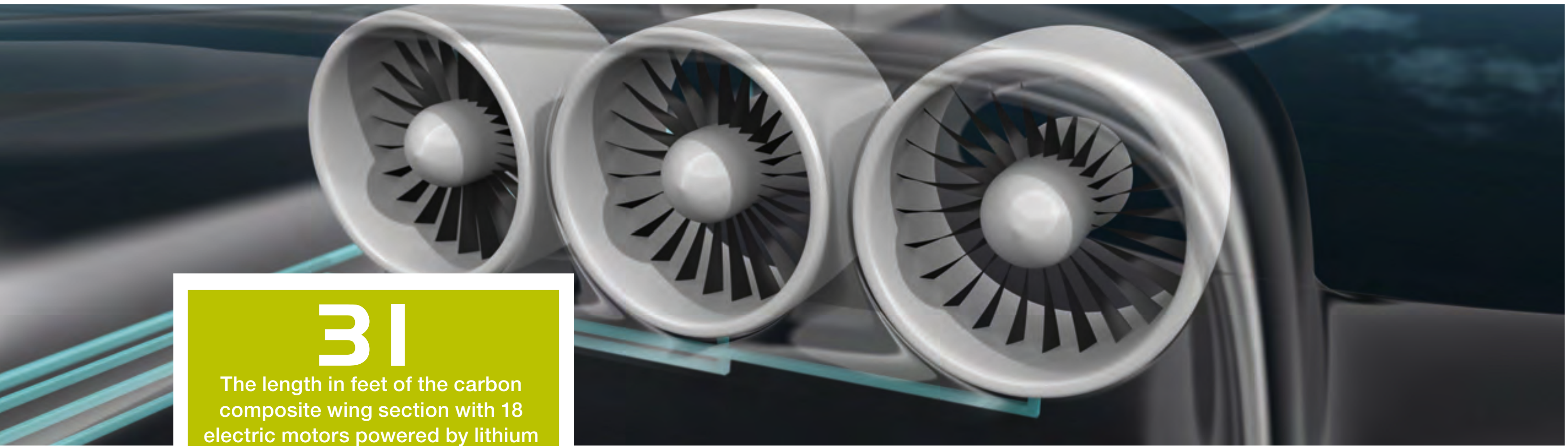
ABOVE: Airbus Group's E-Thrust is a distributed propulsion system featuring numerous electric fans arranged in clusters along the length of each wing. A battery powers the fans, which is also charged by an onboard advanced gas power unit

CHANNEL CONUNDRUM

Airbus Group's E-Fan technology demonstrator (right) became the world's first twin-engine electric aircraft taking off with its own power to successfully cross the English Channel on July 10, 2015, some 106 years after Louis Blériot's epic flight.

From take-off at England's Lydd Airport to touchdown at Calais-Dunkerque Airport in France, the all-electric E-Fan demonstrator performed its 73km (46 mile) crossing in just 36 minutes.

However, Airbus's celebrations were somewhat marred by a crossing made a day earlier by Hugues Duval in a one-seater electric aircraft he developed himself. But Airbus maintained an upbeat tone when pressed on the subject: "We are not worried," said an Airbus spokesperson. "It would not count because we understand he set off from another airplane. We applaud the intrepid aviator that did this, although the actual details are yet to be confirmed."



ABOVE: The E-thrust concept's electric fans are powered by battery, but can also be charged by an onboard advanced gas power unit – the gas plant powers the fans directly, though the battery can be charged to power an emergency landing should the gas system fail

31

The length in feet of the carbon composite wing section with 18 electric motors powered by lithium iron phosphate batteries that NASA is testing as part of its LEAPTech project

75

The maximum authorized battery operation temperature (°C) for Airbus's E-Fan aircraft

"If aircraft could be made quieter, then smaller airports become much more viable," he says. "These are all goals that we would like to help the aviation industry to attain. And so our airplane is not going to become a commercial project. Instead we are building a demonstrator for technologies that could eventually be adopted by private industry and made into commercial projects. If in the next 20 or 30 years, we are able to reduce greenhouse gas emissions and make aircraft quieter, then our goals will have been met," Clarke says.

Clarke and his team are in the first stage of three-phase project. NASA researchers began ground testing of a 31ft-span, carbon composite wing section with 18 electric motors powered by lithium iron phosphate batteries at the Armstrong Flight Research Center in February 2015. The experimental wing, called the Hybrid-Electric Integrated Systems Testbed (HEIST), is mounted on a specially modified truck. Instead of being installed in a wind tunnel, the HEIST wing section remains attached to load cells on a supporting truss while the vehicle is driven at speeds of up to 70mph across a dry lakebed at Edwards Air Force Base.

The team has also rented a baseline aircraft – a Tecnam P2006T – and Clarke and his colleagues began flight testing "to collect stock performance data" at the start of September. Within a few years, NASA hopes to fly a piloted X-plane, replacing the wings and engines of the P2006T with an improved version of the LEAPTech wing. Using an existing airframe will allow engineers to compare the performance of the flight demonstrator with that of the original P2006T.

TESTING APPROACH

NASA is using a time-tested systems engineering approach, which includes functional and environmental testing of each of the experimental components individually before integration into the experimental aircraft. This includes the high aspect ratio wing, the high-performance electric motors, and the batteries. Once these are all integrated together onto the aircraft, full system testing will validate the overall performance.

"Flight testing will require a series of test points to expand the performance envelope in altitude, airspeed, and motor power," adds Clarke. "This way we can carefully evaluate the unique advantages this vehicle will bring – such as the performance gains of putting propulsion at the wingtip to interact with the vortex – as well as the unique challenges such as the increased yaw rate that a single engine loss would cause with the propulsion placed at the wingtips."

The NASA team is yet to decide how many electric engines it will use, but has experimented with as few as eight and as many as 20. Why so many? "Electric motors have few moving parts and are easier to monitor than traditional turbines and piston engines," he explains. "The electrification of propulsion means that we receive constant performance feedback. So for this reason, having a large number of small engines opens up a new design space."

Clarke also reveals that by coupling the propulsion with the aerodynamics of the wing, his team has seen some interesting performance benefits: "In traditional aircraft design, the propulsion system is decoupled as much as possible. But our system relies on those two systems interacting in a tightly coupled way. The coupling has enabled us to design a high-aspect ratio wing that is very efficient at cruise conditions at 150kts or so. But at the same time, the higher induced flow of the wing allows for very good take-off and landing performance. So we can have a lower stall speed with these coupled electric propellers."

The electric motors will be powered by a battery. The team is undecided on battery cell chemistry, but Clarke thinks that "lithium iron phosphate will prove too heavy", and is experimenting with lithium polymer, lithium cobalt, and lithium manganese chemistries.

FAR LEFT: NASA's Hybrid-Electric Integrated Systems Testbed mounted on a specially modified truck

LEFT: NASA's all-electric LEAPTech aircraft, which features 18 independently operated motors

2,982

The E-Fan's lithium polymer batteries are composed of a total of 2,982 cells integrated in the inboard sections of the aircraft's left and right wings

3,200

The number of seconds (53 minutes) the E-Fan demonstrator utilized its onboard lithium battery system during its recent English Channel crossing

ABOVE: The University of Cambridge has developed and successfully tested an aircraft with a parallel hybrid engine – the first ever to be able to recharge its batteries in flight

In phases two and three, the team plans to conduct a number of test flights, each lasting between 30 and 45 minutes and covering a maximum distance of 25 miles. The test flights will take place at the Dryden Aeronautical Test Range, California.

The second phase, set to fly in December 2016, will involve adding the electric motors to the wings of the airplane. In phase three, the team will remove the wings altogether and add the experimental wings to the airframe. Only then, says Clarke, will his team "see the potential benefits of tightly coupling distributed electric propulsion and the aerodynamics of the wing".

TESTING DIFFERENCES

Clarke highlights a number of key differences when testing electric aircraft: "One primary difference between testing and checkout on this vehicle, is that the vibration environment that the avionics and structural components must endure will not be driven by piston engine vibration," he says. "We expect the electric motors to operate more smoothly than the original engines. This will change how we conduct environmental testing for the rest of the aircraft components."

Overall, Clarke does not expect flight testing to differ markedly from more traditional programs, but he does note one key change: "Instead of refueling, we will be recharging the batteries, and we will need to conduct the flights as efficiently as possible to preserve battery energy for the primary measurements of power usage during high-speed cruise," he explains. "We will also have high-voltage power buses routed from the batteries to the motors, so there are some shock hazards that are unique to this vehicle. We expect about a third of the gross vehicle weight to be the battery payload, so that large mass of batteries is a potentially hazardous energy source, so we will monitor battery health carefully to prevent fires."

FUTURE FORECASTS

So just how close are we to a fuel-free aviation future? NASA's Sean Clarke thinks it might take 20 years for the industry to embrace hybrid-electric technology fully.

And if these aircraft ever do enter service, what will be their range? "There are many factors, including industry take-up and advances in battery cell development, to consider," says Airbus Group's Müller-Wiesner, "but looking ahead in the next 15 to 30 years, we could potentially see hybrid airplanes with a range of 500-1,000 miles."

> **"FOR LARGE AIRCRAFT, WE COULD BE LOOKING AT A 30% REDUCTION IN THE TOTAL COST OF OWNERSHIP"**

However, a detailed projection by Munich-based think-tank Bauhaus Luftfahrt envisions a 180-seat aircraft with a range of 900 nautical miles by 2035, assuming there is continuous progress in battery storage technology.

Dr Paul Robertson, a lecturer in electrical engineering at the University of Cambridge, UK, sounds a note of caution with regard to battery cell technology, which he believes is holding back the development of electric-powered aircraft. "The best batteries that you can write a check for now contain about 5% of the equivalent usable energy obtained from burning hydrocarbon fuel. With advances in technology, the improvement rate of batteries is likely to be about 5% year on year – that would mean it would take several decades before there is parity between electric batteries and fuel."

Robertson also believes that even if there is demand for batteries in the aviation industry, they might not necessarily become cheaper and cell chemistry more progressive.

"Why is it that I can buy the cells I can buy at the price that I buy them? It has nothing to do with aviation; it's laptops and phones, because that's what is driving advances in lithium polymer technology," he says. "So if you look at the scale, there hasn't been a market in traction batteries for very large-scale applications, although electric cars are becoming more popular. So even if the E-Fan actually went commercial and a dozen or two dozen of them sold every year, that's going to make no difference whatsoever, because that's not enough volume for anybody to change the way they make batteries."

Robertson, whose team was sponsored by Boeing to develop the first-ever parallel hybrid aircraft able to recharge its batteries in flight, thinks a hybrid airplane is more likely, but the aviation industry would have to be convinced of the economic benefits before introducing the technology on a large scale. "Nobody is going to do it unless it proves cheaper," he says. "The only other reason for introducing the aircraft into service is if major airports ban the standard gas turbine engine."

But the cost incentives are there, insists Müller-Wiesner: "For large aircraft, we could be looking at a 30% reduction in the total cost of ownership, as fuel and maintenance costs are heavily reduced." If ever there was reason to persist with the technology, then this is probably it. ∎

James Gordon is a freelance writer specializing in the aviation, automotive and energy sectors

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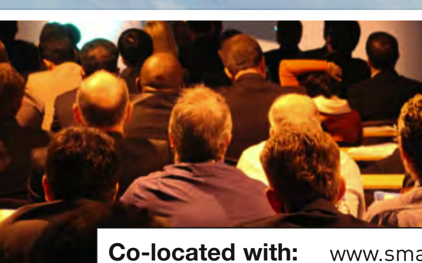

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HERO to zero

Aerospace Testing International looks at an A310's path from VIP jet to ZERO-G research aircraft

BY THOMAS NEWDICK

Beginning this year, Novespace is making use of a new airborne laboratory for its parabolic flight campaigns. The Airbus A310, a former German Air Force VIP transport, began scientific tests in April, following its successful conversion.

Unique within Europe, the ZERO-G flying laboratory provides periods of microgravity in order to conduct scientific experiments in the fields of biology, medicine, physics and technology. Furthermore, experiments have the potential to be migrated to the International Space Station after they have been proved in the aircraft's test environment – the largest of its kind currently available to scientists. As a microgravity research tool, the ZERO-G is unique in allowing scientists with no astronautical experience to carry out experiments in weightlessness by themselves.

During a career beginning in 1999, the previous ZERO-G test ship – an A300 wide-body originally built in 1973 – completed 112 parabolic flight campaigns (including a total of more than 13,000 parabolas) and provided a total of 70 hours of weightlessness. Throughout its career, the A300 completed 5,200 flights amounting to 4,200 flight hours. The aircraft was finally retired on October 31, 2014. Prior to this first-generation Airbus, more than 50 parabolic flight campaigns were carried out using Novespace's adapted Sud Aviation Caravelle ZERO-G between 1989 and 1995.

While the new aircraft is owned and operated by Novespace, a subsidiary of the French National Space Center (CNES), customers for its parabolic flights come from around the globe, and regular clients include Deutsches Zentrum für Luft- und Raumfahrt (DLR – German Aerospace Center), the European Space Agency (ESA) as well as CNES itself.

The new ZERO-G aircraft, an A310-304, the former Luftwaffe VIP transport Konrad Adenauer, was acquired by Novespace in June 2014 after it became surplus to the German Air Force's requirements. Prior to its enlistment with the military as the 'Chancellor Airbus', the A310 had enjoyed a career as a commercial airliner with the former East German state airline Interflug, to which it had originally been delivered in June 1991. Novespace spent around €2.5 million to purchase the aircraft. Over a period of 6.5 months it was extensively reconfigured and provided with new

MAIN: The interior of the ZERO-G aircraft features padded, synthetic mattresses

INSET: The new A310 ZERO-G


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RIGHT: A nano-satellite undergoes a weightlessness test, during the first campaign using the new ZERO-G aircraft

CONVERSION CHALLENGE

Leading MRO provider Lufthansa Technik had its work cut out when converting the former German government aircraft in preparation for parabolic flight. In total, some 1,350 modifications were required in the framework of the conversion program in order to convert the Airbus A310 back to its original factory default state as required by the European aviation authority, EASA. The cabin refit then commenced, with the approximately 20m-long test area proving particularly challenging.

Extra powerful light installations were required for the scientific investigations that will take place on board, with great care being taken to ensure that these would not pose a hazard for the 'weightless' passengers.

Meanwhile the certification requirements proved even more taxing than normal: "The EASA requirements were a real challenge when it came to demonstrating the structural integrity of this aircraft," admits Joerg Paisen, the Lufthansa Technik project manager with responsibility for modifying the aircraft. In total, some 50 technicians were involved directly with the aircraft in Lufthansa Technik's Hangar 5 in Hamburg during its conversion process.

Novespace's new ZERO-G aircraft is the third 'Special Mission Aircraft' in a row for the German completion specialist. Before this, the SOFIA airborne observatory, a joint project of NASA and the German Aerospace Center (DLR), had been in Hamburg for several months for a major overhaul. And Lufthansa Technik also converted a Lufthansa Airbus A340-300 on behalf of the Federal German Government to an evacuation aircraft for highly contagious Ebola patients in the shortest possible time.

certification as a civil aircraft in accordance with European Aviation Safety Agency (EASA) regulations.

The aircraft was first flown to Lufthansa Technik in Hamburg, where it underwent a brief period of maintenance – primarily external work relating to removal of its previous livery and titles. It then went to its new home of Bordeaux-Mérignac, where it embarked on its first test flights in its new guise, albeit still retaining the earlier internal configuration, including VIP cabins and bathroom.

Dr Ulrike Friedrich heads up DLR's parabolic flights program, formally titled Research Under Space Conditions: "The initial phase of tests involved pilots familiar with the previous A300 ZERO-G aircraft. After several test flights flown at low speed, the pilots flew the first parabolas with the new aircraft and it performed very well. The test program was fulfilled without any difficulty, and soon progressed to include parabolas with lunar and Martian acceleration." These different flight profiles – known as partial-g parabolas – play an important role in scientific experiments, representing acceleration of 0.16g and 0.38g respectively. Each parabola provides the scientists with around 22 seconds of microgravity. The aircraft thus provides longer periods of microgravity than drop towers (the DLR drop tower in Bremen offers five to nine seconds).

"After successful test flights in interim configuration, it was time for the Airbus to return to Lufthansa Technik for the big task of removing the VIP interior and bringing the aircraft back to technical status zero," Friedrich continues. Then came the modifications to enable the A310 to serve as the ZERO-G aircraft: almost all the related equipment was new, as opposed to being reused from its A300 predecessor. The centerpiece of the scientific lab is a new cabin, with padded synthetic leather mattresses on the floor, ceiling and walls. Safety nets prevent anything – or anybody – floating out of the experimental area, and grab bars, floor rails and special lighting are also installed to aid the scientists. New equipment included an accelerometer (or 'g instrument') in the cockpit and new sticks for the pilots, as well as converters and other items of electrical equipment to run in-flight experiments.

ABOVE RIGHT: Installing the protective mattresses in the interior of the aircraft

After take-off the ZERO-G aircraft typically heads to a restricted area over the sea, thus avoiding more powerful turbulence. Test areas include over the Atlantic southwest of Brittany and over the Mediterranean near Corsica and Sardinia. Areas above the North Sea are also used. Flight maneuvers begin at a cruising altitude of around 6,100m and a speed of around 825km/h. Ascent then begins, with the pilots pulling the aircraft into a steep climb and a period of hypergravity. After around 20 seconds the maximum angle of ascent is attained (47°, compared with a maximum of 18° for take-off). Then the engines are throttled back to a low thrust setting, putting the Airbus in free-fall, albeit continuing upward for around another 2,000m. The apex of the curve is at around 8,500m, by

13,180
total number of parabolas flown by A300 ZERO-G before its retirement

1,350
modifications made by Lufthansa Technik to convert the A310 to ZERO-G standard

100
square meters – total space available for experiments inside the A310 ZERO-G

TOP: An experiment involving the human heart and circulation system, conducted during the first campaign using the new ZERO-G aircraft

ABOVE: A weightless experiment in the previous A310 ZERO-G aircraft

which point speed has reduced to around 370km/h. Then begins the approximately 22 seconds of weightlessness as the aircraft descends in an open parabola. Once the aircraft reaches a downward angle of 42°, the crew pull back the stick and power up the engines to exit the dive and return to horizontal flight.

PHASE TWO TESTS

By the end of March 2015, the ZERO-G A310 (now wearing the French civil registration F-WNOV) was back at Bordeaux, where it embarked on the second phase of flight testing. "The focus now was on training the new pilots and cabin crew for parabolic flight work," says Friedrich. While some of the flight crew were familiar with parabolic work from the old A300, the remainder were new to the program. Almost 200 parabolas were flown before testing ended on April 24. Parabolic flights are conducted with four flight crew on board. Of these, three are seated in the cockpit while the fourth is off duty. Depending on the experiments being carried out, a pilot will be replaced by the 'spare' after perhaps five or 10 parabolas. When flying a parabola the first pilot controls aircraft movements in pitch, the second in roll, and the third controls engine thrust for forward movement. Special attachments on the column of the control sticks prevent one pilot from controlling more than one axis of the aircraft.

Just three days after the successful completion of the A310's pre-campaign test work, it was time to install equipment for the initial scientific experiments. Reflecting the project aircraft's status as part of a cooperative program, the initial campaign involved experiments from Germany (eight in total, run by DLR under the leadership of Friedrich), France (three, run by CNES) and Belgium (one, run by ESA).

Once all the test hardware had been installed, the aircraft was subject to further testing with scientists and electrical engineers on board. By May 1 the A310 ZERO-G was fully configured with all experimental equipment uploaded, and on the same day a first flight was undertaken in this configuration. A week later the A310 touched down at Bordeaux, bringing to an end the initial scientific test campaign. "Between May 5 and 7, we flew 31 parabolas each day," Friedrich confirms. This tempo constitutes a standard test campaign, and after 20 years of parabolic research, is recognized as delivering the greatest efficiency. While up to 40 scientists can be accommodated in the aircraft, a typical complement amounts to between 12 and 13 participants.

BELOW: Scientists in the waiting area prior to running experiments during the first campaign using the new ZERO-G aircraft

For Friedrich, the A310 has already proved itself an ideal platform as the new ZERO-G aircraft. "The A310 had completed very few take-off and landing cycles, which means it was a very good choice for parabolic work." Each parabola counts as a cycle, which is why it was vital to replace the tired A300 with an airframe that had completed as few cycles as possible. In fact, the only holdup along the path of bringing the A310 into service as the new ZERO-G was on the administrative side, when Lufthansa Technik and Novespace decided in January to delay the initial scientific campaign for three weeks. "That was really only a minor delay from our point of view," admits Friedrich.

The Bordeaux-based A310 will continue to be used for weightlessness research on behalf of the DLR, ESA and CNES, and the German Aerospace Center will routinely contract Novespace to perform parabolic flights for its own test projects. As such, the DLR's next ZERO-G research campaign began in Bordeaux on August 31.

In September, in a cooperative project between the University of Zurich and Novespace, the ZERO-G performed two weightless flights from Zürich-Dübendorf Airport on behalf of the university's researchers. While the Swiss faculty has been involved in Novespace's parabolic flights for a decade, this was the first time the aircraft will be operated from a country other than France. In a novel approach, funding for these flights has been generated by selling 'weightlessness discovery' flights to the nonprofessional public. The profits enable the University of Zurich scientific teams to take to the air to conduct their own work in a microgravity environment. ∎

Thomas Newdick is an aviation and defense writer based in Berlin, Germany


BF-04

Reach for the sky

A joint US/UK test team has made history with the first F-35B Lightning II ski jump launches, while the US Navy is continuing to trial a new electromagnetic aircraft launch system – known as EMALS

BY SYLVIA PIERSON & PMA-251 COMMUNICATIONS TEAM

Two recent land-based ski jumps of the F-35B Lightning II multirole short take-off and vertical landing (STOVL) variant made aviation history on June 19 and July 10 as BAE Systems test pilot Peter Wilson launched the fifth-generation stealth fighter into the skies above Naval Air Station (NAS) Patuxent River, Maryland, USA.

The ski jump tests – conducted by the joint US/UK ski jump team from the F-35 Lightning II Pax River Integrated Test Force (ITF) assigned to Air Test and Evaluation Squadron (VX) 23 — were major milestones for the F-35 program and mark the first and second time that an F-35B has taken off from a ski jump.

The tests will determine the aircraft's compatibility with British and Italian aircraft carriers. The UK and Italy use the ski jump approach to carrier operations as an alternative to the catapults used aboard US aircraft carriers (discussed later in this article). UK and Italian carriers feature upward-sloped ramps at the bow of their ships. Curved at its leading edge, a ski jump ramp simultaneously launches aircraft upward and forward, allowing aircraft to take off with more weight and less end speed than are required for an unassisted horizontal launch aboard US aircraft carriers.

"These extremely successful tests of the ski jump capability of the F-35B show how well the program is maturing toward the regeneration of UK carrier strike capability by 2020," says the F-35 Lightning II UK National Deputy, Royal Air Force Group Captain Willy Hackett, MBE. "The F-35B forms a major part of UK defense capability over at least the next three decades and will be a key element of our combat air mass, enabling us to work alongside our main allies such as the USA."

The UK is the only Level 1 partner with the USA on the joint, multinational acquisition to develop

LEFT: **The Pax River ITF conducts the first-ever ski jump of an F-35 Lightning II during flight 298 of aircraft BF-04 aboard NAS Patuxent River on June 19, 2015** (Photo: Lockheed Martin/Andy Wolfe) and field an affordable, highly common family of next-generation strike fighter aircraft for the US Air Force, Navy, Marine Corps, and eight international partners. Its major role in the F-35's system design and demonstration phase is enabling the regeneration of the UK carrier strike capability, which will result in significant contracts and jobs for UK industry as the F-35B Lightning II and Typhoon become the UK's future fast jet combat air elements.

"The F-35B ski jump was a great success for the joint ski jump team," adds Peter Wilson, BAE Systems test pilot and ski jump project leader. "I'm exceptionally proud of this team. Their years of planning, collaboration, and training have culminated in a fantastic achievement that advances the future capabilities of the aircraft and its integration into UK operations."

"The ski jump testing also validates that the designers of the F-35 have got it right, because the maneuver was so benign it will allow future F-35B pilots to focus on the mission and not be distracted or concerned about leaving or recovering to the ship," adds Hackett.

The F-35B's design allows it to position automatically the control surfaces and nozzles for take-off; a unique capability compared with previous STOVL aircraft. Such automation frees up pilot capacity and provides an added safety enhancement.

