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

AEROSPACE TESTING INTERNATIONAL

JUNE 2014

Space
The next step

NASA's Commercial Crew Program heats up with launch abort testing at SpaceX, while Boeing and Sierra Nevada continue to make progress

737 MAX REPORT
Chief project engineer Michael Teal talks about the latest powerplant testing for the 737 Max

A350 TEST UPDATE
EXCLUSIVE: Details about the recent environmental testing of the A350 at the McKinley Climatic Laboratory

ALTERNATIVE FUELS
A joint research campaign could have far-reaching implications for the global aviation community

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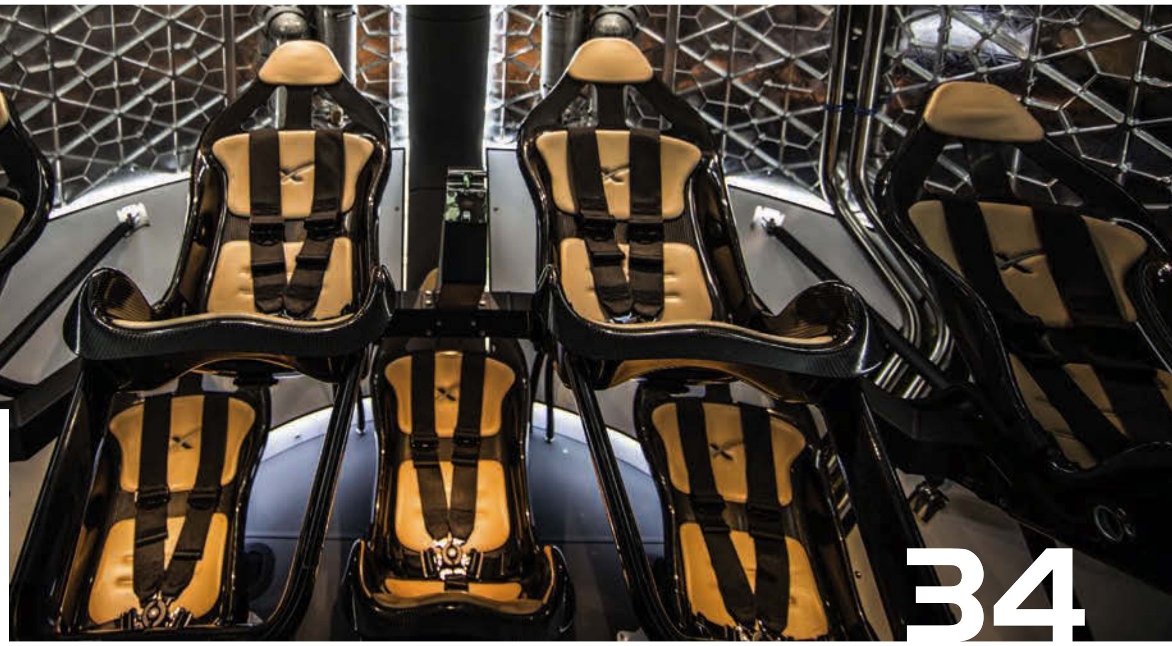
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10


16


28

PRODUCTS & SERVICES

REGULARS

The Chinese airline industry does not have a history in the civil airliner market, and I believe this is a problem. Countries take great pride in manufacturing aircraft that cross continental divides, and the few nations involved in large-scale passenger manufacturing spend decades evolving the practice.

China is developing what it hopes will be its first internationally accepted civil airliner, and I just don't see it happening within any of the timescales given. There are reasons behind this viewpoint, and I hear them coming up repeatedly.

Commercial Aircraft Corporation of China Ltd (COMAC) launched the ARJ21 project in 2002 in an attempt to break into the western-dominated aircraft market. The airplane was promised for 2007, but delivery was pushed back due to technical problems, again and again.

China proclaims it is expecting to become one of the world's biggest aircraft markets over the next two decades, with western aeronautics having been brought into the Chinese aerospace industry. Technology is bought here and technology adapted there. Then there is, of course, the collaboration with Bombardier. In most industrial countries, the aerospace industry