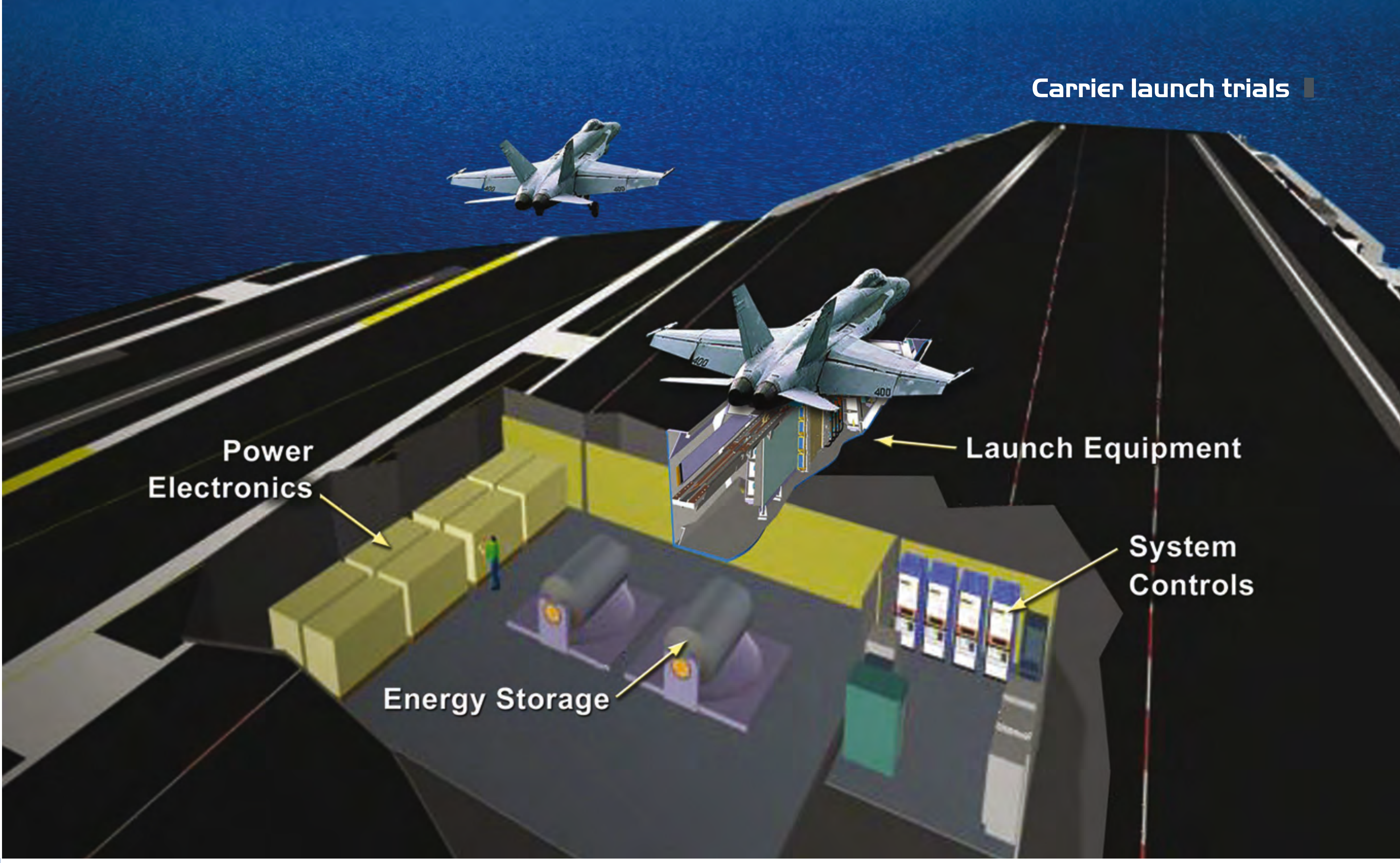
"We designed the control laws on the F-35B to make the task of taking off and landing at the ship much easier than for previous STOVL aircraft," says Gordon Stewart, flying qualities engineer representing the UK Ministry of Defence. "For ski jump launches, the aircraft recognizes when it is on the ramp and responds by positioning the control surfaces and nozzles automatically for take-off and climb. The testing [earlier this year] was our first chance to demonstrate these new control laws using a land-based ski jump. We'll be using the results – along with those from future testing – to help us prepare for the first shipboard ski jump launch from HMS Queen Elizabeth."

BELOW: **An F/A-18C Hornet readies for launch from a test runway at Lakehurst, using EMALS during aircraft compatibility testing in March 2014**

LAND-BASED TRIALS

The ski jumps were conducted from a land-based ramp that was jointly developed by the UK and the USA. Designed and built in the UK by WFEL, the ramp was divided into sections, then transported and reassembled aboard NAS Patuxent River. Prior to the test, the Pax River ITF team partnered with the Naval Air Systems Command (NAVAIR) Atlantic Test Ranges Geomatics and Metrology team to perform a high-fidelity survey of the shore-based ski jump.

"As expected, aircraft BF-04 performed well, and I can't wait until



ABOVE: EMALS is the first new aircraft launch technology to be employed by the US Navy in more than 60 years (Photo: General Atomics)

"THE DE-RISKING THAT WE'RE ABLE TO ACHIEVE NOW DURING PHASE I OF OUR SKI JUMP TESTING WILL EQUIP US WITH VALUABLE DATA THAT WE'LL USE TO FUEL OUR PHASE II EFFORTS"

we're conducting F-35 ski jumps from the deck of the Queen Elizabeth carrier," says Wilson. "Until then, the de-risking that we're able to achieve now during phase I of our ski jump testing will equip us with valuable data that we'll use to fuel our phase II efforts."

"These successful ski jump launches and the first release of UK weapons from the F-35B are notable accomplishments that bring the UK ever closer to the resurgence of its carrier strike force," says Royal Air Force Test Pilot Squadron Leader Andy Edgell, the UK pilot lead for a highly diverse cadre of US and UK technicians, engineers, administrative support staff, and test pilots, referring to the inaugural release of two inert 500 lb dual-mode Paveway IV precision-guided bombs from aircraft BF-03 over the Atlantic Test Ranges on June 12.

The joint US/UK test team will continue phase I of ski jump testing later this year. Two land-based ski jump test phases are the precursors to the first developmental test embarkation of F-35Bs aboard the Royal Navy's new Queen Elizabeth class of carriers, which is currently under construction.

EMALS: CATAPULT OF THE FUTURE

While the UK and Italian navies will rely on ski jumps to get their F-35s airborne, the US Navy employs powerful steam catapults for launching aircraft, and is testing a new technology – the Electromagnetic Aircraft Launch System (EMALS) – the first new aircraft launch technology to be employed by the US Navy in more than 60 years. The system was selected as the catapult for the Ford-class aircraft carriers and began a comprehensive test program in 2010.

Engineers from NAVAIR and contractor General Atomics have been conducting EMALS tests at the land-based, full-scale, single-catapult test site at Joint Base McGuire-Dix-Lakehurst in New Jersey since 2010, and aboard the Pre-Commissioning Unit Gerald R. Ford (CVN 78), concurrently, since August 2014.

The new class of carriers will enjoy many benefits with EMALS, which employs altogether different technologies and provides a wider energy range than offered by steam catapults, expanding operational capability to accommodate heavier aircraft and lightweight air vehicles.

4
The number of EMALS catapults on each Ford-class aircraft carrier

452
The number of manned launches completed so far during EMALS testing

150-200
The EMALS energy storage group is capable of 150-200MJ delivered, 150-200MW peak

HOW EMALS WORKS

The system draws power from the ship's electrical distribution system and stores sufficient energy for a maximum energy launch. Upon initiation of a launch, this energy is released and powers electronic devices that convert the energy and drive the linear induction motor. An electromagnetic field produced by the linear induction motor propels the shuttle down a track within the catapult structure, producing enough force and acceleration for the attached aircraft to reach the end speed required for take-off. The entire launch process is controlled by a closed-loop computer system.

Stored kinetic energy and solid-state electrical power conversion provide a high degree of computer-based operation, monitoring, and automation. With EMALS' integrated health monitoring system, maintenance requirements are

reduced, while the system's modular design allows for expedited troubleshooting and replacement of faulty parts.

EMALS provides a ten-fold increase in efficiency when compared with steam catapults, and its use of linear motors to launch, brake, and retract the shuttle results in a smaller shipboard footprint and decreased weight. The absence of steam also means launches are quieter and cooler for the sailors who work and live aboard the carrier.

Each of the four catapults aboard the ship is supported by four independent powertrains, providing redundancy to increase the system's launch-critical reliability. The technology enables smooth acceleration at low and high speeds, reducing launch-related stress on the aircraft and the ship. EMALS is designed to achieve increased reliability and higher sortie rates while lowering operation and support costs.

F-35 FACT SHEET

The F-35 Lightning II is a single-seat, single-engine, stealthy strike fighter that incorporates low-observable (stealth) technologies, defensive avionics, advanced sensor fusion, internal and external weapons, and an advanced prognostic maintenance capability, to deliver optimum international security via integrated coalition operations. Partner nations include the UK, Italy, the Netherlands, Turkey, Canada, Australia, Denmark, and Norway – as well as three foreign military sales countries – Japan, Israel, and South Korea. The F-35A conventional take-off and landing (CTOL) variant is a multirole, stealthy strike aircraft replacement for the Air Force's F-16 Falcon and the A-10 Thunderbolt II aircraft, complementing the F-22A Raptor. The US Marine Corps declared the F-35B multirole stealthy strike aircraft ready for combat on July 31, 2015. The F-35B is a replacement for the Marine Corps' F/A-18C/D Hornet and AV-8B Harrier aircraft. The carrier-suitable variant, the F-35C, is a multirole, stealthy strike aircraft complement to the F/A-18 E/F Super Hornet. Lockheed Martin is the aircraft contractor and Pratt & Whitney is the engine contractor.

ABOVE: Sailors prepare a dead load, or aircraft-representative weighted sled, for an EMALS test launch on the flight deck of Pre-Commissioning Unit Gerald R. Ford (CVN 78) in June 2015

TESTING THE TECHNOLOGY

The EMALS team has challenged and tweaked the system during functional demonstration and development and demonstration testing at Lakehurst. Engineers have conducted more than 3,000 test launches of aircraft-representative weighted sleds called dead loads, in a variety of configurations and at speeds of up to 180 knots – the highest end-speed requirement.

The team supported two phases of aircraft compatibility testing (ACT), which were successfully completed in April 2014. During ACT, various carrier situations were replicated, such as off-center launches and simulated faults. A total of 452 manned launches was completed with the following aircraft: F/A-18C Hornet; F/A-18E Super Hornet; EA-18G Growler; T-45C Goshawk; C-2A Greyhound; and E-2D Advanced Hawkeye. The test team also conducted a demonstration launch with the F-35C Lightning II.

Meanwhile, EMALS hardware was produced and delivered to the shipyard in Newport News, Virginia, for installation aboard CVN 78. Testing aboard the first-of-its-class carrier began in August 2014, and by June 2015, US Navy history was made with the first successful launch of a dead load from one of Ford's bow catapults.

After numerous single dead loads were successfully catapulted off the ship, tandem launches began. These back-to-back launches, mere seconds apart and with combined energies of approximately 140MJ, illustrated the simply staggering amount of power EMALS delivers.

By mid-July, shipboard testing of the bow catapults was complete and the CVN 78 crew, guided by NAVAIR's test team engineers, turned their attention to the waist launchers.

General Atomics, with assistance from the EMALS team, part of the Navy's Aircraft Launch and Recovery Equipment Program Office (PMA-251), provides hands-on training at the SFD site to the sailors assigned to operate and maintain the system aboard Ford. The test site also enables the team to provide system troubleshooting capability, eliminating risk by conducting such measures away from the ship.

NEXT STEPS

During the next phase of EMALS testing at Lakehurst, an integrated test and evaluation period, repeated dead loads, and additional manned aircraft launches will aid the team in correcting deficiencies discovered during earlier testing or installation and check-out aboard CVN 78, as well as further increasing system maturation and reliability.

As the team continues to refine control algorithms and tweak the system to function at its finest in preparation for its imminent fleet debut, work to establish production and delivery schedules for the next Ford-class carrier, PCU John F. Kennedy (CVN 79), is already well underway.

After more than two decades in development and test, EMALS has arrived and is helping to shape the future of naval aviation. ▮

F-35B ski jump trial text by Sylvia Pierson, F-35 Lightning II Naval Variants public affairs officer, Pax River Integrated Test Force; and EMALS text provided by the communications team from the US Navy's Aircraft Launch and Recovery Equipment Program Office (PMA-251)

Little wing

Light and flexible, easy to store and cheap to produce: how a new flying wing design being developed by NASA could help man to land on Mars

BY GEORGE COUPE

Prandtl-m (inset) could produce images in far greater detail than those captured by the Mars Reconnaissance Orbiter, seen here (Image: NASA/JPL-Caltech)

NASA scientists developing an aircraft to fly in the Martian atmosphere believe they have solved a long-standing aerodynamic mystery. Al Bowers, the chief scientist who is leading the project at NASA's Armstrong Flight Research Center in California, said he hoped to prove the details of the discovery during a wind tunnel test of a "revolutionary" flying wing design at the end of August at NASA's Langley Research Center.

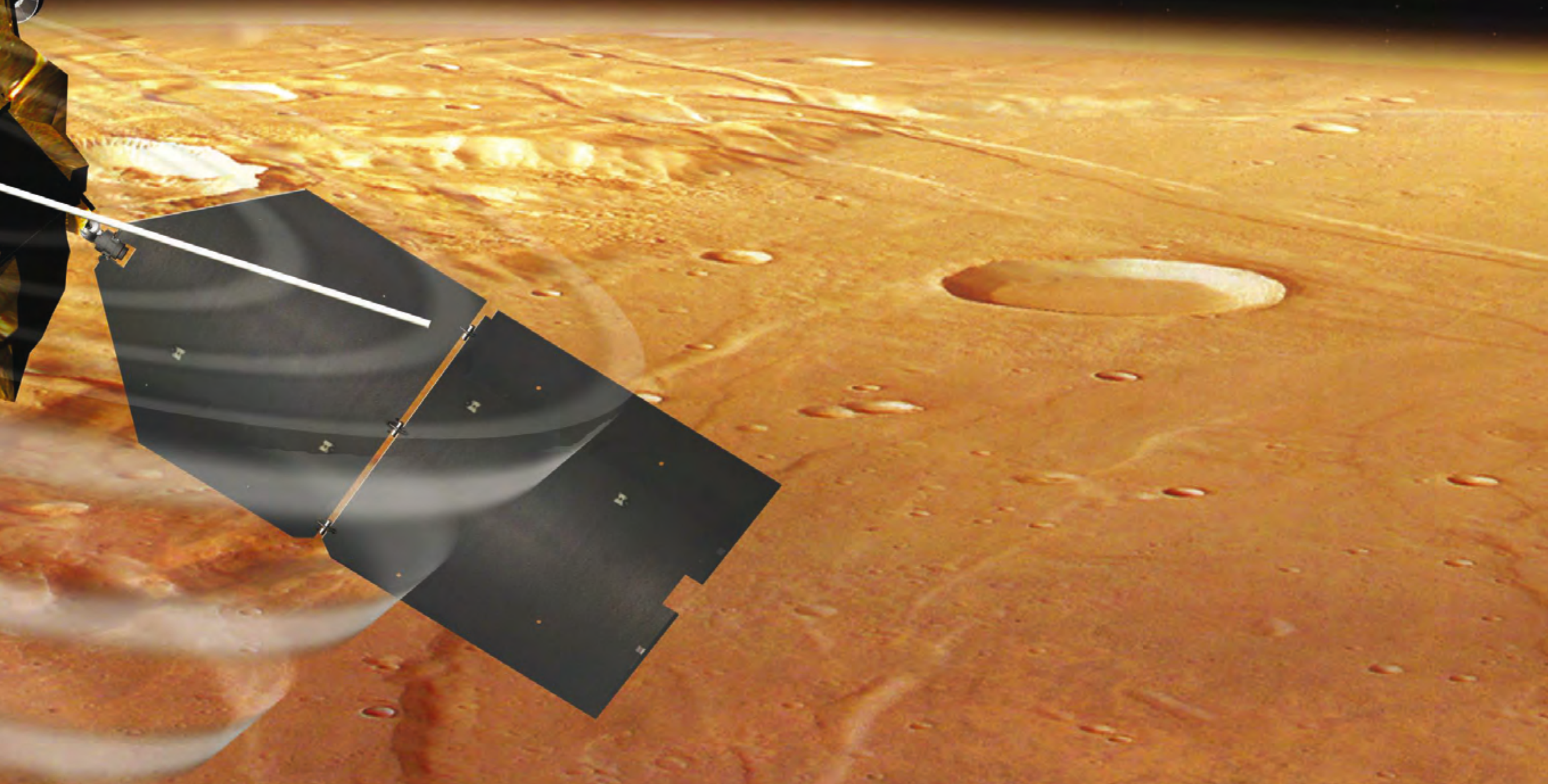
The flying wing, known as Prandtl-m (Preliminary Research Aerodynamic Design to Land on Mars – and a tribute to German aerodynamicist Ludwig Prandtl) is intended to 'piggyback' on a future mission to the Red Planet. The aircraft would then be released to glide in a low-level reconnaissance flight, and gather data on potential landing sites for a manned mission.

In a departure from previous proposals for a Martian aircraft, Prandtl-m is intended to be a lightweight and relatively cheap vehicle, made of flexible material so that it can be 'rolled up' and stowed neatly inside another spacecraft for the ride to Mars. The platform selected for the mission is the flying wing – a design that offers many advantages in the circumstances, says Bowers, but also presents some interesting aerodynamic challenges, which he is keen to overcome.

LOOK, NO TAILFIN

Speaking to *Aerospace Testing International* in August, Bowers, who has worked as an aerodynamicist at NASA for more than 20 years, said his original line of inquiry had been to solve the long-standing problem of how this type of aircraft – and similarly birds – manage to maneuver without a vertical tailfin. He believes he has found the answer in the course of his work on Prandtl-m, and also demonstrated it in flight.

"It turns out that flying wings are a rather difficult problem," Bowers said. "This was in fact my original question, and along the way we believe we have figured out how it is that birds are able



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The proposed flight time (in minutes) of Prandtl-m, when deployed over Mars. The aircraft would glide for the last 600m of altitude (2,000ft) and and have a range of 30-40km

30

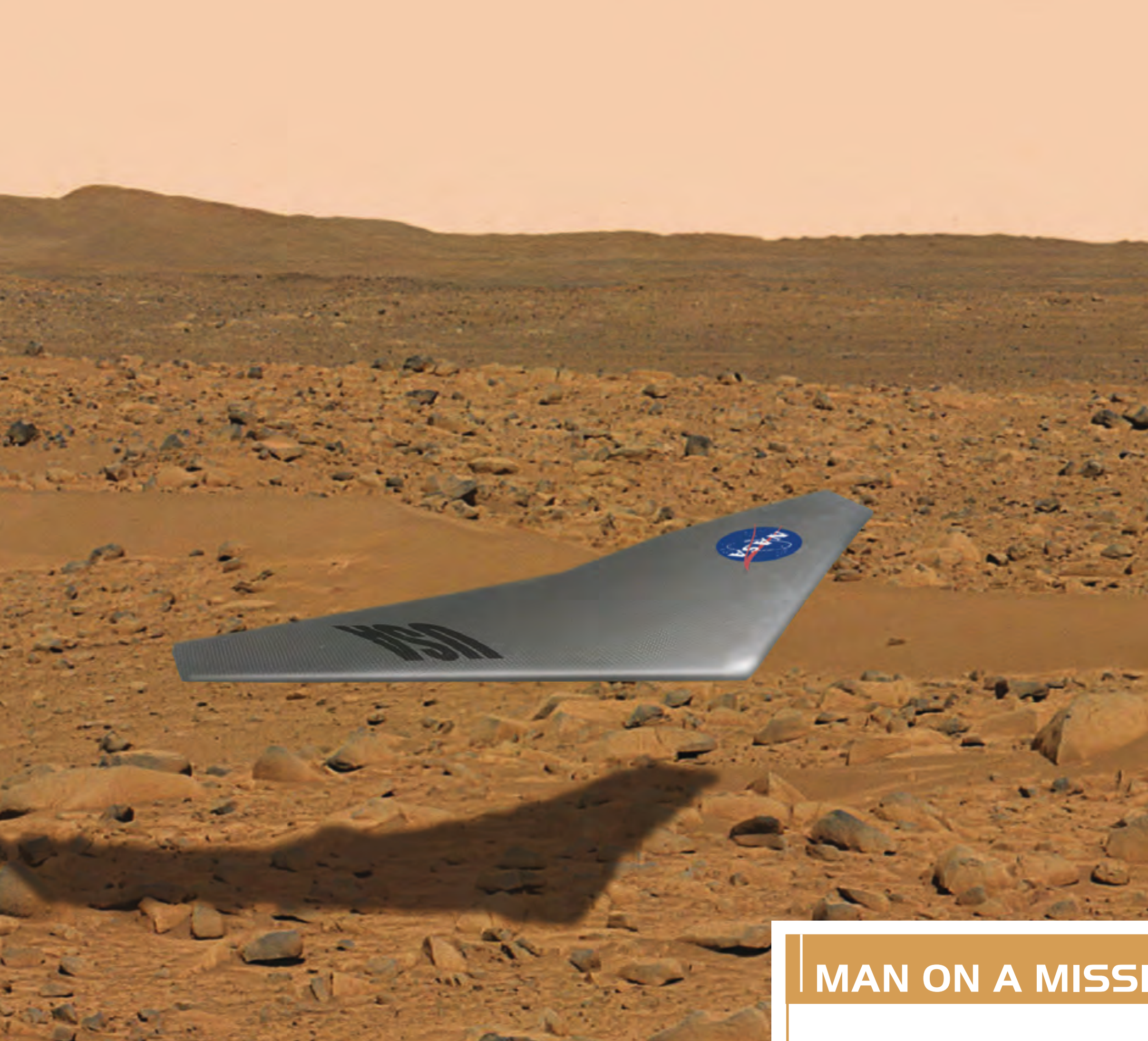
The length of the CubeSat in centimeters, in which Prandtl-m will be rolled up and carried to Mars. At launch Prandtl-m will weigh 900g, but only 340g on Mars where gravity is 38% of that of Earth. The wingspan of the proposed vehicle will be about 60cm (24in)

to maneuver without a vertical tail. We have had some difficulty in convincing the aeronautical community that we have solved this problem. So one of the things we have done is that we have paid for a wind tunnel model and a wind tunnel test at NASA Langley in three weeks [at the end of August]. So three weeks from now I will be in a wind tunnel with the engineers and researchers at NASA Langley with one of these designs, and I can have them generate the data for me."

While Bowers says a journal article on his findings is pending, he adds that the key to the problem was to change the span load of the wing in flight: "We changed the span load, and in the process of changing the span load you change many of the other aerodynamic characteristics in ways that are unexpected."

Prandtl-m is supported by NASA's Flight Opportunities Program at Armstrong. After the wind tunnel,

BELOW: NASA Armstrong's Al Bowers with the second subscale Prandtl-d flying wing following its first test flight, August 2014 (Photo: NASA/Tom Tschida)



ABOVE: Illustration of how Prandtl-m might look when flying above the surface of Mars

Bowers hopes to conduct three flight tests at high altitude beginning in October 2015, where the Earth's atmosphere is similarly thin to that of Mars close to the surface.

Mars aircraft have been proposed as many as eight times in the past, says Bowers. "I have participated on a number of proposals previously, and mostly they were very large vehicles that would carry extensive scientific payloads." Now his team is taking a different approach: to produce a vehicle quickly that is also small and cheap, but still capable of gathering useful information. "We could use it to photograph proposed human landing sites on Mars. We might be able to get superior photographs of the landing sites and provide some of the landing site information for the Human Exploration and Operations (Mission Directorate) at NASA."

Currently, the Mars Reconnaissance Orbiter (MRO), flying at 300km above the planet's surface, can produce images of only 1m resolution horizontally and 3m vertically. Prandtl-m would improve on this by several orders of magnitude. "A field of 85cm boulders, which would not be such a great landing site, is not entirely visible from the Mars Reconnaissance Orbiter. Just doing the math, with our little airplane, we can get down to about 50mm resolution."

The key to the project is the flying wing platform, says Bowers, which will offer relatively good stability in the thin Martian atmosphere. "We tried to pick something that was very stable," he explains. "That was really the piece of the puzzle that I had. It is also a fairly simple aircraft, which didn't require a large boom or tail, and one of the other things that we discarded along the way was a propulsion system. Those are all very desirable things, which help out in many ways – the propulsion system particularly because of the amount of time you have to gather information. But the complexity of adding those things is difficult."

ROLL PLAY

Another challenge is to transport the airplane to Mars and deploy it successfully above the surface. As always, mass and volume are critical factors in space flight, but again the flying wing design offers an innovative solution. Bowers and his team plan to roll up the aircraft and place it inside the aeroshell of another major mission, where it will act as a piece of the essential ballast. This will then be ejected over the planet at the end of the flight. The aircraft will therefore need to be light and extremely flexible, yet capable of unrolling into a rigid and highly aerodynamic shape. Bowers and his team have been trying a range of different composite materials that are both flexible and capable of being 'pressed out' to form a flat aerofoil.

"We are experimenting with S-glass, E-glass, Kevlar, and carbon fibre, and carbon fibre is functioning most beautifully in this regard," reveals Bowers. "One thing we do not know is what are the creep characteristics, particularly for long durations at extreme cold temperatures."

The plan is to place the rolled-up aircraft inside a stack of three CubeSats, measuring 30cm by 10cm; this could then be used as ballast on a larger vehicle. The idea was inspired by missions such as Curiosity, which was flown to Mars in 2011 with 57kg of tungsten on board as ballast. This was necessary because the volume and position of the rover within the aeroshell of the spacecraft caused the center of gravity to be offset.

"To get the center of gravity and the inertias back to the very center for the cruise portion to Mars, you had to put ballast along one rib," explains Bowers. "So they built these slugs of tungsten that were put inside the aeroshell, and then the aeroshell could be spun until it was spin-stabilized during its cruise to Mars. Just before it got to Mars, Curiosity did a de-spin and ejected all the ballast, which fell onto the Martian surface. So we thought that we could be the ballast."

The next step, therefore, would be to deploy the airplane from the

MAN ON A MISSION

Al Bowers has had a long and distinguished career at NASA and during his 34 years there has worked on some of the agency's most ground-breaking projects.

He has been an aerodynamicist for more than 20 years and was chief engineer on the F-18 HARV (High Alpha Research Vehicle), and on NASA's high-speed, high-altitude flight research with the SR-71 Blackbird.

So after all those years at the cutting edge, how does Bowers rate the challenge of Prandtl-m? "I have bitten off some very large and difficult problems in the past, but I have to admit that there are a number of challenges here that have kept me up late at night."

30,000
The altitude in meters at which Prandtl-m will be released from a balloon later this year

40,000
The altitude in meters at which Prandtl-m will be deployed from a CubeSat in the final flight test on Earth. If successful, the team will seek NASA's permission to join a future major mission to Mars

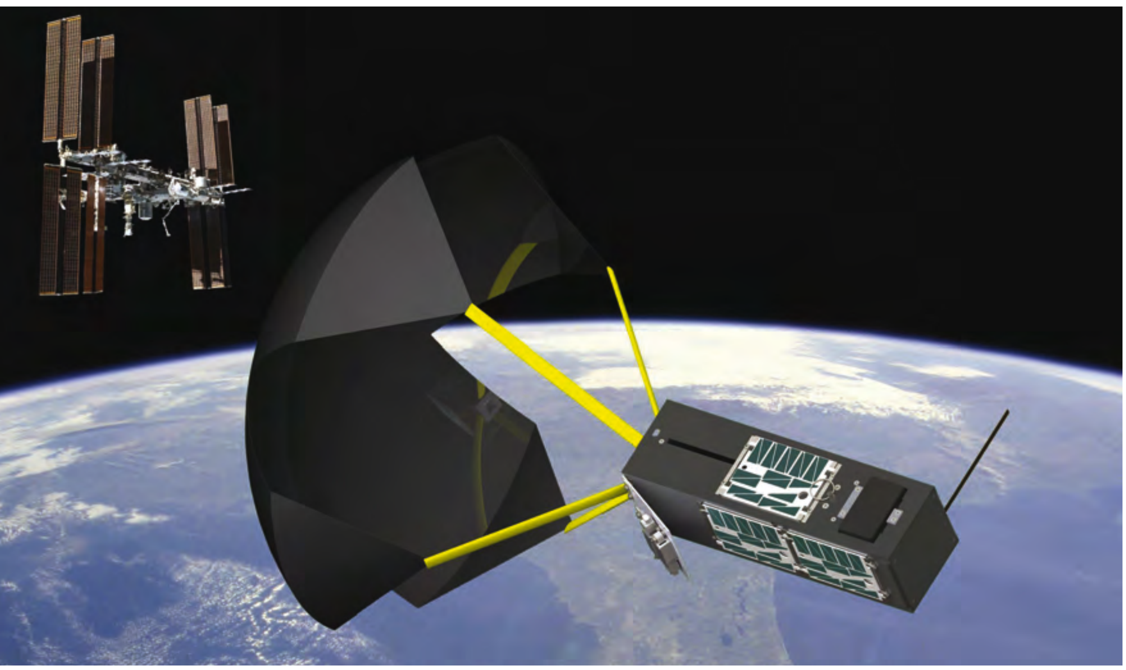
FLIGHT TESTING

The three flight tests, the first of which is planned for October 2015, will be concerned with this stage of the mission: the successful deployment into the Martian atmosphere from the CubeSat and then navigation by autopilot to a way point.

In October, the flying wing will be released from a balloon at an altitude of 30,000m. The focus of this test will be the autopilot technology, which on Mars will rely on a digital terrain map created by data gathered by the MRO. Bowers hopes that by pattern matching between the map and the images it gathers itself, the autopilot should be able to guide the airplane over a series of target areas.

"We should be able to navigate with the images we are gathering for the actual experiment," he says. "The terrain map is coming out of another piece of technology that we developed here, which was our ground collision avoidance. Our truth model, of course, on Earth will be the GPS data. So we are going to see if it can do the pattern matching when we are doing the balloon drop, and then see how accurate that navigation is for us."

Bowers says he suspects the first balloon drop will be over Oregon. For the second balloon drop, the aircraft will be carried to 40,000m inside a 3U CubeSat. The CubeSat will then be dropped on a drogue chute before the airplane is then deployed. Bowers hopes to use a sounding rocket for the third mission to deploy the satellite at near-orbital altitude. The Exo-Brake parachute would be used to bring the CubeSat back to an altitude of 40,000m and then deploy the aircraft. At that altitude, the Earth's atmosphere approximately matches that of Mars close to the surface. "By the time we get down to 25,000m, the experiment is over, and after that you are trying to get home as quickly as possible."



ABOVE: **Prandtl-m will fold and deploy from a 3U CubeSat, which will use an Exo-Brake passive de-orbit system**

CubeSat as it is falling toward the planet's surface "and survive". For this, the team will rely on another new piece of technology developed at NASA's Ames Research Center in California: a giant parachute called the Exo-Brake, which is designed to de-orbit small spacecraft.

"They have a very large parachute that they are putting on CubeSats that they are deploying from the International Space Station. They are using the atmosphere at the altitude of the ISS in orbit to de-orbit the CubeSats and bring them back [to Earth]. This is being done without any thermal protection and is exactly what we want to do. We would love to use their technology on a 3U CubeSat, and as we are descending through the Martian atmosphere, about 5,000m above the surface, we would eject our little airplane and fly away."

Even if the multi-stage deployment can be pulled off as planned, how can such a lightweight and flexible vehicle carry any useful sensing equipment that might be required to make such a mission worthwhile?

There are two issues here, responds Bowers. First is the weight of any experiment. However, on this count, the 38% gravity on Mars is helping out. If the planned payload is 900g on Earth, on Mars it will be an actual weight of 340g. "All the experiments here on Earth are being flown at about the 340g mass," he says.

The second, more difficult problem, adds Bowers, is volume. "Micro-electronics are amazing, but they have not quite got to the point where these parts vanish. We are struggling a bit with that because of the drag that they generate. Right at the moment it is the miniaturization. Getting them small enough so that they don't dramatically affect the aerodynamics of the airplane is our current challenge. We can get the wing to fly very well by itself, then we slowly grow the size of the device on the bottom and the performance degrades considerably. It is very easy to overwhelm the aerodynamics of the wing and make it unflyable."

Among the various experiments that might be included on Prandtl-m, apart from the photographic mission, are a radiometer and a dropsonde to measure atmospheric pressure, temperature and wind, but these depend on successful miniaturization.

The aircraft would have a range of 30-40km, and perhaps fly over a series of targets in a 10-minute mission. After that, it would not have sufficient power to transmit any of its findings directly back to Earth, so the data would be relayed via the orbiter or one of the surface rovers.

If Prandtl-m successfully completes the third flight test, Bowers believes there is a good chance that NASA headquarters will give permission for it to ride to Mars on board a rover mission, perhaps even as early as the beginning of the next decade. ∎

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

Reality check

MAIN: The Active Cockpit Rig provides pilots with a 200° field of view

The Active Cockpit Rig at BAE Systems' Warton facility has played a vital role in testing, proving and extending Typhoon capability for almost three decades

BY PAUL E EDEN

Simulation, from desktop systems linked to aircraft controls, right up to full mission simulators with graphics projected onto the interior of a dome, has become increasingly vital to fast jet training and testing. Students learn everything from the 'muscle memory' needed for repetitive cockpit actions to advanced combat techniques in the simulator, and 'sim' time accounts for a large proportion of operational training in the front-line units of the world's most advanced air arms.

The Royal Air Force operates advanced Eurofighter Typhoon simulators alongside the swing-role fighters at Coningsby, Lincolnshire, and Lossiemouth, Moray, but BAE Systems' Typhoon simulator design aid at its Military Air & Information headquarters in Warton, Lancashire, is a bird of a very different feather. The company has responsibility for all Typhoon cockpit systems development and its dedicated Active Cockpit Rig (ACR) guides, facilitates, and trials upgrades and modifications.

Nevertheless, as Richard Sharratt, Warton's engineering manager for air service integration and implementation, explains, the Typhoon program employs a variety of simulation devices.

"The Active Cockpit Rig came into use around 1986, even before the contract for the program was let. It became a full-dome simulator in the early 1990s and is used to rapidly prototype future aircraft system configurations, allowing the partner nations' pilots to assess moding, symbology, and workload in the single-seat environment," he says. "It's been constantly updated – there's a complete visual upgrade going on now – and remains part of the CAWP [Cockpit Assessment Working Party] process. Pilots come in and fly future system configurations prior to detailed design work, so that there's

4
The number of pilots involved in a test, with typically one from each of the core nations involved in Typhoon production and development (UK, Germany, Italy and Spain)

5
Number of front-line RAF Typhoon squadrons currently operational, as required by the 2010 Strategic Defence and Security Review

an agreed standard, and agreed moding and symbology."

CAWP work usually involves four pilots, one from each of the four core nations: Germany, Italy, Spain and the UK. A dedicated engineering team runs the ACR, pitting visiting pilots against a range of threats and distractions, while analyzing their ability to continue flying and use the weapons system effectively. Pilots gain confidence with the new system, but also generate recommendations that go back to the engineering departments.

SQUADRON LEADERS

BAE Systems' pilots and those of the RAF's 41 (Reserve) Squadron are "tied in to the facility", as Andy Lumb, head of air support capability and service, puts it. "It's not just in the evaluation of design concepts; we work with 41 Squadron and our flight operations people right through the lifecycle, from concept design using the ACR to enriching the training and learning environment. So we have aircrew evaluating the simulation environment we generate, and explore test and evaluation activity as well."

Number 41(R) Sqn is the UK's fast jet test and evaluation squadron (TES), proving capabilities, systems, and tactics. Access to the ACR is vital in its contribution to front-line development.

"The key is to be positively concurrent with the aircraft, so that we provide a simulation capability prior to the aircraft capability being available. The TES is involved in maturity reviews, showing that the simulation is fully representative of the aircraft," explains Lumb.

Sharratt adds: "We have similar procedures with our own test pilots, for development test flight and evaluation. We also have a device in flight operations that's based on the product we use for Typhoon training devices, but we strive to get far more positive concurrency with it. Our pilots especially use it to assess the moding and symbology of a particular software load, which they'll then go and test fly. It means the flying time can be used most efficiently, helping them in their constant

“PILOTS GAIN CONFIDENCE WITH THE NEW SYSTEM, BUT ALSO GENERATE RECOMMENDATIONS THAT GO BACK TO THE ENGINEERING DEPARTMENTS”

ABOVE: An ACR scenario environment typically lasts 2-3 hours

movement between aircraft at different standards.”

Sharratt describes the ACR as a ‘pilot-in-the-loop’ simulator, explaining that company engineers also employ mathematical simulation in Typhoon development. Warton also has a widescreen simulator, used to support aircraft handling qualities and the clearance of control laws associated with the flight control system (FCS). Engineering teams bring the latest control laws to the simulator and, using high-fidelity mathematical and other models, it allows pilots to assess handling configurations before they are installed in the jet. The simulator is subsequently updated to fully represent the aircraft, this concurrency allowing some control law and FCS certification without flying.

ACR TEAM

A dedicated team sits behind every pilot in the ACR, usually comprising the engineers responsible for creating the simulation, and the cockpit design engineers. Large amounts of data are gathered for analysis, pilot feedback resulting in modifications and adjustments to the system under test.

“It’s especially significant when they make mistakes,” Lumb says. “We need to be able to reproduce where they’ve made an incorrect move or been distracted down a wrong path and enabled a piece of functionality that they didn’t need to. We replay that and get their advice on why they think they took that course of action, then see how we need to modify the design.”

Stopping a sim session as soon as a mistake occurs is possible, but less than ideal, since several players are typically involved, as Sharratt notes: “These sessions tend to be quite complex and the pilot may be interacting with people in the control room playing as AWACS operators, or forward air controllers if it’s an air-to-ground scenario. The pilot has to be immersed in the environment, with a workload representative of the mission. Without the immersion, it’s nothing more than an arcade game.”

Although the emphasis is on test and evaluation, a mix of pilots passes through the ACR, especially as far as the German, Italian and Spanish air forces are concerned. Andy Lumb says: “We get a mix of experienced aircrew and pilots new to Typhoon from those nations, but the UK focuses its representation through 41 Sqn, whose pilots have been on the front line, have considerable experience, and know any pitfalls of the current configuration. They’re looking at future developments and features they don’t like on the jet today.”

WEAPONS PROVING

Weapon compatibility is also proven in the ACR, at the very front end of the development process. “Our human factors people work with 41 Sqn and our own flight operations in designing the symbology and making sure symbols can’t be misinterpreted. We

7

Oman became the seventh country in the world, and the second in the Middle East, to operate the Typhoon, joining the UK, Germany, Italy, Spain, Austria and Saudi Arabia, after its purchase of 12 Typhoons in December 2012

NETWORKED DEVELOPMENT

The ACR’s utility is extended through the Dedicated Engineering Network, a proprietary BAE Systems network across facilities including the Queen Elizabeth carriers and Type 45 destroyers. Andy Lumb explains the possibilities: “We’ve had a couple of significant trials in recent years, sponsored by the F-35 program. We emulated the datalink networks that’ll be used during airborne operations, linking the ACR, training aids at Lossiemouth, the carriers, and the Type 45, to provide a representative threat environment where the assets need to cooperate to deliver a mission.”

These ambitious tests required participation from the RAF and Royal Navy, at airfields and on ships, as well as forward air controllers and others. The result is that work undertaken in the ACR could influence how a Type 45 warship delivers information into the battle management scenario and how the command system uses that data. The work also has a “significant influence on F-35 development.”

RIGHT: **The ACR is particularly useful for trialling cockpit symbology**

also make sure weapon ballistics are represented correctly in the cockpit," Lumb says.

Weapons used by the partner nations, but not the RAF, are also trialed in the ACR, Lumb noting that the GBU-10 and -16 guided bombs are typical examples.

Some aircraft capabilities are represented differently in the ACR compared with the jet, since in flight they are visible only to the pilot, but in the sim they must be available to all. In particular, information presented on the head-up display (HUD) and helmet-mounted symbology system (HMSS) in the aircraft, is mixed into the dome imagery in the ACR. For human factors analysis, especially, it is essential that engineers see what the pilot sees, as well as being able to track where he's looking.

"We have eyeball detection systems in the facility so that we can see where the pilot's eyeballs are directed – down into the cockpit or into the outside world – and we can also analyze what he's looking at. We constantly attempt to work out what the pilot's thinking, not just where he's looking," explains Lumb. "Essentially, knowing where the pilot's looking and why, helps us to assess how much the jet needs to do and how much the pilot can 'work out' without being overloaded. It informs where information should be displayed, as well as what."

If a pilot's eyes continually return to a piece of information in the HUD, for example, that data might be more usefully delivered, or repeated, in the HMSS.

At this stage in Typhoon development, the ACR primarily informs software development; physical changes in the cockpit are rare. Nonetheless, some changes that come out of ACR testing are extremely basic and, according to Lumb, they include: "Symbol shapes and colors, and whether they flash or not. Human factors that grab the pilot's attention."

While mathematical or desktop simulation is optimized for testing elements of Typhoon capability, there is no substitute for placing a pilot in a cockpit, albeit in the ACR, to prove the human-machine interface.

As for the amount of data the ACR can process, Lumb says it's hard to quantify: "The ACR is representative of a Typhoon cockpit and the broader system interactions with cooperating aircraft, these being wing men; AWACS; other cooperating forces in the air and in the ground, and so on," he says. "The data it can handle is hard to quantify as a number, but the capacity of the system is significant as a self-contained standalone environment. Operating in networked environment with other synthetic training facilities expands fidelity as opposed to actual data handling," he continues. "The most complex scenarios are those with combined air-to-air and air-to-surface engagements using multiple Typhoons, and working with coalition forces and forward air controllers. We are talking terabytes of data in practical terms as each of the four pilots from each nation is put through his/her paces within the ACR scenario environment of a duration of 2-3 hours. Synthesis of this volume of data is semi-automated to ease the burden of assimilation, analysis, and review."

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

REACTIVE ACR

Many pilots using the ACR are familiar with several aircraft platforms, typically including the F-16, F/A-18 and F-22. Andy Lumb says they all have their "favorite bits of what certain cockpits do" from those experiences, and commonly look to incorporate them into Typhoon. "Sometimes those suggestions are discarded because they're outside the scope of the evaluation; in some instances their ideas are fed into a future capability; occasionally we'll come up with an alternative novel design that provides a different implement solution but delivers the same end military effect. Then the simulator guys work a night or a couple of extra days during the evaluation, creating an adaptation so that they can trial it. It's quite reactive because it doesn't use full airborne code; it's a true design aid."

Q&A

TESTING TALK

Meet Hervé Jammayrac, chief test pilot for Airbus Helicopters, and the man at the helm during the X³'s world speed record

BY ANTHONY JAMES

RIGHT: **Hervé Jammayrac has accrued more than 7,500 flying hours to date**

WHAT ARE YOU WORKING ON AT THE MOMENT?

We have a very wide portfolio of products, from light, to medium, to heavy helicopters, but right now we are developing a new medium civilian helicopter, the H160, which flew for the first time at our Marignane headquarters on Saturday, June 13, after beginning its ground runs at the end of May. The aircraft flew for about 40 minutes in ground effect, allowing the flight test team to check the overall behavior of the aircraft and to verify the measurements. This marked the launch of the flight test campaign and we have since begun to open the flight envelope progressively. The aircraft already reached 130kts during a second flight on Wednesday, June 17, 2015.

WHAT'S DIFFERENT ABOUT THE H160 FROM PREVIOUS MODELS?

This is a totally new helicopter that has been developed from scratch rather than an upgrade to an existing version. It incorporates the newest technology with a particular focus on the reduction of its sound signature, which has involved a lot of work on the design of the blades. The project has also been driven by the goal to improve overall comfort for passengers via the size of the cabin, as well as improving comfort for the crew via an improved human-machine interface. The H160 features what I would describe as a state-of-the-art HMI incorporating all the recent improvements made in this area.

WHAT'S DIFFERENT ABOUT ITS TESTING?

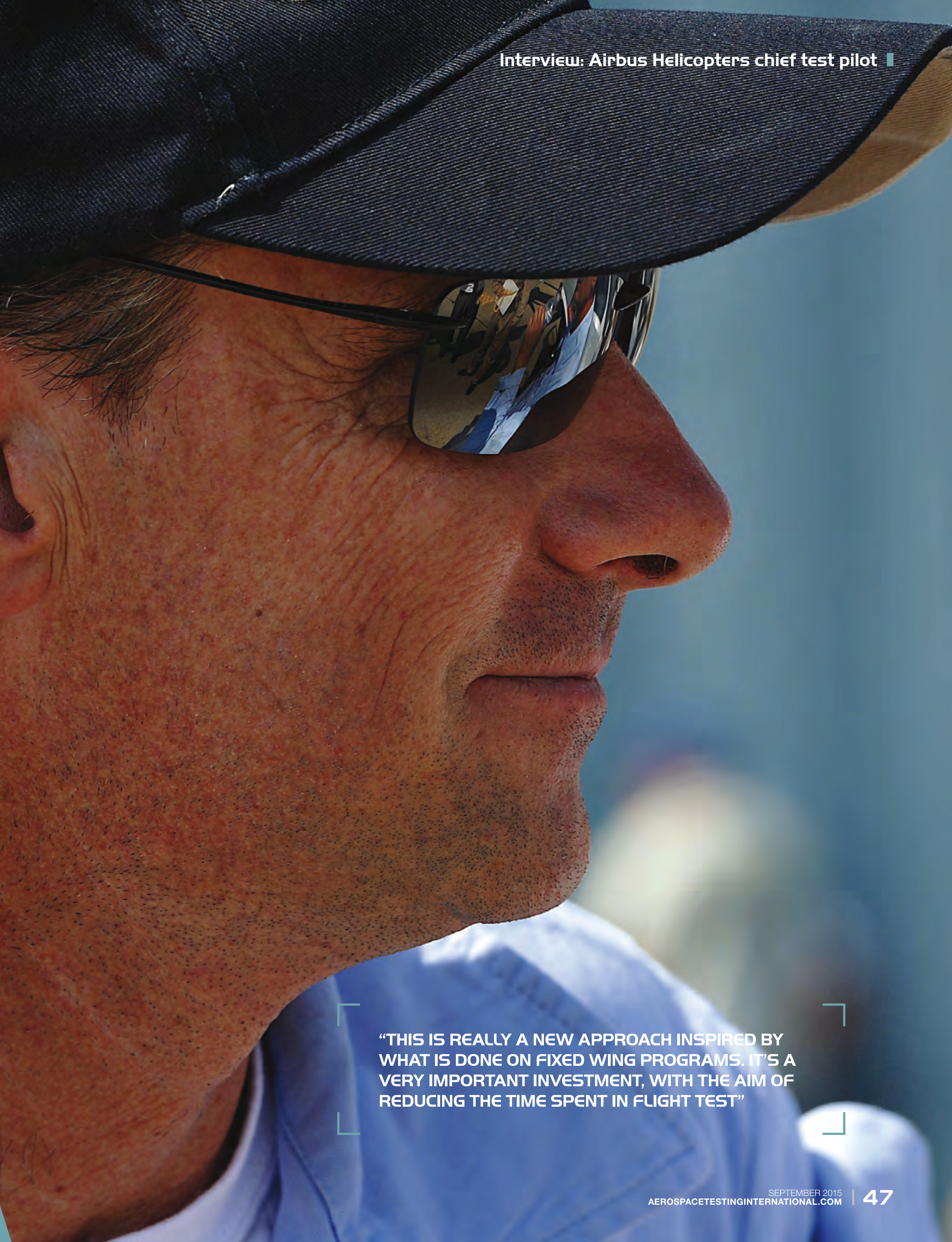
It's the first time we have introduced two key assets – the Dynamic Helicopter Zero and the System Helicopter Zero – before the first prototype. The Dynamic Helicopter Zero is a test bench fully representative of the rotorcraft's dynamic systems, the main and tail rotor flight controls, along with hydraulic, electrical, avionics and health/usage monitoring systems. The System Helicopter Zero integrates the H160's avionics, electrical harnesses, fuel system, hydraulics, flight controls, lighting and all key elements that are connected electrically and involve software. This is really a new approach inspired by what is done on fixed wing programs. It's a very important investment, with the aim of reducing the time spent in flight test. Both assets enable us to reach a higher level of maturity, to test the systems and to be more confident when you reach the first flight.

HOW WILL THIS HELP REDUCE FLIGHT TESTING?

The way I see it, it is more about increasing the maturity level of the test program. It may not dramatically reduce the number of flight hours, but what it may achieve is a reduction in the time of the overall program, because you can do some things in parallel and discover some problems that you are able to solve without stopping the prototype, for example. So in terms of overall efficiency, it's quite obvious. It's also true that modern helicopters feature a host of sophisticated, integrated systems, so we actually cannot afford to wait for the prototypes before integrating these systems. On one hand this is a way to be more efficient, but on the other we have to do it anyway.

WHAT DO YOU THINK ARE SOME OF THE KEY QUALITIES THAT MAKE A GOOD TEST PILOT?

Well, you need experience – you cannot take a pilot and have him sit in an aircraft and tell him 'Okay, do the first flight!' You need specific training.



"THIS IS REALLY A NEW APPROACH INSPIRED BY WHAT IS DONE ON FIXED WING PROGRAMS. IT'S A VERY IMPORTANT INVESTMENT, WITH THE AIM OF REDUCING THE TIME SPENT IN FLIGHT TEST"

"PERSONALLY I THINK BEING NERVOUS IS NOT THE BEST WAY TO CONDUCT A FLIGHT TEST – YOU SHOULD NOT BE IN A POSITION TO BE NERVOUS"

Experimental test pilot training is generally a one-year course where you really learn to fly a helicopter very differently from a professional pilot. But even after this training you still need experience, which often starts with production flight tests before actual prototype testing.

More generally, you have to be able to listen to all the input you are receiving, because testing often involves a very large team. First it's a crew – the pilot and the flight test engineers that are dedicated to monitoring the helicopter's performance and the progress of the test, with the pilot reacting and flying accordingly. In addition you have the telemetry team and the design office input, so you have to be able to integrate all that information while maintaining a 'margin' – to think and act independently and not to be overloaded. You need to be able to take good decisions in flight in real time, if necessary.

You also need to be passionate – and patient – because before for the first flight you have to wait for a year, and then there are weeks of ground tests. But this is how we make sure you are passionate enough! There's certainly no rushing in this business.

DO YOU NEED TO ENJOY TAKING RISKS?

No. On the contrary you need to enjoy managing risks! Obviously there is a level of risk but our job is to manage the risks. In order to manage them you have to identify them and then try to find some means to minimize them. Most of this is done through being involved from the beginning. You are involved in the design, the problems you have encountered in the design, and the way they were fixed. So you have all this background knowledge that will help you minimize the risk.

One risk to watch out for would be overconfidence. If things go very well and you are progressing fast, that's when you have to start thinking about what could wrong. Basically you always have to be thinking that.

SO YOU NEVER GET NERVOUS?

I don't think so. Personally I think being nervous is not the best way to conduct a flight test. You should not be in a position to be nervous. If you are nervous you should be nervous before the flight and ask yourself 'Why am I nervous?' Then you should ask questions and get answers before starting.

EVEN WHEN SETTING A SPEED RECORD LIKE YOU DID WITH THE X³?

No. To achieve that speed record there was a lot of work beforehand. First, to identify the limitations we could be confronted with, be they engine limits, rotor limits or propeller limits. The aim then was to elaborate a strategy to meet all those limits all together, so we did some flights to identify the limits and find the best altitude and temperature where we could meet them all together. This was done working with the design office and via some dedicated flights, so on the day we attempted the record we knew we would achieve it. Or rather, we knew that we had done all the checks to achieve it. We were confident.

However, despite all the preparation, sometimes there are unforeseen events. For example, on this flight the autopilot just kicked out at 250kts – 5kts before the maximum speed! But this just illustrates my point about the correct approach to flight testing. We had already done the flight envelope expansion, with and without autopilot, up to advanced speed. So we knew that the aircraft could be flown without autopilot and that's the best way to prepare yourself for this kind of event. I noticed 'AP off' but the aircraft is very stable at high speed, so I knew it wasn't really an issue and that it was safe to proceed and continue. Even though this event was not expected, the consequences of this event were anticipated.

ABOVE: Airbus Helicopters' X³ hybrid helicopter set a speed milestone of 255kts (472km/h) in level flight on June 7, 2013, with Hervé at the controls

WHAT FLIGHT TESTING MANEUVERS ARE THE MOST CHALLENGING?

Typically for certification you have to demonstrate the height velocity (HV) diagram, which is the envelope in

PILOT PROFILE

Hervé Jammayrac graduated from the French Naval Academy in 1986. He served as a Lynx helicopter pilot in various assignments at sea in the Mediterranean and Persian Gulf theaters. He attended the US Naval Test Pilot School in 1994.

In 1999 he joined Airbus Helicopters (Eurocopter at the time) as the Super-Puma project pilot, helping develop the H225 heavy rotorcraft. He was also the chief pilot for the X³ hybrid helicopter. He is currently the chief test pilot for Airbus Helicopters.

He has flown more than 50 types of aircraft, 29 of them as pilot in command, and has racked 7,500 flight hours. He is married, has three daughters and lives in Marseille in southern France.

> "I BELIEVE THAT IN THE FUTURE, THE FLIGHT TESTING PHASE WILL BE SHORTER"

which you can perform a safe forced landing after an engine failure. So either an autorotative landing for a single-engine helicopter or in one engine inoperative (OEI) condition for a twin-engine helicopter. In terms of skills and risk, this is the toughest test because you put yourself in the most difficult conditions, landing with one engine failed. And you have to do that at maximum weight.

HAS THAT EVER GONE WRONG FOR YOU PERSONALLY?

Before I joined Airbus Helicopters, yes! It was a hard landing – not a major problem but a bit harder than expected. But there are not many flight test programs where this doesn't happen.

WHAT PARAMETERS DO YOU PAY MOST ATTENTION TO DURING A FLIGHT TEST?

On a prototype we have more parameters to monitor than you would on a production helicopter. Beyond the 'normal' engine, gear box, fuel pressure and temperature parameters, in flight test you have many more linked to the helicopter itself and to the structure. From these you are able to determine limitations – air speed, maneuvering, banking and roll – that you then don't have to worry about on the production aircraft.

IS AUTOPILOT ERODING THE TRADITIONAL SKILLS OF A TEST PILOT?

The flying skills of the pilot are still very important, but these skills have definitely evolved. Pilots need to be skilled when performing some of the more difficult testing maneuvers, such as the HV diagram test. However, today's helicopters and airplanes involve many systems interacting altogether. A test pilot has to understand these systems and be involved in their development from the very beginning, even in the design of the system, to ensure a higher degree of understanding be able to anticipate the way they are functioning. This is now all part of testing – understanding the way the systems are interacting helps you to test them in a better way. Autopilot is now much more capable, so it greatly helps the pilot, even during testing, but you have to be able to cope with a lot more technology.

WHAT'S THE BIGGEST CHANGE YOU'VE SEEN IN RECENT YEARS IN TERMS OF FLIGHT TESTING?

The lead times for a new program are much more important than in the past, so now before the prototype we have lots of test rigs and a lot more people involved, which makes things a bit more complicated but also gives you more maturity. I believe that in the future, the flight testing phase will be shorter. It's difficult to put numbers on that, but obviously the objective of all this is to start with a mature project and to dramatically reduce the time between the first flight and the time to market compared with what was done in the past.

FINALLY, WHAT'S YOUR VIEW ON UNMANNED HELICOPTERS?

I think it's a very promising area of operation. Obviously there are many missions that can be performed by unmanned helicopters. However, due to the very wide scope of helicopter missions, I'm convinced there is room for both manned and unmanned helicopters. I don't see them as a direct threat as there are many, many types of operations that for the time being, and for a long time, will be performed by pilots in the cockpit. As for testing, I think that even when testing an unmanned aircraft, there will still be the need for a test crew either on board or on the ground. ∎

Anthony James is editorial director at UKIP Media & Events Ltd, publisher of Aerospace Testing International

ABOVE: **The H160 is the latest Airbus Helicopters' model to undergo flight testing, with the first flight taking place in June 2015**

H160 KEY STATS

Airbus Helicopters' all-new, twin-engine, fully composite 5.5-6 ton class H160 is powered by a new Turbomeca 1,100-shp Arrano engine. With a cruise speed of 160kts, the H160 can carry 12 passengers up to 120 nautical miles for oil and gas missions, and has a 450 nautical mile range with a 20-minute reserve in public service or for search and rescue tasks.

The H160 boasts two Airbus Helicopter firsts: the largest-ever Fenestron shrouded tail rotor, which is also double-canted at 12° angles, further enhancing anti-torque control efficiency; and the all-new Biplane Stabilizer, whose unique design involves a staggered placement of the dual-level, interconnected stabilizers. This feature facilitates pilot maneuvers and greatly reduces aerodynamic penalties in low-speed flight and hover.

The H160's main rotor blades benefit from Airbus Helicopters' Blue Edge technology, reducing exterior noise levels by 50% (3dB) and allowing a payload increase of up to 100kg over traditional rotor blades, depending on flight conditions.

A Helionix avionics suite increases operator safety via reduced pilot workload, enhanced situation awareness, improved flight envelope protection and system redundancy.

Development of the H160 began in 2013, with service entry planned for 2018.

Three dedicated prototype aircraft are supported by two test benches on the ground – the Dynamic Helicopter Zero and the System Helicopter Zero – to ensure the highest levels of maturity before flight testing and to shorten the entire development process.

Double agent

Visibly modified for engine trials, Honeywell's Boeing 757 test aircraft has a hugely important, often simultaneous avionics testing role to play, too

BY PAUL E EDEN

Honeywell's Boeing 757 testbed was among the first of its type delivered, going to launch customer Eastern Air Lines in February 1983. Later the aircraft served with the UK's Airtours, before it joined Honeywell's fleet in 2004. Four years later, the jet began its trials career and continues to average about 50 test flights per annum. Most obviously equipped for engine test work, with a large pylon mounted on its starboard forward fuselage, the 757 also flies vital avionics trials, including the testing of flight safety and passenger connectivity-related systems.

Joe Duval, a veteran of many years' flying with the US Air Force, is Honeywell's chief test pilot. He explains the basics of trials procedure with the 757: "The test installations are mostly engineered and implemented in-house by our flight test engineering team and technicians/mechanics. Being able to modify the airplane in-house, responding rapidly to our internal engineering customers, is key to providing a competitive edge for our products. We have six engineers, two engineering technicians, and four mechanics to manage test installations, data acquisition and regular aircraft maintenance.

"Larger projects, like a major modification to support engine testing, are overseen by flight test engineering,

MAIN: Honeywell's 757 acts as an engine testbed for its HTF7000 and TFE731 business aviation engines – note the engine undergoing testing attached to the distinctive pylon on the starboard side of the jet's forward fuselage

"WE'VE MOVED AWAY FROM TELEMETRY DUE TO THE LOCALIZED (LINE-OF-SIGHT) REQUIREMENT AND THROUGHPUT LIMITATION"

but would be designed by an outside firm. Computer-based modeling is used extensively for test installation design, and simulation is used before a higher risk test is performed, by way of a local airline's 757 simulator."

The aircraft is instrumented to record data from "thousands of capture points", storing gathered information on servers offering "terabytes of capacity". Duval notes that onboard storage is currently preferred over telemetry: "Engine testing can include several hundred parameters of data – mostly temperature and pressures – sampled throughout the engine and yielding large amounts of data. Furthermore, avionics testing (often done concurrently with engine testing) also generates large amounts of data.

"All this data is stored on onboard computers and typically offloaded directly after a flight. We've moved away from telemetry due to the localized (line-of-sight) requirement and throughput limitations. We do use some forms of internet-based data transfer, however, and with the new JetWave system's bandwidth, we hope to increase real-time data transfer on some programs."

TEST CONFIGURATION

Two pilots are required for every flight, typically accompanied by between five and seven engineers or technicians, one of them acting as primary flight test engineer (FTE) and test director. There are 20 seats in the cabin, however, facilitating the 757's important additional role of technology demonstration to customers and media.

Avionics testing calls for accurate and unusual flying from Honeywell's experienced pilots, who are selected "…extremely carefully to give us a good balance of experience and expertise across all of the testing scenarios that we create."

If a weather radar system is under test, for example, the crew might go in search of storm systems, flying toward them to validate the radar and the warnings it provides on the flight deck. The crew also looks at the intuitiveness and ergonomics of displays, checking that radar data is delivered in a useful form.

In a recent test, Honeywell assessed the performance of its RDR-4000 IntuVue weather radar system against ice crystals, during work flown over Cayenne, French Guiana. Duval describes the effort, which was sponsored by the High Altitude Ice Crystals (HAIC) Consortium. "We had a very successful campaign, operating the IntuVue radar on the 757 as it followed one or two other aircraft in the same weather system. Those aircraft had multiple probes collecting information about the system, including ice content. The data they collected is combined to correlate what our radar sees."

The HAIC trials are only one aspect of the 757's IntuVue work. "The 757 has been used extensively throughout the world to prove the radar's functionality, from low-level windshear testing to high-altitude radar functionality," says Duval. "The cockpit displays are evaluated in the lab on computers before implementation in the airplane, but the human factors of those displays in the cockpit environment are evaluated on the airplane as well."

EUROPEAN WORK

This year the 757 flew extensively over Europe, primarily testing the mechanically steerable, fuselage-mounted JetWave antenna. Honeywell exclusively produces the JetWave equipment to support Inmarsat's Global Express (GX), a Ka-band broadband connectivity system for commercial aircraft. Already available to business aircraft operators as Jet Connex, the system will eventually draw on four satellites for global connectivity at speeds up to 50Mbps.

SAFETY AND COMMUNICATIONS TEST SUBJECTS

- ADS-B In and Out
- Advanced air data systems
- Connectivity solutions including JetWave antenna for the Global Express Ka-band system
- Datalink systems including controller pilot datalink communication
- Flight management systems
- IntuVue RDR-4000 3D weather radar
- SmartLanding/SmartRunway

560
Maximum speed in knots (0.85 Mach)

16,500
Maximum test engine thrust in pounds (73.38kN)

45,000
Maximum altitude in feet

LEFT: **RDR-4000 IntuVue weather radar system undergoing testing on board the 757**

80,200

Two Rolls-Royce RB211-535E437 turbofans deliver a combined maximum of 80,200 lb (356.65kN) thrust

240,000

Maximum gross take-off weight in pounds (108,862kg)

ABOVE: The 757 acts as flying technology lab to test the various flight deck avionics, weather radar and cabin connectivity systems offered by Honeywell

RIGHT: Honeywell's chief test pilot, Joe Duval

Duval explains the thinking behind the GX tests: "We want to be sure the system is robust, no matter how the airplane is maneuvered. Higher latitudes mean different angles to the satellite, and speed can also affect the angle of the airplane and therefore the angle of the antenna to the satellite. We maneuver through many altitudes and speeds, as well as extreme turns, to fully test the robustness of the system and its connection to the satellite.

"The first satellite in orbit is over the Indian Ocean and its furthest western coverage is over Western Europe. Also, our Honeywell office in Tewkesbury, Gloucestershire, is where a lot of the engineering for this system takes place. For those two reasons, we chose to operate out of Birmingham, but we'll test the system over multiple regions to exercise the satellites and ground stations."

Honeywell's test fleet represents a considerable investment in resources and dollars, and multiple tests on different systems in the same flight are common, as demonstrated in the two recent visits to Europe. "The aircraft was involved in extensive datalink testing of the newest ground and airborne controller pilot datalink communication systems," says Duval. "Specific routes were flown and multiple landings made to test systems throughout Europe. We also tested a new hybrid traffic collision and avoidance system. Both these tests are particularly interesting in Europe because of the vast amount of air traffic in the region."

The ability to easily deploy the 757 away from its dedicated hangar at Phoenix's Sky Harbor International Airport is important to Honeywell's test and demonstration programs. Its size allows a degree of self-deployment capability and, despite its age, the airframe remains fully compliant. "The aircraft is kept worldwide capable from the standpoint of current air traffic mandates and the crew is trained for all areas of the world," explains Duval. "For trips away from home, we travel with mechanics to look after the aircraft and a 'fly-away kit' containing consumables, tools, and repair items."

ENGINE TEST

The 757's engine test duties have most significantly involved it in proving the HTF7000 series of small turbofans aimed primarily at business aircraft, and the seminal TFE731, where test work continues in support of the latest developments of the 1972 vintage turbofan.

Duval explains the basics of the aircraft's modifications and engine test procedures: "Because we have an internal FTE capability, the through-process for design of any test installation is to keep it as generic as possible. We can test all the propulsion products Honeywell produces, from turboprops to turbofans. The test installation has purposely been made universal, with adaptability to all these engine types. The pylon, fuel system, and so on, are designed to support engines up to 16,500 lb thrust."

Flying engine test profiles places quite different demands on the flight deck crew, but still requires all the accuracy of an avionics test. "An engine test is planned for anywhere from four to seven hours, depending on its complexity," says Duval. "Typically, our engine flights start out at a low altitude (5,000ft) and climb in a step pattern to various altitudes and airspeeds, ending at the highest altitude for that day's test. Each test point has a specific altitude and airspeed that the pilots must precisely maintain. This can take quite a bit of coordination with air traffic control, unless we use a designated test area allowing a large block of airspace where we're allowed to maneuver independently. Much of the time the engineers want to operate the engine as high as possible and as slowly as possible, and this is where the pilots really need a lot of skill, and where the 757 shines, since it has quite a large operating envelope."

Under its flight test operations department, Honeywell's wider flight test fleet includes examples of the Convair 580 and Beechcraft King Air turboprops; Rockwell Sabreliner, Dassault Falcon 900 and Cessna Citation V business jets; Embraer 170 airliner; and Airbus Helicopters AS350. Alongside the Boeing, these aircraft support Honeywell's aerospace product line as their "first customer", according to Duval. Flown by a small cadre of ex-commercial and military pilots, the flight test operations fleet and personnel deliver "…the flexibility to design and deliver safe and controlled airborne testing programs across the entirety of Honeywell's portfolio." ▮

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

Blade runners

Van Horn Aviation fast-tracks in-house testing to prove its composite helicopter rotor blades beat legacy metal rotors

BY FRANK COLUCCI

Van Horn Aviation (VHA) finds good business replacing the metal rotor blades of OEMs with refined composite blades that cut helicopter operating costs and enhance performance. The small company in Tempe, Arizona, has sold more than 2,500 composite tail rotor blades for the Bell 206 JetRanger since 2009 and expects to receive a Supplemental Type Certificate (STC) for its Bell 206 main rotor blades later this year.

"We're an engineering firm that builds our own products," summarizes VHA president James Van Horn. "Our business model consists of redesigning legacy fleet products such as the 206 series and MD 500 series metal rotor blades using composite materials to increase performance and service life, and to cut the direct operating costs of the blades. What we strive for is, at a minimum, doubling the life of the blades."

Aftermarket helicopter blades made with parts manufacturing approval (PMA) from the FAA have to be tested to the same design and manufacturing standards applied to OEM parts. "Our ability to do our own testing is one of the things that distinguishes us from some of the other PMA houses," claims Van Horn. "Testing is very rigorous. If you don't have that capability, you're probably asking for a very extended test program that's very expensive."

VHA conducts blade fatigue and other tests on its own instrumented ground rigs and quickly transitions prototype blades to instrumented helicopters. "There's nothing like the real thing," says Van Horn. "Many times, we're going into a test knowing we're looking for something to be uncovered." Ground and initial hover testing is conducted largely at the company's Tempe manufacturing facility. Most flight testing is done at Falcon Field in Mesa, Arizona, with excursions to Flagstaff, Arizona, or Leadville, Colorado, for high altitudes and Bakersfield, California, for noise measurements.

VHA announced a memorandum of understanding with Bell Helicopter in February 2014 to develop composite main rotor blades for the familiar Bell 206B3 JetRanger and 206L LongRanger. The company first hovered a Bell 206B3 with prototype main rotor blades in December 2014 and began certification flight testing in March 2015. Collected test data earned FAA Type Inspection Authorization (TIA) for the JetRanger composite main rotor blades in June, a precursor to the STC that clears the new blades for market. VHA aims for a 10,000-hour service life on the new Bell 206 main rotor blade, double the current 5,000 hours.

Fatigue testing enables VHA to set the service life of the blade by applying loads to various blade components and cross-sections until a predetermined number of cycles are completed or the tested specimen breaks. Company engineers conduct fatigue tests using various rigs, many of which have been designed and built in-house. The largest fatigue test rig contains seven actuators designed to push, pull and twist a main rotor blade section to simulate flight loads. Position feedback sensors on the actuator cylinders, and multiple strain gauges on the blade section, provide the fatigue data. Pitch links and other flight components not made by VHA also undergo fatigue testing on other instrumented rigs.

Certification testing for the Bell 206 main rotor blade included sling lifts with a 500 lb (225kg) hook load

RIGHT: **The main hub of the leased Bell 206B was instrumented for flight tests of the VHA main rotor blades**

According to Van Horn, the test effort associated with helicopter main rotor blades far exceeds that for tail rotors. "There's no comparison. Tail rotor testing is relatively straightforward and simple. A tail rotor is short and stiff; it doesn't twist and torque like the main rotor. The maneuvers that affect tail rotor loads are half those that affect main rotors… it's much more difficult to conduct the test on the main rotor. There are so many more degrees of freedom on the main rotor compared with the tail rotor blade."

COMPOSITE PAYOFF

James Van Horn became involved with aftermarket metal rotor blades for McDonnell Douglas Helicopters in the 1990s. He launched his own company in 2001 to offer enhancements for helicopters of other manufacturers and soon turned from metal aftermarket blades to composites. "If we were going to play in the arena of the PMA market, we decided we needed to do something radically different."

More efficient rotor blade airfoils and planforms captured in lighter composite materials promised tail rotors with more thrust and less noise. Fiber-reinforced composites that resist fatigue could also pay off in longer blade lives.

VHA first developed and certified composite tail rotor blades for the Bell Huey based on the Boeing VR7 airfoil. The cambered airfoil increased tail rotor authority and decreased vibration compared with metal tail rotor blades. Carbon-epoxy skins on polymethacrylimide foam cores meanwhile doubled the life of the original 1,200-hour metal blades.

LISTEN FOR THE BLADES

Helicopter noise blends multiple sources. Main rotor impulsive noise in high-speed forward flight comes from air compressed by the advancing blades. At lower speeds, blade vortex interaction from successive blades generates the distinctive helicopter 'chop'. Tail rotor blades provide their own impulsive contribution to mix with main rotor, engine and transmission noise. Van Horn Aviation turned to Acoustical Analysis Associates, Inc. (AAAI) to certify composite tail and main rotor blades on the Bell JetRanger under US Federal Aviation Regulations Part 36. "We're acoustical consultants," explains AAAI president and FAA acoustic designated engineering representative Mike Bucka. "Environmental noise is our specialty."

AAAI performs noise analyses on a range of aircraft. "We tend to specialize on the smaller helicopters," notes Bucka. "The OEMs of the bigger ones tend to have their own acoustical departments."

The 3,350 lb (1,520kg) Bell 206B with VHA blades flew simplified sound exposure level (SEL) tests at quiet Willow Button Airport near Bakersfield, California. "It's basically a runway and a windsock. That's why we like it."

The measurements made for VHA were collected by a single Brüel & Kjær precision recording station. Based on the aircraft size, the SEL test required the helicopter to fly over the recorder at 492ft (150m) and hold 0.9Vh – maximum horizontal speed. FAA rules require a minimum of six passes to average noise measurements, but AAAI typically conducts twice as many runs for accuracy. "It's simple because the sound level meter will give you the number directly," explains Bucka. "We work out a course, a heading and so forth beforehand and do a couple of practice flights. For this test it's pretty easy. The helicopter is flying level and the pilot can just look down and see where the station is."

LEFT: Van Horn Aviation flew its composite tail rotor blades on a Bell JetRanger in 2009 and composite main rotor blades in 2014. The aftermarket blade maker relies on in-house testing expertise to certify new products

VHA chooses composite materials from those characterized under the Advanced General Aviation Transport Experiments (AGATE) begun by NASA in 1995. The AGATE database today standardizes composite fabrication technology, material standards and certification methods for general aviation aircraft. VHA does some coupon testing, but as Van Horn says, “Companies like us are not required to do basic material testing, which is very expensive. What we do is find the material we like best and make do. We don’t have to compromise.”

VHA typically lays up Toray carbon-epoxy prepreg in-house on Rohacell PMI foam machined outside. The company has a 19ft (5.8m) long autoclave for main rotor blade fabrication.

The choice of airfoils and other blade details is likewise driven by known performance and producibility. “We give a nod to the current technology,” explains Van Horn. “It’s scientific from the standpoint of a literature search. Since we’re not trying to eke out the last ounce of performance, that’s all that’s required.”

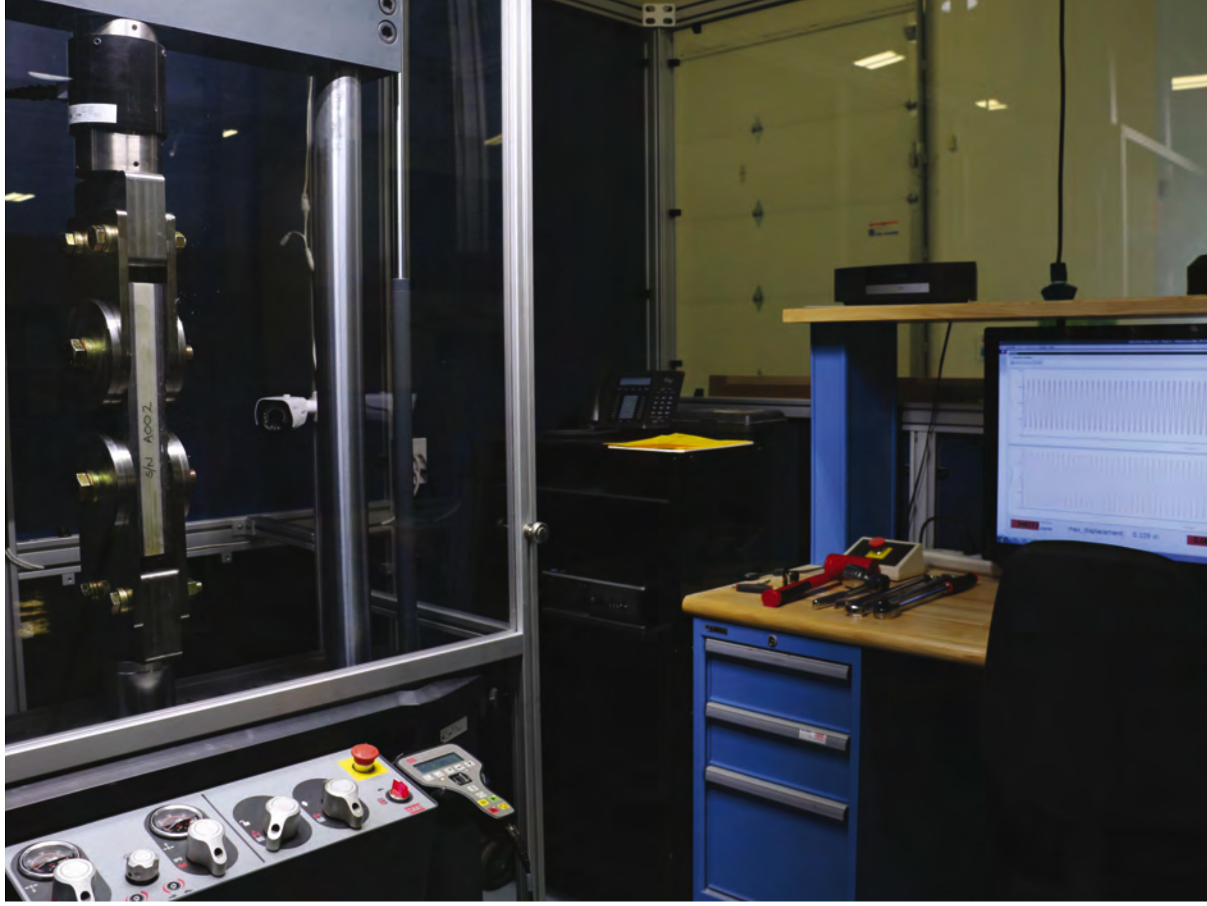
“THE 5,000-HOUR SERVICE LIFE DOUBLED THAT OF THE OEM TAIL ROTOR BLADE FOR A 40% INCREASE IN PRICE”

VHA tail and main rotor blades for the Bell 206 and still-to-be-certified main rotor blades for the MD 500 series helicopters are based on the public domain RC(4) airfoil developed by NASA and the US Army at NASA Langley Research Center. VHA made the thin, laminar-flow airfoil from composites and gave its JetRanger replacement tail rotor blade a swept tip, an erosion-resistant nickel leading edge, a titanium root fitting, and a new pitch bearing. The 5,000-hour service life doubled that of the OEM tail rotor blade for a 40% increase in price. “We’re competing against a 50-year-old metallic blade,” notes VHA general manager Dean Rosenlof. “The goal is to increase the life of the blades.”

Though the composite tail rotor blades caused no changes in the Bell 206B performance charts, testing at Leadville, Colorado, showed that otherwise unmodified Bell 206L3 and L4 LongRangers could gain about 170 lb (77kg) in allowable weight hovering in ground effect at high-density altitudes. Significantly, the new airfoil and swept tip also demonstrated a 40% reduction in tail rotor noise in flight tests, compared with the original JetRanger blades. “It’s a discernible difference that you can hear,” observes Van Horn.

SYSTEMATIC TESTING

VHA begins all its rotor blade development programs with baseline measurements taken on the target aircraft with metal rotors. “We’re not as interested in the blade as we are in the rest of the helicopter,” says Van Horn. “We instrument the things the blade affects – the pitch links, the mast and



2,500
number of composite tail rotor blades VHA has sold for the Bell 206 JetRanger since 2009

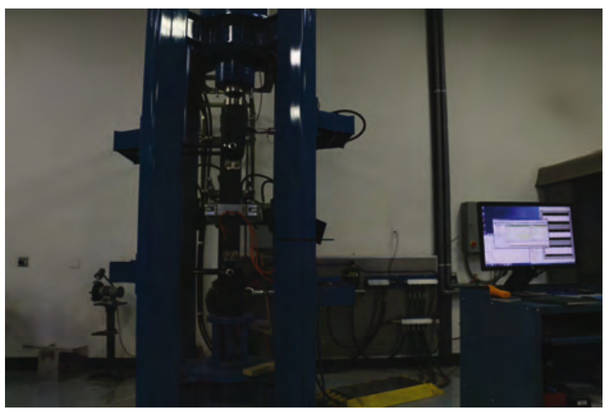
5,000
hour service life on the Bell 206 composite tail rotor blade

10,000
hour service life on the Bell 206 composite main rotor blade

the powertrain." For the Bell 206 main rotor, VHA began baseline main rotor testing with a leased JetRanger in October 2014 and flew a series of maneuvers at various speeds and in several configurations, including sling-lift flights with a 500 lb (225kg) hook load. "What we care about are the control loads, the bending and lagging loads, the torque and the power being delivered to the aircraft. We do an entire flight strain survey with the metal blades. Then we put our blades on and repeat the test, looking for differences that we need to address."

Tail and main rotor blade ground tests are essentially precursors to flight testing. VHA engineers measure vibrations and control loads while the rotor blades are spinning at less than full flight power. Main rotor blades also undergo a track-and-balance procedure like that performed in the field when helicopter mechanics replace old blades with new ones. While field mechanics track and balance certificated blades with only small adjustments to pitch links, new blades in ground test sometimes reveal internal changes necessary to achieve the correct center of balance. Adding lead tape to the leading edge of prototype blades enables VHA flight test engineers to put more or less weight on various areas of the blade to determine where internal weight adjustments are needed.

VHA seeks to test prototype rotors on helicopters quickly to expedite test programs. "We take our best shot at safety-of-flight and other parameters, and then test them on the aircraft," says Van Horn. "It's much faster than protracted analyses prior to first flight." Flight test hours for VHA products are not released but Van Horn estimates VHA flight testing does the work of a three-year analysis-based blade development program with a test-only program in six to nine months.



ABOVE: In-house fatigue testing on the new blades establishes service life

TOP: Root material undergoes fatigue testing in the VHA facility

"We go into product development signing up for major changes. Many times we'll conduct tests to determine where we stand," he says.

Composite blade flight test plans mirror those used to test metal blades. Rosenlof notes: "The test cards are the same whether you're testing composite or metal – the same data is required of both." The main rotor instrument suite flown on the JetRanger recorded 40 flight parameters including control positions, acceleration velocities and angles, and outside air temperature. "As the electronics get better, the instrumentation gets better," says Rosenlof. "We've done slip rings and jumped to telemetry/RF from the head, the spinning components, to the cabin." The in-house instrument suite also integrates all the test sensors, such as the strain gauges and position transducers, with a radar altimeter. Arizona provides ample opportunities for hot-weather testing, and the AGATE material qualification provides sufficient cold-weather documentation. Acoustic testing requires special facilities and expertise, so VHA contracted Acoustical Analysis Associates, Inc. to measure atmospheric noise propagation with the re-bladed JetRanger flying over a ground microphone. "You're looking for the integrated noise from the time it can detect the aircraft to the time it fades below maximum. The equivalent noise level has to be below that set parameter. It's a fairly sophisticated test," Van Horn notes. "The majority of current metallic blades can meet acoustic requirements. However, there's a change coming to the regulations that we may need to address in the future."

VHA expects to certify composite main rotor blades on the Bell 206L LongRanger in 2016 and is already considering its next development and testing program. "It's a toss-up between the Bell 212/412 tail rotor and the MD 500 main rotor blade," says Van Horn. The innovative blade maker flew composite main rotor blades on the MD Helicopters 530F in 2013 but put the effort on hold when the OEM withdrew the test aircraft. "Probably the MD 500 will be the next one we tackle," predicts Van Horn.

Frank Colucci is a specialist in rotorcraft design, civil and military operations, test and avionics programs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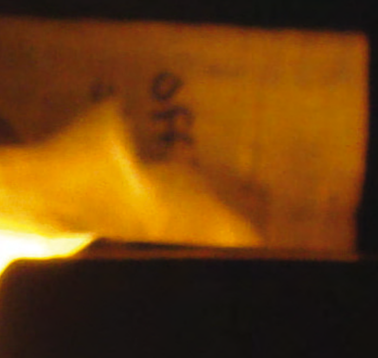


Burning issue

FAA Fire Safety Branch experts are tackling the disparate challenges of developing a new oil burner for engine fire safety testing and finding a replacement for halon in aircraft fire-extinguishing systems

BY PAUL E EDEN

In the case of powerplant fire testing, the Federal Aviation Administration (FAA) is both a regulator and researcher, and its Technical Center Fire Safety Branch has taken the lead in developing a next-generation (NextGen) fire test burner. The requirements of fire testing are exacting and, for powerplant work, ideally satisfied by an oil burner, but the majority of such products mentioned in FAA advisory circulars and reports are no longer in production.

Power Plant Engineering Report No. 3A, Standard Fire Test Apparatus and Procedure (For Flexible Hose Assemblies), Revised March 1978, for example, lists acceptable fire test burners, including the Lennox OB-32, Carlin 200 CRD, and Stewart-Warner HPR 250 and FR-600 – none of which remain commercially available.

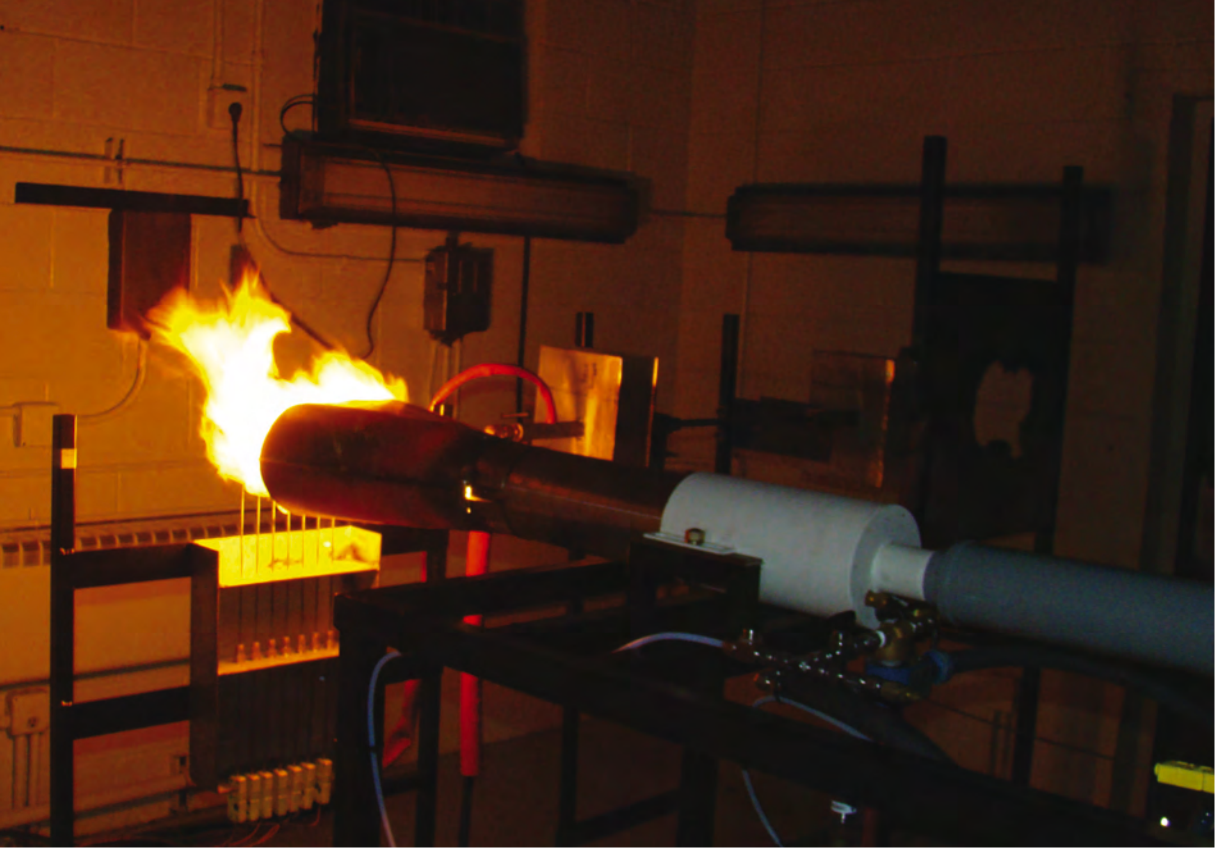
Advisory circular 20-135, Powerplant Installation and Propulsion System Component Fire Protection Test Methods, Standards, and Criteria, published in February 1990, references the same burners, adding the SAE 401 propane-fueled burner adjusted to 9.3BTU/ft^{2}s, and propane and oxy-acetylene torch-standard and diverging nozzles (for small components) to the list. The pattern has continued with subsequent reports, referencing existing notes and even introducing alternative burners, including the Park DPL 3400 (also no longer available) and the SAE AS401B propane burner.

FAA advisory circulars deliver general guidance on acceptable means of compliance to regulations, and though specific test equipment may be specified, they note that alternative acceptable devices may be used. The aerospace industry is left operating existing oil burners, but primarily using propane burners for powerplant fire testing, which, although capable of matching regulatory standards, require careful handling to replicate a powerplant fire.

TEST ENVIRONMENT

When an engine installation burns, oil, fuel, and hydraulic fluids are typically involved, generating flames of similar temperature and heat flux to propane, but of greater opacity. Tested with a propane burner, materials re-radiate heat into the transparent propane flame as they near its temperature, causing a rapid loss of surface heat – there is no heat loss through a flammable-liquid flame. Thus the Fire Safety Branch set about defining standards for the NextGen, or sonic burner, aimed at delivering fully representative, repeatable test conditions.

Compared with the Park DPL 3400, which had been in widespread use, the NextGen burner is engineered to deliver greater consistency using compressed air and a pressurized fuel system in place of the earlier model's electric motor. Nitrogen gas applies a head pressure to the burner's jet fuel supply for consistent pressure and flow rates, and modifications to the burner configuration include installation of a flame retention head. The latter increases flame uniformity and early material fire tests revealed the potential for improved test result repeatability, all initially thanks to work based on



LEFT: The FAA's NextGen burner is being developed to deliver fully representative, repeatable test conditions

a US$50 part purchased from a central heating supplier. Indeed, the NextGen burner has been developed for ease of reproduction, so that machines assembled at different locations will behave as identically as possible.

In early NextGen burner tests against a slug calorimeter (a sheet of copper with a thermal absorptive coating and thermocouple(s) on its rear face to determine heat flux), 2024 aluminum sheet and a double layer of 8611R polyacrylonitrile, the FAA confirmed consistency between individual burners. Flame temperatures and heat flux were similar to those generated with the DPL 3400. Through the FAA's extensive collaboration with industry, nine laboratories subsequently became involved, testing against 12 materials.

When all the test data has been collated, analyzed, and confirmed to be consistent, work will begin on rewording AC20-135. Steve Summer, from the FAA's Fire Safety Branch, explains: "We're conducting research to implement the burner in all the areas where it'll be used – in materials flammability tests for seat cushions, cargo liners, and powerplant fire testing. In the latter, the burner is used as a certification means to determine the fire worthiness of a component or material. Components must maintain their function for a specific period of time when exposed to the burner."

HALON PROGRESS

While the NextGen burner will help to prove passive fire safety – the ability of components to withstand fire and continue to function – there is a raft of unrelated research and test work aimed at finding a replacement for halon 1301 in fire-extinguishment systems. Combined with fire detection sensors, fire-extinguishment equipment provides active fire safety.

"THE NEXTGEN BURNER HAS BEEN DEVELOPED FOR EASE OF REPRODUCTION, SO THAT MACHINES ASSEMBLED AT DIFFERENT LOCATIONS WILL BEHAVE AS IDENTICALLY AS POSSIBLE"

Universally ratified by the UN on September 16, 2009, the Montreal Protocol on Substances that Deplete the Ozone Layer banned continued halon production. The EU and ICAO specified that alternative engine/APU fire-extinguishing agents must be used in new-design aircraft after 2014, while the EU also requires the completion of retrofit work to replace halon equipment in legacy aircraft by 2040. Regardless of these deadlines, regular maintenance requirements are dependent upon recycled halon supplies, which will become depleted over time.

To date, the FAA has approved several built-in non-halon fire extinguishers for litter bins, as well non-halon hand fire extinguishers for use in the cockpit and cabin. However, only one built-in non-halon fire extinguisher has been approved for engine use. The FAA's William J Hughes Technical Center continues to work with the International Aircraft System Fire Protection Working Group on non-halon research, supporting industry in developing alternative fire-extinguishing agents suitable for use in the challenging environment of the engine/APU and cargo hold.

This group created the minimum performance standards (MPS) for all aircraft applications. The MPS provide recognized test protocols establishing the performance equivalency of the non-halon agent compared with halon agents. Completion of the MPS is the first step in approving a non-halon extinguishment/suppression system for use on transport-category aircraft.

Additional installation issues must be addressed to obtain FAA approval, including operation of the extinguishing/suppression system considering the effects of altitude, temperature, humidity, and so on, at worst-case operating temperatures. The possibility of material interaction between the agent and the parts that are likely to be exposed to it during storage or discharge must also be evaluated, as must its shelf life and installation life limitations on the aircraft.

Meanwhile, the Halon Alternatives for Aircraft Propulsion Systems (HAAPS) consortium was formed in October 2014 to "mitigate both the regulatory and supply risks by leveraging the combined resources and knowledge of the aircraft manufacturers, fire-extinguishing system suppliers, engine/APU/nacelle companies, governments, and other key stakeholders to develop a non-

TEST SETTINGS USED ON NEXTGEN BURNER WITH FRH FITTED

FUEL PRESSURE:	90-100psi
FUEL TEMPERATURE:	42°F (±10°F)
AIR PRESSURE:	50psi
AIR TEMPERATURE:	50°F (±10°F)
AVERAGE FLAME TEMPERATURE OVER 14 TESTS:	1,901°F (6°F standard deviation)
AVERAGE HEAT FLUX OVER 14 TESTS:	6,065BTU/h (370BTU/h standard deviation)

Q&A

STEVE SUMMER FROM THE FAA'S FIRE SAFETY BRANCH

HOW WILL USERS ENSURE THEIR NEXTGEN BURNER IS CREATING A FLAME OF THE REQUIRED STANDARD?
"Calibration specifications of the fuel and air flow rate and temperature will be specified to ensure the flame is of the proper intensity. Once the required flow rates and temperatures are determined, periodic checks of the burner will be required to ensure proper functioning of the equipment."

HOW CLOSELY IS THE FAA WORKING WITH INDUSTRY ON NEXTGEN BURNER TESTING?
"We're working extensively with industry, collaborating with several test labs to assess burner performance and consistency. This work is coordinated through the Powerplants Fire Test Task Group, which functions as part of the International Aircraft Systems Fire Protection Working Group."

HAS THE DEVELOPMENT OF NEW AIRFRAME MATERIALS INFLUENCED THE NEXTGEN BURNER'S DESIGN?
"Not its design, but we are evaluating the process to identify what changes the test requirements might need to properly test those components."

WAS ANY INDIVIDUAL IN PARTICULAR RESPONSIBLE FOR NEXTGEN DEVELOPMENT?
"Dr Robert Ochs of the FAA Fire Safety Branch developed the burner for a recent regulation on insulation burn-through resistance. It has since been incorporated into many of the materials' fire test requirements for seat cushions and cargo liners. We are now looking to incorporate it into the powerplants' fire test requirements."

DOES THE NEXTGEN BURNER HAVE A PLACE IN HALON-REPLACEMENT RESEARCH AND DEVELOPMENT WORK?
"No, the burner doesn't impact halon-replacement research, but it will have a key role in proving the passive fire safety standards of future powerplants and components. It's used to ensure the proper functioning of equipment and materials under a realistic fire condition, whereas halon replacement focuses on finding a suitable replacement that provides the same fire suppression."

halon replacement." Comprising representatives from Airbus, Boeing, Bombardier, Embraer, Textron, and the Ohio Aerospace Institute (OAI), HAAPS is managed by OAI's Carol Cash.

A HAAPS update document released in May this year proposes a three-phase approach, with Phase I – creation of the consortium – complete. Phase II, tentatively timetabled to last one year from the third or fourth quarter 2015, will develop a technical statement of work, while Phase III, likely to run for 12 months from the third/fourth quarter 2016, will include test and analysis work to identify a replacement agent and systems.

Doug Ingerson is part of the FAA's engine nacelle halon replacement effort. He confirms: "Test work is progressing, with multiple FAA offices involved. We've become the focal point for conducting the testing, coordinating with industry and other airworthiness authorities. There are particular test protocols for the powerplant, cargo compartment, handheld extinguishers on the main deck, and fire extinguisher bottles in trash cans in the lavatories of all transport-category aircraft."

Many factors will decide on the effectiveness of the halon replacement, among them the rate at which it is released. With the cargo compartment, Ingerson notes: "In some of the systemic design considerations, quickness can be detrimental (in an oversimplified example, injecting too much candidate into the compartment too rapidly might defeat the structural boundary of the cargo compartment, thus losing the necessary containment).

"Effective function would also include minimal production of noxious decompositional by-product as the halon replacement is exposed to the fire and thermally decomposes during its resident time. Also, the cargo compartment must contain the fire whether the fire-extinguishing agent is resident or not. This part of its design is assessed without consideration of a fire-extinguishing system used to protect the compartment. Fire containment and fire extinguishment are two different design goals in the cargo compartment." ▮

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

"TEST WORK IS PROGRESSING, WITH MULTIPLE FAA OFFICES INVOLVED... MANY FACTORS WILL DECIDE ON THE EFFECTIVENESS OF THE HALON REPLACEMENT, AMONG THEM THE RATE AT WHICH IT IS RELEASED"

BELOW: **FAA's NextGen burner in the lab**

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Organized by UKIP Media & Events Ltd, the publisher of *Aerospace Testing International* magazine, the conference takes place November 17-18, 2015, at the Bremen Messe, Germany.

With key speakers from Airbus, NASA, Rolls-Royce, plus many other leading industry players and academics, the two-day event will cover all aspects of aerospace activity, from commercial aviation to military applications, providing instant access to the ever-growing amount of research into the increased electrification of aircraft and the possibilities and challenges that brings.

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NOVEMBER 17-18, 2015 BREMEN, GERMANY

Day 1 Tuesday, November 17

09:00 - 12:10
Opening Keynote Presentations

Room A

Opening Keynote Address

09:00 - NASA Glenn: powering the future with green propulsion technologies
Dr Janet Kavandi, deputy director, NASA John H Glenn Research Center, NASA, USA
The presentation will provide an overview of the NASA Glenn Research Center research and technology portfolio in future green propulsion technologies for aviation.

09:25 - ACARE and the move toward Flightpath 2050
Dr Gareth Williams, VP business development research & technology, Airbus/ACARE/Flightpath 2050, France

09:50 - Unlocking cutting-edge power density and efficiency using silicon carbide electronics
Anthony Law, systems engineer, McLaren Applied Technologies, UK
McLaren Applied Technologies will describe technologies that can be used to achieve a step-change in power density and efficiency for power electronics and electric machines. Experiences from motorsport applications and performance targets for future developments will be shared.

10:15 - Exploring the Integrated Drive System for electric aircraft
Dr Frank Anton, executive vice president, Siemens AG - CT NTF AIR, Germany

10:40-10:55 – Coffee Break

10:55 - NASA investments in hybrid-electric technologies for large commercial aircraft
Dr Rubén Del Rosario, project manager, NASA, USA
The presentation will provide an overview of NASA's research and technology portfolio in the area of hybrid-electric and distributed propulsion as it relates to large commercial transport aircraft.

11:20 - Recent advancements in sizing and analysis of hybrid-electric aircraft
Prof. Dimitri Mavris, AP Langley NIA Distinguished Regents Professor, Georgia Institute of Technology, USA
This paper will discuss recent advances at Georgia Tech in the sizing of radical hybrid-electric aircraft propulsion systems. The closely coupled nature of a hybrid-electric system requires that new synthesis and sizing methods be developed to solve the energy management problem that is now introduced into the sizing phase. Recent progress in studying optimal architectures across vehicle size classes, identifying optimal fuel and energy storage splits across operating, and development of new tool sets to facilitate the conceptual design of hybrid-electric aircraft will be presented.

11:45 - Hybrid-electric distributed propulsion aircraft superconducting power systems
Prof. Peter Malkin, professor of Electrical Power Systems, Cranfield University, UK
Extensive models have demonstrated that by using the hybrid approach significant savings are possible in aircraft emissions and running costs. These aircraft use superconducting power systems that will also enable new fuels to be used that further reduce emissions. The paper will also cover the possibilities of further gains from the hybrid approach around the flight cycle as has been seen from other hybrid transport applications. Although these may be smaller than in other sectors, they will act to supplement the gains in other areas such as propulsion efficiencies, which further adds to the potential benefits of these techniques.

12:10-13:00 – Lunch

13:00 - 15:30
Session 1: More Electric Aircraft

Room A

13:00 - Aviation 2050 – propulsion and aircraft options
Prof. Mirko Hornung, executive director research and technology, Bauhaus Luftfahrt, Germany
Propulsion and energy systems are key drivers for the ecological and economical improvements of the next generations of transport aircraft. With a long-term perspective, viable options for efficient energy and thrust generation will be shown, including radical turbo machinery concepts up to hybrid propulsion systems and universal electric architectures. Potentials on the aircraft level will be discussed, and integrated performance potentials will be highlighted.

13:25 - Hybrid-electric propulsion – a European initiative for technology development
Peter Rostek, sector manager long-term concepts, Airbus Operations GmbH, Germany
It is a huge challenge to bring hybrid-electric propulsion onto the aviation market. But a smart combination of combustion engines and electric components would be the basis for two major changes: hybrid architectures will improve the overall efficiency of the propulsion chain; and synergies between technology bricks will open the aircraft design space. Within the European research program Clean Sky 2, Airbus – together with a research partnership network – will explore those opportunities. This presentation provides general information on the potential of hybrid-electric propulsion in commercial aviation and on current development activities in the scope of Clean Sky 2.

13:50 - Distributed electrical aerospace propulsion
Stephen Mark Husband, lead engineer, electrical systems and technologies, Rolls-Royce plc, UK
This presentation investigates the development of the hybrid-electric distributed propulsion system. It will identify a number of potential performance benefits including improved aerodynamics, propulsion, thermal and operational efficiency (based on energy management) and increased aircraft design freedom. It will explain how this was collaboratively investigated as part of an Airbus Group Innovations, Rolls-Royce plc and Cranfield University UK government-funded project. The presentation will discuss the key enabling subsystems including boundary layer re-energising fan systems, higher off-take engine solutions and superconducting electrical networks, and will show that an integrated design process is required.

14:15 - Delivering innovative and optimized solutions for the More Electric Aircraft
Pascal Thalin, vice president, research & technology and technical director, Thales Avionics Electrical Systems, France

14:40 - Fuel-cell electrical generator for aircraft
Adrien Gasse, project manager, Snecma / SAFRAN, France
The present study focuses on the feasibility of an airborne complementary power generator in the range 2.5-5kWe, based on a HT-PEMFC hybridised with a NiCd battery. The system has high modularity compliance with various kinds of missions. The presentation will discuss integration requirements and technical solutions to ensure function, performance and safety. It will also look at the numerical model of the whole system designed and used to validate the system architecture in its environment.

15:05 - High-performance HVDC starter/generators for the more electric airplane
Jean-Marc Le Peuvedic, R&T project manager, Dassault Aviation, France
The presentation will put in perspective the Clean Sky-supported project Aircraft Electrical Generation System with Active Rectification and Health Monitoring. It will disclose how the project was initiated, what the aircraft level goal was, and how the key challenges have been solved. We will conclude with the achieved performance level, the new horizons and the new challenges we have discovered.

15:30-15:45 – Coffee Break

15:45 - 17:50
Session 2: More Electric Aircraft & Associated Systems
Room A

15:45 - Hydrogen fuel cell powertrain for aircraft applications
Prof. Josef Kallo, head of energy system integration, German Aerospace Center, Germany
Hydrogen and fuel cells are a very promising technology for electrical power sources in aircraft applications, from APU replacement to main propulsion. This presentation will summarize the efficient integration of such technologies in an aircraft environment, fulfilling safety, gravimetric and efficiency requirements. It will also point out developments needed to increase the energy density and reliability of hydrogen and fuel cell systems.

16:10 - Integration of batteries into aeronautic applications – challenges and opportunities
Philipp Berg, research associate, Technische Universität München, Germany
The relevance of lithium-ion batteries is on the rise due to expansion of the electric vehicle market. Market growth and continuous research efforts have helped to considerably improve the specific energy and specific power density of today's lithium-ion cells. Because of these advancements, lithium-ion batteries are also of increasing interest for challenging tasks such as electrification of aircraft. It can be shown that simple adoption of batteries for electric vehicles is not a viable approach for electric aircraft. Instead, technical hurdles have to be overcome and aeronautical requirements need to be met with regard to the major aspects of weight, safety and reliability.

16:35 - Radically new technologies for meeting the aviation industry's environmental goals
Dr Thomas Roetger, assistant director, environment technology, IATA, Switzerland
Radically new technologies will be needed to reach the ambitious carbon reduction goals the aviation industry has committed to, including 50% reduction of global emissions by 2050. IATA and DLR have investigated various radical technologies regarding potential market share and the need for preparative actions for their deployment. Battery-driven commercial aircraft could cover a good part of short-range flights. However, their implementation requires not only strongly improved battery energy density, but also proper logistics and power supply at numerous airports, which needs appropriate lead time. The impact of lower flight speed on ATM also needs to be considered.

13:00 - 15:05
Session 1: Alternative Aircraft Design & Technology
Room B

13:00 - Clean Sky & Clean Sky 2 delivering breakthrough technologies
Giuseppe Pagnano, coordinating project officer, Clean Sky, Belgium
Clean Sky is the most ambitious aeronautical research program ever launched in Europe. Its mission is to develop breakthrough technologies to significantly increase the environmental performances of airplanes and air transport, resulting in less noisy and more fuel efficient aircraft, hence bringing a key contribution in achieving the Single European Sky environmental objectives.

13:25 - WheelTug – driving aerospace toward full electric aircraft
Jan Vana, director, WheelTug plc, Gibraltar
WheelTug plc has brought to market the first technology that enables aircraft to taxi without using their main engines and without the assistance of tow tugs. This presentation will explore the efficiency of high-torque electric motors used in such a way, and also the benefits to both airlines and other aircraft operators in terms of reduced fuel consumption, reduced engine damage, reduced brake wear and tear, and reduced maintenance costs. The improved ground operations and schedule efficiencies will also be covered, as will the important positive environmental impact created by using such a system.

13:50 - Solar Impulse – the first human-carrying aircraft capable of perpetual flight
Christoph Schlettig, flight director/flight test engineer, Solar Impulse, Switzerland
Michael Anger, lead mission engineer, Solar Impulse, Germany
With over a decade of development, Solar Impulse will have to do what nobody else has done before: fly through five consecutive days and nights without using any fuel, so as to cross oceans from continent to continent, attempting to achieve the first round-the-world solar flight. The presenters will provide an insight into the challenges and lessons learned during testing and operation of Solar Impulse 2. Key points are inflight energy management and the resulting operational constrains, and batteries – blessing and curse.

14:15 - Safety assessment and pioneering projects – dream or reality?
Lorenzo Murzilli, certification engineer - systems and safety expert, Swiss Federal Office of Civil Aviation, Switzerland
The presentation will outline the safety assessment process that was designed by Swiss FOCA to issue the Permit to Fly for the Solar Impulse mission. The focus will be on what was special about this project, the challenges involved and how a tailored but rigorous process helped both Swiss FOCA and Solar Impulse achieve the ambitious goals of this pioneering project.

14:40 - Aeroscraft cargo airship: delivering game-changing innovation for global logistics
Igor Pasternak, CEO, Aeroscraft Corporation, USA
How technological advances in onboard buoyancy management empower new cargo airships to deliver independently from infrastructure, providing speed, flexibility, efficiency, greater accommodation and environmental stewardship. Greatly surpassing the speed of sealift in global logistics, transport airships are poised to dramatically increase heavy cargo lift capability and destination alternatives, while reducing the current cost of air delivery. They will significantly reduce fuel consumption for aircraft operations on a ton/mile cost basis, permit new heavy load operations in austere areas, and radically alter the hub-and-spoke logistics structure to one of direct, flexible delivery.

NOVEMBER 17-18, 2015 BREMEN, GERMANY

15:05-15:20 – Coffee Break

15:20-17:50
Session 2: Alternative Aircraft Design & Technology

Room B

15:20 - Aerospace drives: toward more power density, reliability and efficiency
Dr Michael Galea, lecturer, University of Nottingham, UK
As the industry keeps moving toward aircraft electrification, one of the main current interests is electrical and hybrid propulsion. This presentation will cover recent research activities at the University of Nottingham, where excellent performances in terms of power and torque density, reliability and efficiency have been achieved for machines and drives for aerospace applications. These experiences will be shared in light of the feasibility to apply these technologies to electric propulsion. A brief introduction to the aerospace effort at Nottingham will be followed by a discussion on current and future enabling technologies and their impact on technology readiness.

15:45 - Conceptual Development of Electric Drive Trains for Commuter Aircraft and Helicopter, within the Bavarian Research Project 'PowerLab'
Dr Peter Jaenker, head of hybrid power, Airbus Group Innovation Works, Germany
The paper describes the recent research activities within the POWERLAB project, supported by the Bavarian state. A collaboration of academic and industrial researchers investigates key components of hybrid-electric drive trains for a commuter aircraft and a light utility helicopter. Both applications require a propulsion power of about 600kW. The major aim of the project is to develop extremely lightweight e-machines including power electronics. For modelling purposes, smaller high-performance motors have already been tested on a ground rig with a power-to-weight ratio > 5kW/kg. For the commuter propeller drive and generator, a conceptual study is under way; for the helicopter main rotor drive, a full direct-drive prototype is under development and will be produced and tested on the ground rig mentioned above. In addition, concepts of future propulsion battery storages are examined and, finally, aspects of certifiability and infrastructural impacts are elaborated.

16:10 - Aerodynamic aspects of electric aircraft propulsion systems
Juergen Frey, research assistant, TU Dresden, Germany
Electric propulsion systems and, particularly, energy storage devices are, and will be within the foreseeable future, significantly heavier than conventional ones. Thus the structural weight does not contribute as much to the total weight as before. Meanwhile, aerodynamic quality contributes to the total thrust, power or energy necessary to keep the total weight airborne or travel a given distance. This is why the most successful electric aircraft so far have been powered gliders. The presentation examines the aerodynamic performance limits resulting from the relationship of weight, aspect ratio and Reynolds number.

16:35 - Airlander 10 is the first full-scale hybrid air vehicle
Andy Barton, business development director (commercial markets), Hybrid Air Vehicles, UK
The Airlander 10 is a revolutionary new aircraft that combines the properties of an airship (buoyant lift), aeroplane (aerodynamic lift) and helicopter (vectored thrust). This combination of properties gives the Airlander exceptional endurance (three weeks' flying without refuelling), low operating costs and an ability to operate on water or land without a prepared runway. The prototype Airlander 10 flew successfully in the USA in 2012 as a military aircraft, and will soon be flying again in the UK as a civil aircraft. It will be even more capable once it is fitted with electric propulsion.

PAUL STEIN,

chief scientific officer,

Rolls-Royce, UK

SPEAKER SPOTLIGHT

What are the challenges in developing electric or hybrid aircraft?
Electric and hybrid-electric aircraft concepts are being driven by the ambitious environmental protection goals of the European Commission, stated in the *Flightpath 2050 – Europe's Vision for Aviation* report. Significant improvements in aircraft and propulsion systems are required to achieve these goals, and electric or hybrid-electric are being studied as a potential solution. The goals can only be achieved through revolutionary changes in engine technology, system architecture and engine/airframe integration. Introducing such revolutionary changes is challenging in a typically conservative industry.

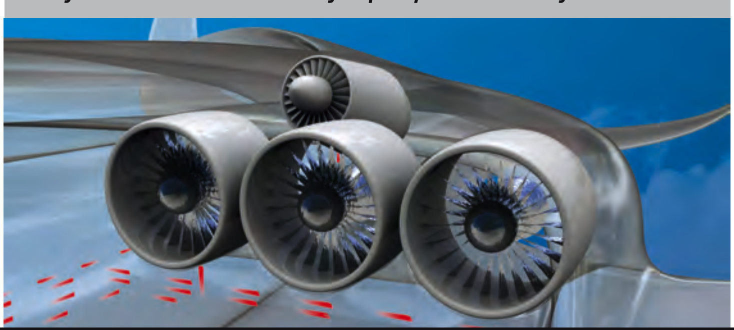
Electric or hybrid-electric aircraft provide the capability to minimize non-propulsive power use throughout a flight, and electric propulsion could enable significant aerodynamic improvements because of its propulsion integration flexibility. The main challenges relate to the size, weight and reliability of the required electrical equipment. Therefore the obvious technology enablers are more power-dense electrical generators, batteries, distribution systems, power controllers and motors. Superconducting systems have also been studied for electric propulsion applications. Advanced system architectures also play a role in minimizing size and weight, while maintaining redundancy and safety. Other key technologies relate to propulsion system/airframe integration and revolutionary aerodynamic approaches. For large aircraft, these systems are multi-MW, necessitating high-voltage transmission/conversion and large electric power off-take from turbine engines in hybrid-electric systems.

What projects has Rolls-Royce carried out in this sphere?
A significant Rolls-Royce team is working in this field and a number of individual hybrid and electric projects have been completed globally supporting NASA, Airbus and others. The work has been supplemented by a number of additional areas of research undertaken through our world-leading University Technology Centre network and our recent commitment to the Aerospace Integration Research Centre. A wide spectrum of analysis is exploring innovative solutions to future challenges.

The application of hybrid power system technologies across in land, sea and air is a steady trend which receives a significant fraction of the Rolls-Royce R&D budget and provides a significant opportunity to benefit from technology synergies across the group.

Won't an electric aircraft put RR Aero Engines out of business?
Hybrid-electric solutions using gas turbine engines are the most probable solution for all but very small aircraft unless there are some dramatic breakthroughs in electrical energy storage technology. Our hybrid-electric capabilities are well matched to this approach and we will continue to develop our capability. Our world-leading engine core developments will provide the major energy source, and our fan designs will provide integrated propulsion solutions to optimize aircraft performance.

Paul Stein will deliver a presentation entitled 'Planning the journey for hybrid-electric – a Rolls-Royce perspective' on Day 2



Day 2 Wednesday, November 18

09:00 - 12:10
Session 1: Propulsion Technology

Room A

09:00 - Planning the journey for hybrid-electric – an R-R perspective
Paul Stein, chief scientific officer, Rolls-Royce plc, UK
This presentation discusses the potential aerospace journey toward hybrid-electric. The key historic and current R-R experience will be used to show the current aerospace technology capability. The need for greater integration will be demonstrated through the drive toward a more electric aircraft as an example. The industry challenges will be presented and the business and technical innovation key enablers required to deliver a more integrated solution will be highlighted. The presentation will conclude by showcasing some hybrid-electric studies Rolls-Royce has been involved with.

09:25 - Spiral development of distributed electric propulsion from ground to flight
Starr Ginn, deputy aeronautics research director, NASA Armstrong Flight Research Center, USA
The National Aeronautics and Space Administration's Aeronautics Mission Directorate has begun to research the challenges in the development and implementation of electric propulsion. The initial steps in this roadmap call for the ground and flight testing of small-scale electric aeroplanes that will ultimately lead to large-scale electric propulsion. Several NASA centres and small US businesses are collaborating on multiple projects that range from a 250kW hardware-in-the loop hybrid-electric distributed propulsion Ironbird, to flight testing of an all-electric 2,500 lb sub-scale distributed electric propulsion aircraft.

09:50 - Flight demonstration of regenerative air brake and multiplexed electric motor
Dr Akira Nishizawa, section leader, The Japan Aerospace Exploration Agency, Japan
The Japan Aerospace Exploration Agency (JAXA) has researched and developed an aircraft-use motor system. In 2014 and 2015, JAXA conducted piloted flight demonstration tests with a motor glider that used the new electric propulsion system in place of its existing reciprocated engine. JAXA's unique power regeneration function allows the propeller and motor to generate power as the aircraft is descending, while also serving as a substitute air brake. The electric motor system is composed of four motor elements connected in series, and its redundant function ensures better fault tolerance in flight.

10:15 - Pilot interface design of electric aircraft for regenerative flight
Dr Tomoko Iijima, researcher, The Japan Aerospace Exploration Agency, Japan
The Japan Aerospace Exploration Agency (JAXA) had conducted flight test evaluation for a motor glider that is equipped with a new original electric propulsion system proposed by JAXA in 2014. JAXA developed a prototype pilot display and power control system as a pilot interface for regenerative eco-efficient flight of the electric motor glider. We present the prototype of the new pilot interface and flight evaluation of pilot workload for regenerative flight.

10:40-10:55 – Coffee Break

10:55 - Hybrid Turbine/Electric Propulsion System
Naiara Petralanda, research engineer, Embry Riddle Aeronautical University, USA
A 600 Hp hybrid gas-turbine/electric motor is being studied for implementation in the aviation industry. The main focus is to determine the optimal conceptual design of a 400 shaft to 200 electric horsepower distribution. The implications on the airframe, avionics and aircraft systems are also being evaluated while the existing tools are being refined.

11:20 - Hybrid turbine-solid oxide fuel cells for aircraft propulsion and power
Prof. Christopher Cadou, associate professor, University of Maryland, USA
This paper explores the possibility of replacing mechanical generators on aircraft with more efficient solid-oxide fuel cells that are integrated directly into the engine flow path. A model of such a system has been developed that incorporates realistic turbomachinery performance, thermal modelling, species transport, component sizing and multi-step chemistry. The results show that substantial (>5%) reductions in fuel flow rate can be achieved at electric-to-propulsive power ratios of 0.05, and that much larger benefits (~25%) are available at larger ratios. The cost in specific power is modest (<10%) but external aerodynamic design is crucial.

11:45 - The first US hybrid-electric aircraft, and full electric in development
Dr Luis Gonzalez, assistant professor Aerospace Engineering, Embry-Riddle Aeronautical University, USA
Embry-Riddle's Eagle Flight Research Laboratory is positioning at the forefront of electric and hybrid aviation with two projects: the successful demonstrator that participated in NASA's Green Flight Challenge in 2011, the first hybrid-electric aircraft in the USA; and with the experience gained, EFRC is now working to produce a fully electric general aviation aircraft, expected to fly by the end of this year.

12:10-13:00 – Lunch

13:00 - 17:00
Session 2: Power Generation

Room A

13:00 - High-efficiency and high-power-density generator rated for 1MW
Cristian Anghel, technology fellow, Honeywell, USA
This presentation describes the technical characteristics of an efficient, high-speed, high-power-density generator designed to generate 1MW of high-voltage electrical power continuously, which can be used for turbo-electric propulsion and other applications requiring large power and compact installations. Honeywell has an unparalleled generator range, including fixed- and variable-frequency AC and DC generators, and air- and oil-cooled generators, based on 100 years of product development. Building on this experience, a 1MW generator was developed and manufactured. We are currently testing this generator and 540kW of output power has been demonstrated to date.

13:25 - Small Electric UAVs: a small scale test platform for long endurance power technologies
Taras Wankewycz, CEO, Horizon Energy Systems Pte, USA
Think big, but start small. Hybridization of novel energy harvesting technologies together with novel energy storage technologies for long endurance electric flight has already begun for first phase commercialization in the field of small electric flying drones. Prior to using the combination of such new technologies, extended flight endurance capabilities were restricted to larger, more costly platforms, mainly due to today's battery limitations. Beyond power, weight and energy, the implementation of these technologies helps to reduce the number of take-offs while simultaneously expanding mission radius and operation coverage. As these technologies continue to advance, so do the performance and capabilities of smaller cost-effective vehicles, and so does their potential for application in larger commercial aircraft.

NOVEMBER 17-18, 2015 BREMEN, GERMANY

13:50 - Exceeding Si-Fe with magnetic materials and technologies for aerospace application
Jan Michael Weickhmann, head of product marketing application engineering, Vacuumschmelze GmbH & Co KG, Germany
To make the conversion of energy as loss-free as possible, efficient methods are needed. It is important to minimise losses. The aim of this paper is to cope with this challenge of exceeding the limits of Si-Fe and to present the following considerations. With Ni-Fe alloys, the iron losses of a motor may be kept as low as possible, by increasing the resistivity by appr. a factor. The reduction of iron loss may be, for example, with a lamination thickness of 0.1mm between 70% and 80% versus Si-Fe lamination stack, depending on the frequency.

14:15 - Bi-functional thermoelectric generator/pre-cooler: DC power from aircraft bleed air
Basham Johnson, president, Alteg Systems, USA
Hot compressor bleed air is the core of an aircraft's environmental control system. Much of the thermal energy within that air is vented to the atmosphere as waste. A novel tubular thermocouple can be used as a passage for bleed air, converting some of its thermal energy into electricity. Several couples threaded together will create a low-complexity solid-state DC generator that can produce kW-level electricity. Designed as a replacement for a bleed pre-cooler, the device would offer an additional electrical source without additional power-plant burdens.

14:40-14:55 – Coffee Break

14:55 - Thermoelectric energy harvesting for aerospace applications
Ludek Janak, research engineer, UNIS AS, Czech Republic
The presence of temperature gradients on board aircraft conveniently provides the opportunity for supplying various electronic systems. The heat energy provided by temperature gradients can be converted into electricity using thermoelectric energy harvesting. The presentation describes prospective applications of thermoelectric generators on aircraft, rotorcraft and their onboard systems. These applications particularly include backup power supplies, and various zero-power sensors (SHM, HUMS) implemented in wireless sensor networks. Special emphasis is put on the results of the FP7 EU project ESPOSA – Efficient Systems and Propulsion for Small Aircraft, related technology demonstrations and further challenges.

15:20 - Leverage automotive electric/hybrid challenges for success in aerospace technology
Dr Nathan Blattau, senior vice president/CTO, DfR Solutions, USA
Gas-electric hybrid vehicles with their complicated electronics are more reliable than their gas-powered counterparts, achieved through a comprehensive assessment activity to ensure high reliability in harsh automotive environments. This approach provides a path forward for similar success in the aerospace market using Physics of Failure. This paper presents an explanation of physical models that could be deployed through this method; namely, wire bond failures, thermo-mechanical fatigue (solder and PTH) and vibration. This approach is being accepted by system assemblers, as it permits failure-orientated accelerated testing, and 'what if' analyses in lieu of traditional accelerated life testing.

DR JANET KAVANDI

deputy director, NASA John H Glenn Research Center, NASA, USA

SPEAKER SPOTLIGHT

Can you provide an update on the progress made so far with NASA's LEAPTech project?
The LEAPTech (Leading Edge Asynchronous Propeller Technology) concept is one of many exciting electric and hybrid-electric propulsion configurations that we are currently investigating at NASA. LEAPTech is being supported by researchers from NASA's Armstrong Flight Research Center at Edwards, California, and NASA's Langley Research Center in Hampton, Virginia, along with partners Joby Aviation and ESAero. They are currently completing ground tests of a wing with distributed propellers mounted on a truck bed to demonstrate the viability of this concept for general aviation. During the Technology Symposium, various presentations from NASA and our partners will highlight the progress that has been made in the LEAPTech concept and in many other aspects of electric and hybrid-electric aircraft propulsion, including the Turbo-Electric Distributed Propulsion Concept. These presentations will also expand on our investment strategy for advancing critical technologies to enable the electrification of commercial aviation.

How does the research you are doing at Glenn differ from research into green propulsion at other NASA sites?
NASA's Aeronautics Research Mission Directorate has recently unveiled a strategic implementation plan outlining its vision for the future and has aligned its research activities to meet the future needs for efficient, flexible, and environmentally sustainable air transportation. The transition to low-carbon propulsion in aviation is one of NASA's strategic thrusts that drives the search for alternative and greener propulsion systems for advanced aircraft configurations. Our research portfolio is very broad and inherently multidisciplinary, and requires us to draw upon expertise that is spread across our agency, as follows: propulsion expertise at Glenn, aerodynamics expertise at Langley, flight research capabilities at Armstrong, and modeling and simulation expertise at NASA's Ames Research Center in Moffett Field, California. Glenn has a rich history in conventional aircraft propulsion research, as well as expertise in power and propulsion systems that will be a core element of NASA's push to enable the transition to electric and hybrid-electric aircraft systems.

What is the greatest challenge presented today in realizing fully electric aircraft?
Fully electric aircraft in the general aviation market are already becoming a commercial reality: one- and two-seater light aircraft have successfully flown, and just recently Airbus conducted the first flight of its electric eFan trainer concept across the English Channel. However, the overall power density of energy storage and electrical systems remains as the limiting factor that dictates the size and mission duration of electric and hybrid electric vehicles. For commercial aviation and larger vehicle classes, electrification will require innovations in a range of technology areas. It is also likely that hybrid-electric approaches based on a combination of conventional and electric propulsion systems will be developed first before fully electric systems become viable. With our partners, we are working on a wide range of critical technologies including: high power density electronics, efficient power management and distribution, ambient temperature and cryogenic superconducting electric motors and generators, and advanced materials. These technologies, in conjunction with radically new aerodynamic configurations and concepts, can enable the exciting future of electric aviation.

Dr Kavandi will present a paper entitled 'NASA Glenn: powering the future with green propulsion technologies' on Day 1

LEFT: **NASA's N-3X vehicle concept**

www.electricandhybridaerospacetechnology.com

09:00 - 12:10
Session 1: Power Storage & Electrical Systems
Room B

09:00 - Batteries: key elements to the success of More Electric Aircraft (MEA)
Holger Schuh, managing director, Saft Batterien GmbH, Germany
The battery system is a key element for the sustainable development of the MEA. Aware of the challenges, Saft has developed a roadmap to target the highly demanding specifications of fully electrical aircraft. This presentation will cover the key points demonstrating that although Li-ion battery systems are definitely suitable for the mid-term requirements, other electro-chemistries and battery systems will have to be developed to meet longer-term expectations.

09:25 - Progress in safety of lithium-ion batteries
Dr Olaf Gunnewig, branch manager, SGS Institut Fresenius GmbH, Germany
The safety of lithium-ion batteries for propulsion has made significant progress in the last decade, partly driven by automotive applications. Safety improvements start from the choice of the cell active material, the separator and the electrolyte additives. Cell design and a reliable pressure release are important for the cell safety. The battery management system has to care for all the cells of a battery to remain in the safe operating range at any time, and usually will provide safety functions to protect the battery against overcharge and external shorts. Important for safety validation is the close interaction between the risk analysis and the test procedures, which allows for a more quantitative severity and safety description.

09:50 - Layered Battery Management Framework
Patrick Mazzariol, founder, PJ Networked Systems, USA
The performance optimization of battery systems is a challenging task involving many practical system factors such as the dynamic load fulfillment, hardware and software design. To facilitate system optimization, inspired by the success of communication protocol stacks in the field of communication networks, we propose a novel layered charge/discharge management framework for large-scale battery systems. In the layered framework, each layer takes a unique role in optimizing the system performance, and individual layers only interact with their adjacent layers, therefore enabling highly modular and flexible battery system optimizations.

10:15 - Characterization by power cycling of electric and hybrid aerospace power electronics
Mathew Clark, field application engineer - Europe, Mentor Graphics GmbH, Germany
High-power electronics devices are used widely in many industries from elevators and wind turbines to hybrid and electric vehicles as well as aeroplanes, resulting in different usage and test scenarios. However, with different application cases the lifetime or failure criteria of an IGBT can change significantly on a case-by-case basis. The general test method for power cycling is described by the JEDEC JESD22-A122, but is insufficient to cover different design assemblies. This paper aims to discuss the differences and results of varying cycling strategies including their setup and resulting failure modes, including a methodology to characterise high-power electronics thermally in-situ.

10:40-10:55 – Coffee Break

10:55 - Advanced supercapacitors for the aerospace industry
Dr Hardi Hõimoja, project engineer, Skeleton Technologies, Estonia
Development of supercapacitor technology is set to provide a solution to the pulsed power problem in aerospace applications. Skeleton Technologies' novel carbide-derived carbon-based supercapacitors show four times more specific power and two times more specific energy values than the competitors. The potential added values include voltage balancing, thermal management and data acquisition in multicell configurations, as well as reliability enhancement by faulty cell exclusion. Skeleton's joint efforts with the European Space Agency and its affiliates, launched back in 2011, mean these advanced supercapacitors will be orbiting in the near future.

11:20 - Extended temperature range high-power sources for next-generation launchers
Dr Yvan Reynier, research engineer, CEA-LITEN, France
In next-generation launchers (Ariane 5ME and Ariane 6), primary and secondary batteries will be used for powering avionics, pyro systems, guidance and control electronics, and communication systems. Such applications require unrestricted operations between -20°C and 70°C. CEA has developed and optimized two Li-ion technologies in 18650 format: NMC-LTO with high power sizing (~20C rate), and NMC-Si for medium power (5C). For low-power application, CFx primary lithium battery was selected for its very high energy (>275Wh/kg), and prototypes developed in AA 14500 format. Performance results in representative mission profile for both technologies will be shown and compared.

11:45 - Annealed pyrolytic graphite for airborne thermal solutions
David Mullen, project manager and lead applications engineer APG, Thermacore-Europe Ltd, UK
k-Core, a very high-performance thermal management technology, is now manufactured within Europe and will allow aerospace equipment suppliers to more efficiently manage their thermal issues using a lightweight, high-performance product. Thermacore Europe has transferred its k-Core technology into the United Kingdom; along with its existing design and development expertise, the company can offer a complete system solution if necessary. The k-Core product offers customers a lightweight, aluminum composite with a significantly enhanced thermal conductivity of up to 1,000W/mK, but maintaining the versatility of aluminum.

12:10-13:00 – Lunch

13:00 - 17:00
Session 2: Power Storage & Electrical Systems
Room B

13:00 - Analyzing a ±270VDC aircraft harness under thermo-electrical and vibration loads
Holger Sparr, mechanical engineer, BTU Cottbus-Senftenberg, Germany
Due to the evolution of alternative power sources like fuel cells generating DC power and the increasing push toward 'more electric' aircraft, ±270 VDC electrical devices and networks have emerged in aircraft. This motivates the analysis of the electrical harnesses involved in carrying the HVDC power. This research analyzed the effect of vibrations and thermal-electrical loads on ±270 HVDC electrical harnesses inside an aircraft using experimental as well as numerical modelling. The vibration loads generated by the 'windmilling imbalance' condition of the aircraft were the primary focus.

13:25 - Ultracapacitor-based power systems for space applications
Dr Riccardo Signorelli, chief executive officer, FastCAP Systems Corp, USA
FastCAP is an international leader in the development and commercialisation of cutting-edge rugged extreme environment ultracapacitors – lithium-free, high-powered, rechargeable devices that operate at extreme temperatures, shocks and vibrations. Compared with today's spacecraft battery technology, the proposed ultracapacitor will provide much higher power with no thermal management, and will avoid downsides associated with batteries. In applications where batteries are oversized for power handling, we expect dramatic reductions in weight. FastCAP has identified a variety of aerospace applications where this disruptive technology will have a significant impact on energy storage weight/volume reduction, complexity reduction and life extension.

13:50 - Power supply and control systems moving toward MEA
Rolf Bellman, Sales Manager, AES Aircraft Elektro / Elektronik System GmbH, Germany

14:15 - Development of novel electrically conductive injection-moldable composite materials
Dr Craig Reeder, scientist, TE Connectivity, USA
Weight savings can be achieved in aircraft by replacing metal components, such as shielding boxes, with injection-moldable, electrically conductive composites. The ability to injection mold composite materials presents two additional advantages over die-cast metal parts: greater flexibility in the part geometry and potential for miniaturization. Our studies describe the development of injection-moldable conductive composites with densities below 2.6g/ml and electrical resistivity values as low as 1.4 x 10^{-3} cm. These novel materials are 33% lighter than commercially available conductive composites with resistivity values that are increased by only a factor of 3.

14:40-14:55 – Coffee Break

14:55 - 17:00
Session 3: GA Propulsion & Technology

Room B

14:55 - Beating combustion – designing competitive electric aircraft
Axel Lange, CEO, Lange Research Aircraft GmbH, Germany
Building and delivering certified electric aircraft since 2004, sister companies Lange Aviation GmbH and Lange Research Aircraft GmbH have continuously focused on creating electric aircraft where the mission profile allows the aircraft to compete with, and surpass, combustion-based propulsive solutions. The presentation describes the lessons learned from completed designs and projects, as well as giving an overview of the current development project: the Antares H3, a fuel-cell-powered aircraft with extreme endurance.

15:20 - A step change in general aviation via hybrid flight
Neil Cloughley, managing director, Faradair Aerospace Limited, UK
Minimal noise and zero emissions – what's not to like about electric flight? However, battery technology weight and useful life are currently hindering the transition to a cleaner aviation future. Faradair wants to bridge the all-electric future aviation potential via hybrid flight opportunity today. Faradair's first aircraft is called BEHA (Bio-Electric-Hybrid-Aircraft), a six-seat, triple box-wing aircraft combining twin ducted electric fan motors and a biodiesel pusher engine. An innovative 21st century tri-plane!

15:45 - DEHPS: the costs and emissions of a single engine, with the performance and safety of a twin
Marco Marotta, CEO, P2M Sagl, Switzerland
Automotive technologies are being imported into the aviation sector. This is true for engines, where electronic injection and common rail are becoming more widely used in general aviation. The DEHPS (Diesel Engine Hybrid Propulsion System) concept brings automotive-derived hybrid technology to general aviation and the Carbon Speed Canard 2.0 Aircraft, offering the operating costs and emissions of a single engine, and the performance and safety of a twin. This is achieved through the combination of the benefits of a light, highly efficient aircraft, downsized diesel engine and ultra-light electric motor.

16:10 - Analysis of a hybrid aero-propulsion system with lightweight micro gas turbine
Andrea Perrone, research assistant, Università degli Studi di Genova, Italy
Several hybrid propulsion systems are being investigated in order to reduce aircraft fuel consumption, emissions and noise. The paper presents a critical review of different aircraft hybrid propulsion systems, mainly regarding the available technologies for energy storage, electrical motors and hybrid-electric architectures. In the second part, a feasibility analysis of a hybrid-electric architecture is described; a combination of a micro gas turbine engine and an electric motor/generator, coupled to drive the propeller, is considered; and technical details of the gas turbine design are highlighted. Particular focus is put on weight, efficiency, overall dimensions and flight range requirements.

16:35 - Design of a hydrogen-powered general aviation aircraft
Alex Ames, researcher engineer, University of Wisconsin-Madison, USA
A team of UW-Madison undergraduates has designed a fully electric general aviation aircraft that meets the Federal Aviation Administration's regulations for small aircraft, enabling entry into the commercial market. The Epimetheus is a low-wing, single-engine aircraft powered by a fuel cell system fed from a spherical liquid hydrogen tank. Its performance is comparable to current-generation internal combustion aircraft, making it an attractive option for environmentally conscious private pilots.

*This program may be subject to change.

PROFESSOR JOSEF KALLO

head of energy system integration, German Aerospace Center, Germany

SPEAKER SPOTLIGHT

Why do you feel hydrogen fuel cells are the future of aircraft propulsion?
Global air transport is doubling every 15 years, increasing the noise and global greenhouse emissions of CO_2 and nitrous oxides. Electric flight can achieve emission-free and low-noise aircraft operation and completely new efficient propulsion concepts. Thereby fuel cells are advantageous over existing batteries and can achieve an energy density of around 600Wh/kg in systems. The hydrogen can be produced from increasing environment-friendly regenerative power sources, further decreasing greenhouse emissions. Moreover, regional airfields in urban areas will benefit from lower noise emissions, allowing more flights even at night and leading to new transportation concepts.

What are the next steps in realizing such an aircraft?
A two-seater electric aircraft powered by fuel cells has already flown, proving feasibility. The next steps are improving fuel cells toward maximum efficiency with regard to the special conditions in aircraft; and then successively increasing the size of the aircraft. Based on existing projects, a four- to eight-seater aircraft with a range of 1,000km is feasible. Within the next 25 years, a 70-seater electric aircraft will become feasible. The main challenges are in proving safe operability and reliability of such systems in aviation, and optimization of the overall system by the multidisciplinary integration of fuel cell systems, drivetrain and aircraft.

What are some of the challenges involved in testing hydrogen fuel cells?
The integration and testing of aircraft is very time consuming and expensive. As electric drivetrains and fuel cells in aviation are a relatively new field of research, obtaining airworthy systems, integration and testing are even more challenging. Testing under reproducible realistic aircraft operating conditions, such as lower pressure, is one of the main challenges in testing. The development of electric aircraft requires a holistic approach, considering the power source, the drivetrain and the aircraft body. Therefore, each modification and test requires many time-consuming checks and changes to ensure safety and reliability during each test.

Professor Kallo will present a paper entitled 'Hydrogen fuel cell powertrain for aircraft applications' on Day 1

STAR attraction

AEROSPACE ELECTRICAL SYSTEMS EXPO EUROPE

BREMEN HOSTS NEW **AEROSPACE INDUSTRY SUMMIT**

SPACE TECH EXPO EUROPE

Bremen is one of Europe's leading aerospace hubs, with more than 140 companies and institutions employing over 12,000 staff. For three days in November they will be joined by thousands more engineers, contractors, system integrators, buyers, manufacturers and industry leaders at twin exhibitions covering the entire supply chain for space technology and aerospace electrical systems.

Space Tech Expo has already established itself as the premier space event on the US West Coast, and with the 2015 event growing 45% in attendance and 25% in exhibitor numbers it has become one of the world's major industry gatherings. Now its launch in Europe gives the continent's space industry a focused marketplace for the design, manufacture and testing of spacecraft, satellite, launch vehicle and space-related technologies.

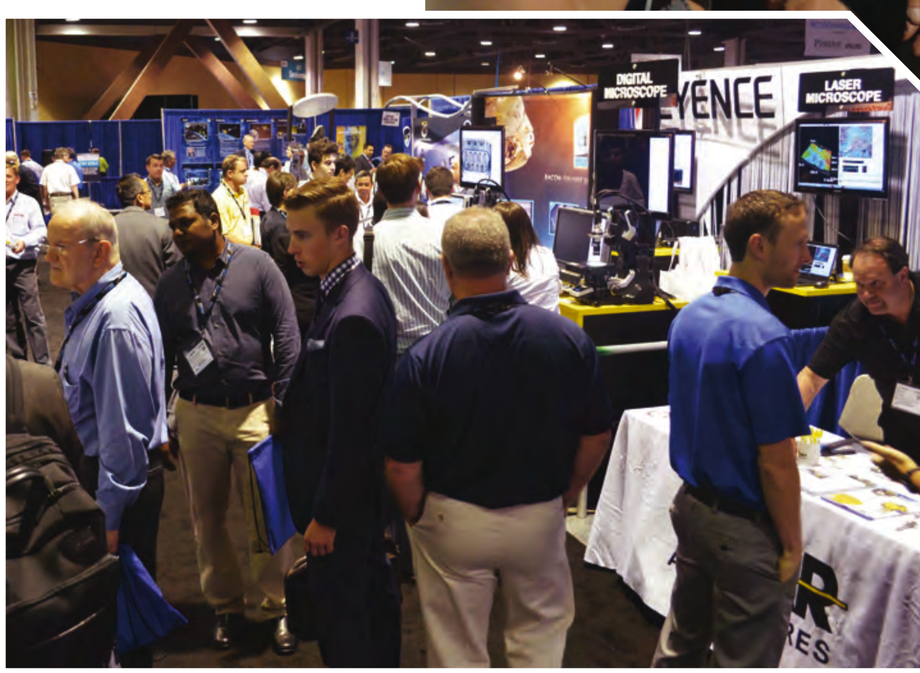
The co-located Aerospace Electrical Systems Expo Europe showcases the components and capabilities that bring aircraft and space vehicles to life, including battery and power systems manufacturing, power distribution and conversion, wire cable and harnesses, electronics, box building, control assemblies, software, data acquisition and testing.

There is also an exhibit area and an area dedicated to testing technologies, equipment, processes and research. The Testing Zone will see testing capabilities for airframes, subsystems, components and electrical power systems for both the aerospace and space sectors presented by a wide range of international companies and organizations.

More than 150 exhibitors are already signed up, among them such industry, research and testing majors as OHB, DLR, Thales Alenia Space, Tesat-Spacecom, W L Gore, Zodiac Data Systems, SEA, Olympus, Curtiss-Wright, European Test Services and Fraunhofer Space.

Backing the shows are dedicated free-to-attend forums and a complimentary B2B matchmaking service that will enable attendees to connect with other businesses on a one-to-one basis. Organized in cooperation with Enterprise Europe Network Bremen, the matchmaking service offers scheduled one-to-one meetings, along with the opportunity to upload to a dedicated website an online profile, your business requirements and invitations to meetings.

Meanwhile high-profile speakers at the free-to-attend forums include: Dr-Ing. Johann-Dietrich Wörner, Director General, ESA; Dr Pascale Ehrenfreund, chairwoman of the executive board, DLR; Guy Perez, CTO, OHB; Bart Reijnen, head of orbital systems and space exploration and head of site Bremen, Airbus Defense and Space; and Daniel Lockney, technology transfer program executive, NASA.



TO REGISTER FOR A FREE PASS PLEASE VISIT THE WEBSITES:

Networking lunches and receptions held on the show floor during the expo will help visitors further maximize their time, providing the opportunity to meet hundreds of industry professionals in a relaxed, professional environment.

Participants in the latest US edition of Space Tech and Aerospace Electrical Systems at Long Beach, California, in May were overwhelmingly positive in their reaction. Willard Strozier, director of the US Air Force Space and Missile Center's office of small business programs, and a panelist at the Space Tech Conference, summed up the mood: "It's been wonderful," he said. "I've met a lot of interesting people, the displays are fantastic and some of the technology I've seen is amazing."

Now the same opportunities for engaging with key clients and partners, and networking with industry peers, are available in Europe at a fraction of the price and time resource necessary for other large aerospace meetings. ∎

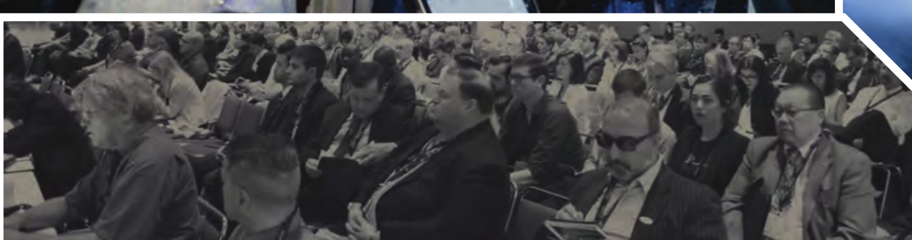
USEFUL INFORMATION

OPENING HOURS

Tuesday, November 17	9:00am – 5:00pm
Wednesday, November 18	9:00am – 5:00pm
Thursday, November 19	9:00am – 3:00pm

VENUE DETAILS

Space Tech Expo Europe, co-located with Aerospace Electrical Systems Expo Europe, takes place at Messe Bremen, WFB Wirtschaftsförderung Bremen GmbH, Findorffstrasse 101, 28215 Bremen, Germany.



INDUSTRY AND TECHNOLOGY FORUMS

Parallel free-to-attend forums running alongside all three days of Space Tech Expo Europe feature contributions from leaders of the international space industry.

The Industry Forum kicks off with a day dedicated to markets, business models and cross-sector collaboration, with key themes including launch services, ESA technology roadmaps, advanced propulsion technologies and future fuels. The second day focuses on trending technologies and growth opportunities, including space station use, the space logistics market, on-orbit servicing and exploration technologies. Day three spotlights the small satellites market in terms of economics, applications, launch capabilities and enabling technologies.

The Technology Forum, meanwhile, is designed to offer the entire supply chain a platform to share the latest R&D findings, technical innovations and product development methodologies. Key themes on the first day include lunar exploration technologies, the use of advanced composites on satellites, reducing the cost of manufacturing, and opto-mechanical design and integration. Day two will see discussions on the growth of spacecraft data, avionics testing and compliance testing. The final day continues the testing theme, looking at optimizing system integrity and test efficiency, automation technologies for testing, robotic systems for non-destructive testing and model-based testing for embedded systems.

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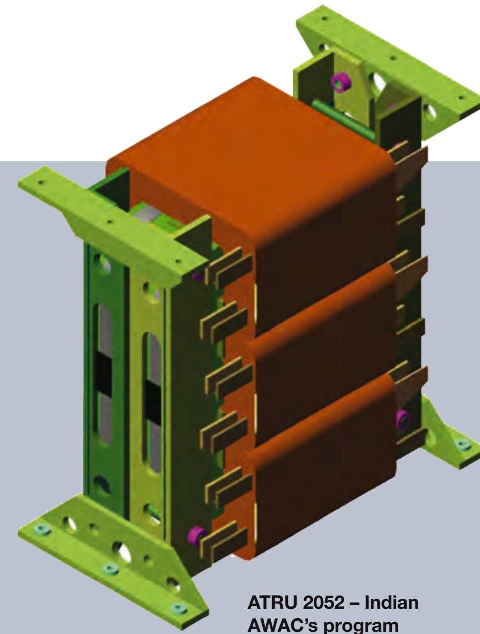
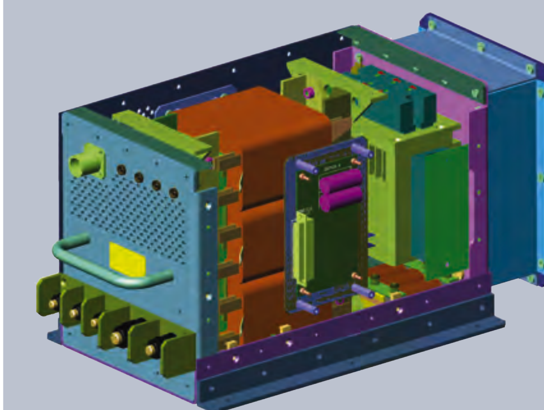
WHO TO MEET



ATRU 2052 – Indian AWAC's program



Visit HTV at stand **H60**

HTV HIGHLIGHTS TEST EXPERTISE

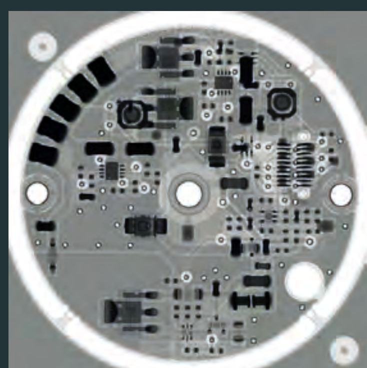
After more than 10 years in space, the Rosetta spacecraft currently escorting comet 67P on its return journey toward Jupiter is demonstrating the accuracy of a test program that wrapped up in 2004 at Bensheim-based Halbleiter-Test & Vertriebs.

HTV specializes in quality assurance though comprehensive testing and analysis services. Its technological expertise has been built up over nearly 30 years in the fields of testing, device programming, long-term conservation and analysis of electronic components.

Proper functionality and quality of electronic components depends on careful examination, and HTV has a long list of analytic and qualification tests and methods to investigate them in the most minute detail. Its capabilities include examination of layer thicknesses by x-ray fluorescence (XRF) analysis, metallurgical inspections, analysis of goods with uncertain origin, PCB evaluation, and elaborate analysis methods to investigate, for example, process, PCB and component failures.

The company's unique HTV-TAB long-term storage, meanwhile, ensures the availability of discontinued components for 50 years or more by reducing the critical physicochemical aging processes, making lack of long-term availability less of a concern.

For the Rosetta program HTV tested more than 5,500 components, including processors, transistors, diodes and complete boards over a six-year period.



X-ray of a sensor control unit

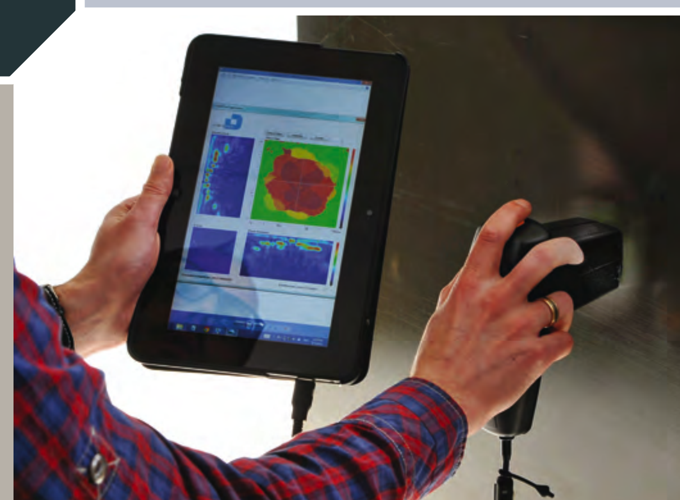
Visit DolphiTech at stand **F72**

IMPROVED NDT TECHNOLOGY FROM DOLPHITECH

Ultrasound technology company DolphiTech will demonstrate a major hardware upgrade to its DolphiCam ultrasound camera as well as additional functionalities for the associated DolphiCam Expert software. An improvement of 12dB in signal-to-noise ratio greatly enhances the ability to detect and size damage in carbon fiber reinforced plastic.

The DolphiCam Expert software's new functionalities include a tablet mode with an improved user interface that makes the system easy to use on touchscreen devices. Multiview support adds flexibility to selecting which views are visible on screen. And a new drilled-hole inspection tool makes it easy to size and measure interlaminate defects in drilled holes. The tool includes region-of-interest concepts with increased frame rates in combination with imaging methods to help focusing on drilled hole damage close to the front and back surfaces of laminates.

The DolphiCam Expert software update is available free of charge to existing DolphiCam customers. Advanced users are offered the optional DolphiCam Research software, which adds post-processing, pulse shaping and user-defined filtering to the DolphiCam.



Scanning impact damage with DolphiTech's improved DolphiCam

Visit Wärtsilä JOVYATLAS EUROATLAS at stand **C62**

POWER PRODUCTS MADE IN BREMEN

Wärtsilä JOVYATLAS EUROATLAS hopes to exhibit the prototype of an auto-transformer rectifier unit (ATRU) for a new utility helicopter program. Its appearance will depend on the progress of the program, but either way there will be real hardware products representing both military and commercial aviation projects on display.

The Bremen-based company's core competence is in the design of power products for the demanding military and civilian aviation industry. "We design and manufacture power products, including the main wound components, in-house," says a company spokesman. "We are a leader in this field with a proven track record."

Products on show will include the ATRU 2052 for the Indian Air Force AWACS program, the TRU 2030 or CRU for the SAAB Gripen fighter, the PARS 3-LR power distribution unit for the Airbus Tiger helicopter, and the Model 4074A mini frequency converter for the Airbus A350 and A380.

An Airbus supplier since 1989, Wärtsilä says its aircraft and helicopter power products combine the lowest weight with the highest performance available on the market. The company has supplied more than 30,000 frequency converters and its TRUs equip fighter aircraft operated by eight air forces.

The ZARM centrifuge has a diameter of 12.5m and can accelerate test items to a speed of 160km/h

TTTech's 24-port deterministic Ethernet switching product family

Visit TTTech at stand **D42**

TTTECH RELEASES 24-PORT DETERMINISTIC ETHERNET SWITCHES

TTTech Computertechnik will display its AFDX TTTech 24-port Deterministic Ethernet switches. Both the AFDX (ARINC 664) and TTEthernet (SAE AS6802) variants support full 1Gbit/s line speed, as well as deterministic synchronous and asynchronous communication for advanced integrated architectures. Customers benefit by being able to deploy dependable networks and real-time controls more efficiently and profitably, while use of a proven architecture and ease of system integration translates into shorter time-to-market and reduced cost. TTTech will also exhibit the AFDX-Switch Lab and the TTE-Switch A664 Lab. The AFDX switch is fully compliant with ARINC 664 p7, enabling seamless integration into existing 10/100 Mbit/s AFDX networks and integrated modular avionics systems. Both switches support 10/100Mbit/s as well as 1,000Mbit/s. The TTE-Switch A664 Lab implements TTTech's DO-254 and DO-178C DAL A chip IP and supports three traffic classes (IEEE 802.3, ARINC 664 p7 and SAE AS6802). The technology is said to be suitable for the integration of new functional capabilities and the design of scalable integrated architectures that can be adapted for various aircraft platforms and applications. This is one of the reasons, the company says, why TTEthernet solutions are deployed in the NASA Orion manned spacecraft.

Visit ZARM at stand **E60**

DEBUT FOR NEW ZARM TEST CENTER

The University of Bremen's Center of Applied Space Technology and Microgravity (ZARM) has combined its wide variety of test labs for small and large scale aerospace components in the ZARM Test Center and will bring models of three of them to the expo.

Focusing on the investigation of gravity-dependent phenomena and space-related research, the center can test products in vacuum, in extreme and variable thermal environments and under vibration, as well as in hyper- and micro-gravity. Facilities include the ZARM drop tower and Europe's only large-scale hyper-gravity centrifuge for testing aerospace components in full operation.

Other testing facilities include the vibration test lab, which can test devices not only while they are in full operation but also under exposure to additional endurance test loads such as temperature cycling, icing or pressure surge. The ZARM centrifuge – the only hyper-gravity facility in Europe that can test and certify objects of up to 1.5 tons in weight – offers the unique capability of being able to expose test objects to a hyper-gravity environment (up to 30*g*) while they are fully operational. And the ZARM thermal vacuum chamber is frequently used to simulate the aerospace environment to test flight hardware as well as components designed for space missions.

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CONFINED NOISE MEASUREMENTS

How DLR improved noise transmission flight tests on the Airbus A320 using a new multifield microphone

Multifield microphone showing its small dimensions in comparison with a conventional ½in measurement microphone. Aircraft cabins are difficult spaces to measure, limiting the effectiveness of conventional microphones

Like most new aircraft, the next-generation A320 from Airbus will build on the success of its predecessor. To ensure this is the case, DLR has established a project to simultaneously measure the excitation, transmission and noise propagation into the cabin of an A320. "We needed an understanding of the physics, and how the noise gets into the cabin," explains Carsten Spehr of DLR's Institute of Aerodynamics and Flow Technology. "Airbus asked us what the optimal aircraft noise level is," he continues, "and of course this is difficult to answer. Other passengers make noise, so it's actually quite pleasant to have a nice, deep noise that masks the noise of the other passengers. So the research we do here is to find the optimal cabin comfort for airplanes."

The intention was to also improve this type of flight test. Since the 1980s, flight tests have normally used different aircraft at different times, with an absence of a shared database making correlation of data difficult. DLR was determined to improve on this with a new, more consistent method.

The main issues for interior acoustics are cooling system noise, fan noise, the turbulent boundary layer, and overall airframe noise. "There are two ways for the acoustic energy to come from outside to inside: either through the shock mounts and the structural coupling, or through the air between the structure and the lining," says Spehr.

Microphones help to distinguish between these different sources. However, aircraft are difficult 'rooms' for acoustic measurements because they are reverberant, long and thin, and give a very different acoustic response depending on the direction and location of the measurement. "For these kinds of tests, we don't know if the soundfield is diffuse or something else," says Spehr. "We also put microphones between the aircraft structure and the lining. And what are the conditions like there? We don't know, so we use the multifield microphone."

Multifield microphones were placed along the longitudinal section of the aircraft, facing upward in the positions taken by the passengers, in an F-frame array that covered a cross-section of the aircraft.

DLR also developed arrays of multifield microphones for closed test sections. "The area is small, so we couldn't use a normal preamplifier," says Spehr. "Because they are smaller than ½in microphones, multifield microphones are easy to use in such a confined space."

DLR measured the transfer paths with accelerometers, and measured the turbulent boundary layer with pressure sensors placed in three dummy windows. In all, the testing used 65 multifield microphones, 154 accelerometers and 30 pressure sensors.

There were no problems setting up the multifield microphones: "They use a standard CCLD input, so you know that there are no problems," explains Spehr. "Sensitivity is usually an issue, as normally ¼in microphones are not so sensitive, so it was really nice to have small microphones with the same sensitivity as ½in microphones."

"Aircraft are reverberant, and not the same in different directions – where there are different dimensions – but we didn't have to think about that. We knew we would make an error in every direction, so to minimize this error it is best to have an omnidirectional microphone that doesn't care about that."

When doing these kinds of tests, there can be issues with electromagnetic interference. But this wasn't an issue in this case: "With the titanium build, we didn't have any problems at all, even on the inside of an aircraft where there is a 400Hz electrical field – which is a quite strong – we didn't have to even think about it."

By combining sound measurement results with those from pressure sensors and accelerometers, the tests established the link between coherent fluctuations in the turbulent boundary layer and the noise experienced in the cabin. In the aerodynamic part of the measurement – the turbulent boundary layer – the coherence in acoustic waves is quite large, which, as Spehr explains, is significant: "If you have coherent fluctuations, then they can excite the fuselage, and that can create noise you can really hear. So the interesting point from this is that even without adding mass or anything else, you can really change the behavior. It was a nice flight test, and the analysis is still ongoing. I have had some more requests because it was such a success."

The multifield microphones were an optimal solution for DLR. "The only possible alternative to a multifield microphone would be to use ½in microphones, where we would then have to consider whether it was a free-field condition or any unknown condition," says Spehr. "For cabin noise the multifield microphone is perfect."

DLR's ATRA (Advanced Technology Research Aircraft) is a flying test platform
(Photo: DLR (CC-BY 3.0))

VIRTUAL TESTING OF COMPOSITES

Airbus Group Innovations continues to make breakthroughs in aircraft composite design using Siemens PLM Software technology

Compared with metals, composites exhibit much more specific failure modes. In order to provide safe designs that fully exploit the potential of these new materials, aircraft stress engineers need to identify possible delamination, as well as damages that may appear inside the plies of the layered composite structures. Additionally, the non-linear geometric effects of thin-walled composite structures are complex to analyze and cannot be ignored. Advanced expertise in non-linear analysis is required to obtain accurate results so that realistic safety margins can be determined.

Virtual testing is essential in decreasing the number of physical tests on composite components to support aircraft certification, and Siemens PLM Software plays a vital role in this process for Airbus Group Innovations via its LMS Samtech Samcef software, a finite element analysis (FEA) package dedicated to mechanical and structural virtual prototyping.

PROVIDING A FOUNDATION

With more than 35 years of experience working with leaders in the aerospace industry, Airbus Group Innovations experts perform research and assist aircraft original equipment manufacturers (OEMs) with the implementation of dedicated structural analysis technology and optimization scenarios, as well as solid predictive solutions for composites. Airbus Group Innovations improves its knowledge by enabling the simulation of composite material damages so it can analyze large composite thin-walled structures. For full-fledged programs, efficiency improvement projects include developing dedicated and improved models, which take into account modeling possible failures in the composite structure.

"The Airbus Group Innovations team dedicated to advanced composite analysis and simulation is used to incorporating engineers from the French university École Normale Supérieure de Cachan (ENS Cachan), especially from its Laboratoire de Mécanique et Technologie (LMT Cachan)," says Didier Guedra-Desgeorges, vice president and head of the Technical Capabilities Center, structure engineering, production and aeromechanics at Airbus Group Innovations. "The very high level of the research programs and the number of new composite material laws and models for composite structure damage developed by LMT Cachan explains the strong relationship between us."

Guedra-Desgeorges adds, "Laboratoire de Mécanique et d'Acoustique, Aix-Marseille University (LMA Marseille), another French university laboratory working in the same field, is also a research partner of Airbus Group Innovations. The LMS Samtech development team is the cornerstone of these partnerships, contributing to the dissemination of these new material laws as a result of the implementation of these advanced concepts into its LMS Samcef solver."

GAINING A DEEPER UNDERSTANDING

Bearing in mind the growing competitive pressure within the aviation sector, it is clearly important that the Airbus Group reacts extremely quickly to the market by designing products right the first time and by using new methodologies for integrating advanced modeling of composites.

"As a result of the implementation into LMS Samcef of advanced composite material laws developed in collaboration with LMT Cachan and LMA Marseille, Airbus Group gained much deeper physical insights, thus extending the gap with its competitors by positioning itself as the first and leading research department able to offer such advanced expertise," says Guedra-Desgeorges.

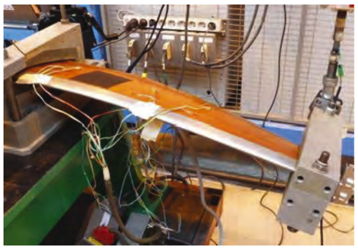
The formulation of the selected model has been extensively validated against experimental results. It takes into account the different kinds of failure modes and damages of composite materials, as well as the interdependencies of these phenomena.

"The successful implementation of these laws in the non-linear LMS Samcef finite element solver was completed with the support of the Siemens PLM Software team," says Serge Maison Le-Poec, head of Structure Analysis at Airbus Group Innovations. "Even if openness is available via material user routines, a native implementation in commercial software provides a more reliable solution."

He notes, "Advanced numerical regularization techniques have been set up in order to preserve good convergence properties of such highly non-linear analyses, including strong discontinuities. The fact that LMS Samcef software provides a robust, state-of-the-art technology environment in an industrial context is strategic for us."

This new functionality has been successfully tested by Airbus Helicopters for the prediction of the non-linear structural behavior of a composite blade, including a transverse crack. The precise correlation between the simulation and the physical test results confirm that it is possible to analyze complex scenarios on composite structures.

As a result of the demonstration of its methods and models reliability and the extension of the spectrum of analyses to real-life complex behaviors on composite structures, Airbus Group Innovations has positioned itself as a leader when applying for existing and new industrial programs.



Virtual testing is an essential tool to decrease the number of physical tests on composite components

HIGH-CYCLE FATIGUE EVALUATION

Assuring safety and reliability in high-performance fastener applications

Aerospace fasteners – bolts, studs, screws, and rivets – are among the most critical components used in aircraft manufacturing. While static tensile tests provide a measure of fastener performance under peak load conditions, and microscopic examination can be used to characterize basic material properties, laboratory testing that simulates actual operational conditions is crucial to a thorough understanding of the fastener's performance over its service life. For aircraft manufacturers and fastener suppliers, conformance to government and industry standards such as NASM 1312-7 and ASTM E466, as well as to individual manufacturer specifications, can be guaranteed only by testing with systems that reproduce realistic dynamic loading conditions.

Fatigue failures are the result of cumulative stress cycles, which can be applied by thermal, mechanical, or vibratory effects. How aerospace fasteners perform under vibratory loading over the course of numerous cycles at stresses well below the ultimate strength of the material is crucial. These cycles may alternate tension and compression loading, or lie completely within the tensile or compressive loading regimes.

High cycle fatigue (HCF) refers to the effect of low-amplitude, high-frequency vibration within the elastic strain region for a number of load cycles N, where typically N > 106. While the applied stress is within the material's elastic region, plastic deformation can still take place on a microscopic level as the part ages, eventually leading to failure of the component.

A component or material's fatigue characteristics can be quantified by generating the graph of stress versus cycles at a given load, known as the Wöhler curve, where fatigue strength is determined from the maximum stress the fastener can withstand for a specified number of cycles. The fastener's endurance limit is then defined as the stress level below which failure does not occur, meaning the component has theoretically infinite life. Because fatigue failures can occur quickly if the endurance limit is exceeded, fastener performance must be guaranteed by demonstrating adequate fatigue strengths via cyclical testing simulating installed conditions.

Magnetic resonance testing machines, also known as high-frequency pulsators or Vibrophores, are advanced systems for HCF testing. Vibrophores are specifically designed for rigid metal or ceramic specimens, and can induce low-amplitude stress cycles at loads similar to those experienced in aircraft applications. Operating at high test frequencies, Vibrophores can perform a fatigue test in a short period of time, enabling increased specimen throughput: a Vibrophore requires 20-40% of the time a servohydraulic machine requires to run the same number of cycles. This rapid testing capability is essential in a production environment where several specimens from every lot must be successfully tested before the lot can be released for use.

The Vibrophore functions like a driven oscillator, where a large mass on the end of a spring is subjected to an external, time-dependent force. When installed in the testing machine, the specimen functions as the spring, and is oscillated by the excitation mass via the resonance drive. The greatest force amplification occurs when the oscillation amplitude matches the natural frequency of the specimen, as installed in the test machine. A proportional-integral-derivative (PID) controller provides a feedback loop based on mean force (or stress), frequency, and displacement, and tunes the force exerted by the resonance drive to the natural frequency of the testing system.

From a cost-of-ownership perspective, magnetic resonance systems can be installed in most labs without infrastructure modifications and consume only 2% of the power of a comparable servohydraulic test system. Operation of the Vibrophore is straightforward, requiring minimal training. Furthermore, with few parts subject to mechanical wear and tear, Vibrophores are reliable and low-maintenance machines.

Zwick/Roell has recently introduced a new generation of Vibrophore systems, available in capacities from 50kN to 1,000kN and offering a frequency range of 30-300Hz. These products are the result of decades of HCF testing experience with Zwick's Amsler line of high-frequency pulsators.

The new Vibrophores utilize an electric drive for controlled static loading similar to a static materials testing machine, and a magnetic resonance drive for controlled dynamic loading. This enables both dynamic HCF evaluations and pure static testing. With up to eight frequency steps achievable through the activation of top-mounted weights, tests can simulate changes such as partial loss of torque due to thermal effects, or provide additional system damping if component heating during the test is a problem. In addition to testing by force or strain control, true crosshead position is available as a control parameter.

The four-column Vibrophore frame offers improved stiffness and 360° access to the specimen and test fixtures. The test area accommodates specimens up to 1,200mm in height without frame adjustments, and has sufficient width for a temperature or environmental chamber. Hydraulic grips offer secure gripping by wedge action without requiring the specimen to be bolted in place. The grips are self-centering for flat or round specimens, providing repeatable specimen mounting. The integrated T-slot table with an ergonomic working height of 800mm enables the operator to work easily and safely with specimens and grips.

The new Vibrophores use Zwick's proven testControl II digital controller, which delivers 10kHz data acquisition and a control loop update rate with 24-bit signal resolution. Dedicated software packages allow customization for static and dynamic applications and include test programs for single- and multistage HCF. All software runs on a standard PC; the computer can be placed on the electronics cabinet for a compact footprint in the lab. A remote control unit supports the operator during machine setup and provides a real-time display of critical test parameters. ▮

Zwick remote-controlled Vibrophore 100 system provides ergonomic testing in a compact footprint

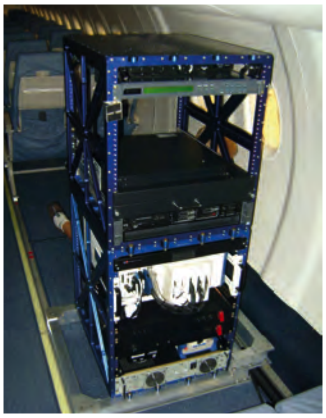
ADAPTABLE FLIGHT TEST INSTRUMENTATION

FMS Aerospace combines its expertise in flight test engineering and instrumentation with the company's aircraft structural integration capabilities to create an adaptable flight test instrumentation solution. At the heart of the FMS Aerospace solution is the modular and scalable equipment rack that can be reconfigured to fit the aircraft interior and scaled to meet equipment requirements. The instrumentation suite can tap into existing aircraft systems to measure and record analog and digital signals, as well as use supplementary sensors such as pressure transducers, swivel-head YAPS probes and GPS receivers to meet customers' flight test needs.

The FMS Aerospace flight test equipment rack has been installed in multiple aircraft types for large and small flight test programs and avoids the need for new rack designs for each aircraft. The company's DERs provide FAA approvals for instrumentation and equipment installation regardless of job scale or platform.

FMS Aerospace offers a customizable virtual interface (VI) that was developed to enable flight test engineers to maintain situation awareness as well as perform real-time post-processing of the test data in flight. The customizable VI is tailored to the instrumentation needs of the specific aircraft being tested. The real-time post-processing reduces the need to repeat flights, thereby avoiding costly delays.

The combination of the reconfigurable rack, the customizable VI and real-time post-processing results in a solution that minimizes cost and greatly reduces the risk of schedule slips. More information on FMS Aerospace capabilities can be found on its website: www.fmsaero.com



THE END OF THE FLYWHEEL?

Test-Fuchs engineers have devised an innovative approach to the testing of air turbine starter systems. Most current in-service test systems employ the use of cumbersome flywheels to provide the appropriate inertia simulation during tests. Test-Fuchs has devised a groundbreaking approach to simulating the same inertia conditions, by replacing flywheels with the intelligent use of electric motors.

Most test engineers agree that the use of flywheels in air turbine starter test systems not only presents a great safety risk to operating personnel, but also requires a high maintenance effort due to the need to mount and dismount flywheels to simulate various inertia conditions.

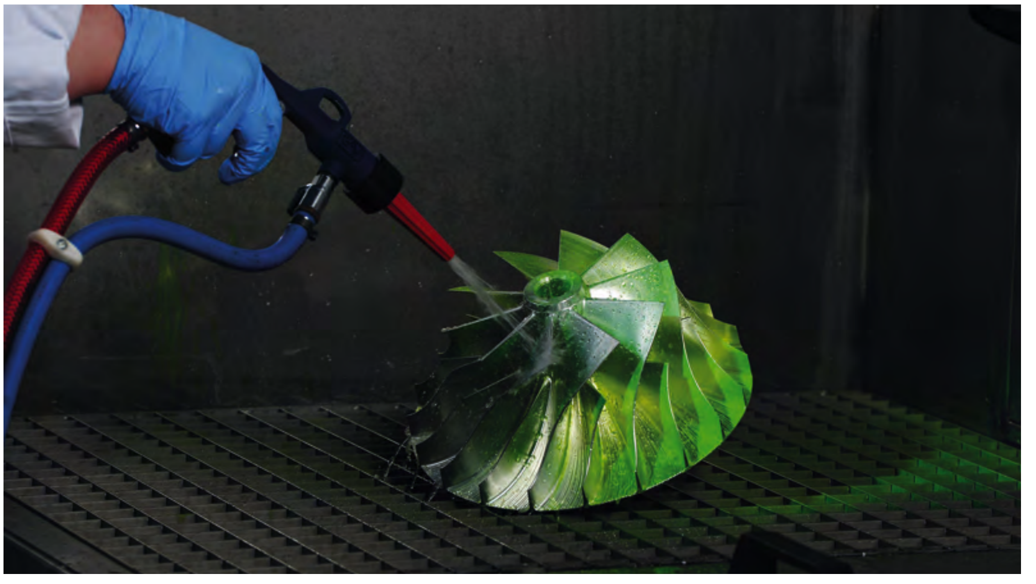
Using the new Test-Fuchs system, the operator can change between inertia values in a fraction of the time, by being able to adjust settings through electric motors. Hence a wide range of tests for different components can be conducted without any additional equipment or labor-intensive operator actions.

Interestingly, the use of electric motors incorporates two motors, one of which is built into the drive shaft. This is used to accelerate and decelerate the air turbine starter, removing the need for a gearbox for both over-running and green run tests.

A pneumatic supply, essential for air turbine starter testing, is also employed. The new design of the test system is compact and the modules – the pneumatic supply and the inertia simulation – can be operated independently. The inertia simulation module can even be used as a standalone module in an adequate infrastructure.

While the air turbine starter is under load, the motor feeds energy back into the electrical supply, thus saving a good proportion of the operating energy costs.

NDT AND SURFACE TREATMENT TECHNOLOGIES



Market demands are rising steadily in all areas – from quality assurance and productivity to supplier reliability and environmental compatibility. This is especially true for the aerospace industry. Under the brand names Ardrox and Naftoseal, Chemetall offers advanced and sustainable specialty chemicals that meet the high quality demands of national and international industry and military standards, such as Airbus, Boeing, AMS, EN ISO, MIL, Rolls-Royce, GE, Safran, Pratt & Whitney, MTU and Lufthansa.

Chemetall's product range can be found in all fields relating to the manufacture, service, maintenance, overhaul and repair of airframes and aero-engines for military and civil aircraft, including their components. The portfolio comprises cleaning and pretreatment technologies, corrosion protection products and sealants.

For a fast and safe indication of defects on metal surfaces, Chemetall develops advanced non-destructive testing (NDT) products for penetrant testing (PT) and magnetic-particle inspection (MPI or MT). Many innovative products have been launched since the first Ardrox approval in 1948. For instance, the introduction of azo-dye-free and NPE-free penetrant products. The latest generation of eco-friendly fluorescent penetrants are low in odor, can be easily washed off and have excellent sensitivity and background characteristics. Selected NDT equipment and expert services around the world round-off Chemetall's value for customers.

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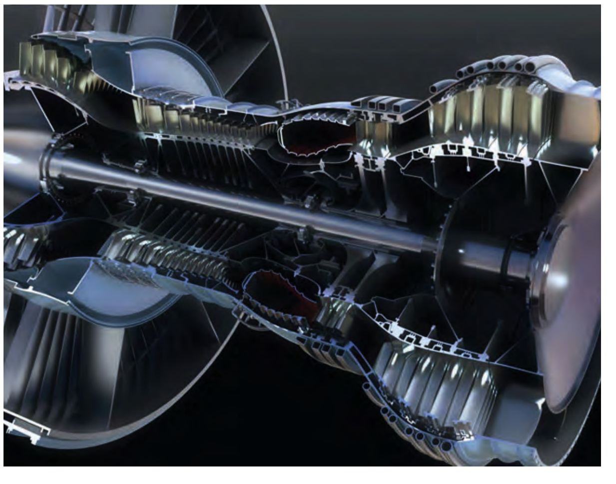
FORCED VIBRATION OF PROPULSION STRUCTURES SIMPLIFIED

Predicting component survivability under forced vibration loading is always difficult to achieve accurately – especially in the field of aero engine development. Common requirements are to model propulsion system protuberances such as intakes, nozzles and support structures, and to predict deflections under sympathetic vibrations emanating from the fan, compressor or turbine systems. To do this, the analyst uses finite element analysis to predict performance before physical testing. This can be a lengthy process and fraught with danger.

Frewer Engineering has developed techniques that give the designer early predictions of what might happen in service simply by using a natural frequency search and then looking in detail at the modal effective masses and Eigen values/mode shapes to assess vibration threats early on in the design phase. This gives the confidence to go into advanced vibration analysis with a deeper understanding of what to expect. These techniques apply to both metallic structures and those based on composite materials.

This method of analysis can considerably reduce the risk of large iterative loops in design and also minimizes error rates. It provides valuable information when compared with actual measurements taken when the equipment is in service. It's a case of all knowledge is useful!



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HIGH-PRECISION MEMS ACCELEROMETER

The Dytran series 7600B are high-precision variable capacitance (VC) accelerometers, designed to be used as a drop-in replacement for piezoresistive units in new or existing zero-to-medium frequency instrumentation applications.

Available in multiple ranges, the Dytran series 7600B incorporates a MEMS capacitive sensing element and an advanced ASIC to simulate piezoresistive bridge operation, as well as an integrated VC accelerometer chip with high drive, low impedance buffering. Units also respond to both DC and AC acceleration. The onboard regulation minimizes supply voltage variation effects, making them relatively insensitive to temperature changes and thermal gradients. In addition, the 7600B series sensors are hermetically sealed for reliable operation in high humidity and dirty environments, and feature a custom integrated circuit amplifier and differential output stages, with a four-pin M4.5 x 0.35 radial connector and easy mounting via two 4-40 screws.

The Dytran series 7600B accelerometers use the same power supply as piezoresistive and strain gauge sensors, enabling them to operate as standalone differential output accelerometers or in place of piezoresistive bridge-type accelerometers.

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XMC CARDS FOR MIL-STD-1553/ARINC429

AIM GmbH has just introduced the models AXE1553-x and AXE429-x conduction-cooled XMC cards designed specifically for rugged, embedded MIL-STD-1553/ MIL-STD-1760 and ARINC429 applications. The AXE cards use the field-proven AIM Common Hardware Core derived from the existing AXC1553-x/AXC429-x test and simulation cards, delivering the low power consumption required for rugged environments and embedded applications.

The cards are qualified for VITA-47 shock and vibration for class V3 in conduction-cooled applications and class V2 in air-cooled applications. They are also designed to meet the shock requirements specified in ANSI/ VITA 47 for class OS2. As standard, AXE cards provide conduction cooling and rear I/O (no front panel connector). Conformal coating is optional.

With onboard flash memory, the cards boot up autonomously after power up. Therefore, the cards are prepared for embedded applications requiring fast and autonomous boot-up to operational mode, such as with MIL-STD-1760. The DMA engine is optimized for bus transfers and low PCIe use for real-time applications.

An onboard IRIG-B analog time encoder/decoder is included with sinusoidal output and 'freewheeling' mode for time tag synchronization.

AXE1553-x modules handle up to four dual-redundant MIL-STD-1553 channels with eight Open/Ground Avionics Level (+35V) discrete I/O signals plus trigger I/O. A Bus Controller Disable function supports Remote Terminal Only applications. Transmit inhibit for Monitoring Only applications is an assembly option. Single function variants of the cards are also available.

AXE429-x modules handle up to 32 fully programmable (Tx/Rx) ARINC429 channels with a maximum of eight Open/Ground Avionics Level (+35V) discrete inputs and eight Open/ Ground Avionics Level (+35V) discrete output signals in addition to trigger I/O. Transmit Inhibit for Monitoring Only applications is an assembly option.

An easy-to-use application programming interface (API) is provided, along with low level 32/64-bit operating system-specific drivers for Windows 7/8, Linux and VxWorks to ease systems integration.

AIM Gmbh has offices in both the UK and the USA, and its main design and manufacturing facilities are located in Freiburg, Germany.

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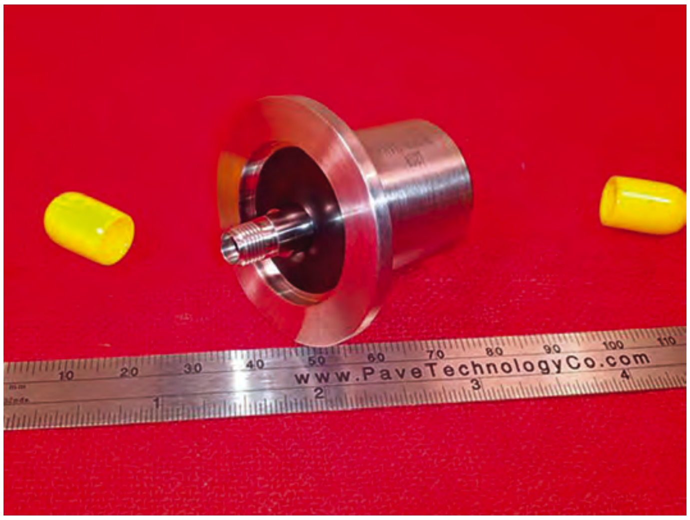
HERMETIC HIGH MICROWAVE COAXIAL BULKHEAD CONNECTORS



A new line of RF microwave high-frequency hermetically sealed coaxial connectors for low and high pressure and vacuum use is now available from Pave Technology. Operating pressures are from high vacuum to 10^{-8} Torr to low or high pressures of +100 bar, and operating temperatures from -65°C to +125°C. Hermetic connector or cable versions include 2.92mm SMK to 40GHz Ka-band use, 1.85mm or SMPM to 65GHz use, G3PO to 100GHz use, and 1mm to 110GHz use.

The connectors are available in a variety of bulkhead mountings and sizes, including jam nut o-ring, ISO flange, NPT, laser weld and miniature piston o-ring seals. All the connectors are RoHS compliant.

SMA, SSMA, GPO/SMP, GPPO/SSMP/SMPM, K/2.92mm, 2.4mm, V/1.85mm, 1mm/1.0mm, MMPX and G3PO/SMPS are available, as well as phase-matched sets and phase-offset sets (27GHz, 40GHz, 65GHz and 110GHz).

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INDEX TO ADVERTISERS

Bugatti 100P

The Bugatti 100P is arguably the most elegant aircraft ever built – and was also one of the most technologically advanced of its time

BY ANTHONY JAMES

On August 19, 2015, the Bugatti 100P, painstakingly rebuilt to its original glory by retired fighter pilot Scotty Wilson together with the assistance of a multinational team of aviation experts, took flight for the first time at the former Clinton Sherman Air Force Base in Burns Flat, Oklahoma, USA, where it had previously undergone taxiing and engine testing.

Ettoré Bugatti built 8,000 automobiles, but he built only one aircraft. Designed and built in 1937 by Bugatti and Louis de Monge, it was the most elegant and technologically advanced aircraft of its time. Few people knew of its existence. Hidden in a French barn to protect its secrets from invading German forces in 1940, the airplane was lost for more than 50 years. Now, the original Bugatti aircraft rests quietly in the Experimental Aircraft Association's (EAA) AirVenture museum in Oshkosh, Wisconsin, USA, beautifully restored but far too fragile to be moved. Sadly, it never flew and cannot be made flyable.

Wilson's international team of aviation experts, all volunteers, has created a reproduction of this unique aircraft to showcase the beauty of its design – a combination of art deco and art nouveau – as well as demonstrate the efficacy of the design, which incorporates five unique patents. However, building a reproduction of a 70-year-old aircraft has its challenges, as Wilson explains: "We have tried to find as much background on this airplane as we can. The Bugatti Aircraft Association and the de Monge family have been incredibly helpful, but the plain fact is that there's little in the way of engineering information available. To our knowledge there are no known blueprints for the airplane's structure. The drawings we do have are highly detailed, but together they don't represent the entire airplane.

"Fortunately the EAA has very kindly given us access to the original aircraft and lent us many original parts such as the internal radiator ducting and the aerofoil that we've been able to reverse engineer."

This is why the team is at pains to stress that the aircraft is a reproduction, rather than a replica. "This isn't just semantics," says Wilson. "A replica is an exact copy of the original, the two separated only by time. We just don't have the detailed information available to create a replica so ours is a reproduction. Externally – aerodynamically – it's very close to being an exact copy. We've also incorporated elements of the five patents Bugatti won for the 100P – the balsa-wood sandwich construction; the powertrain; the V-tail control system; the low-drag cooling system; and the automatic flight control system. However, we're not always certain how Bugatti and de Monge arrived at their engineering solutions – for the transmissions and drive shafts, for example – so we're forced to create our own and include additional margins for strength and safety."

FIRST FLIGHT

The first flight of the aircraft also proved challenging, as Wilson, the initiator, owner and pilot of the Bugatti 100P on its maiden flight, explains: "While the airplane flew perfectly, we lost braking action on the right wheel at the end of the landing roll. As a result, the airplane departed the hard surface to the left side of the runway. Thunderstorms had passed through the area in the hours before the flight, and the ground was quite soft. The airplane tipped up on its nose at a very slow speed, damaging the spinner and both propellers. This takes nothing away from the beauty of the design or its superb flying qualities. The irony is that had the original airplane landed at Etampes after its first flight, it too may have tipped up on its nose."

Given the extraordinary worldwide interest in the story and the aircraft, the Bugatti 100P will shortly undergo a world tour of various air and car shows for the public to enjoy. "We're looking for partners to join us on the Reve Bleu tour, which promises to be a commercial, as well as critical success," concludes Wilson. For further information, please contact the team via www.bugatti100p.com.

KEY STATS

Span: 8.2m

Length: 7.7m

Height: 2.3m

Weight: 1,425kg

Wing area: 21m²

Wing loading: 67kg/m²

Power loading: 0.64hp/kg

Max speed: 800km/h

Engines: Two Bugatti Type 50B (450hp @ 4,500rpm)

Photos courtesy of Albanese Branding and Communication WWW.ALBANESEBRANDING.COM Aldert van Nieuwkoop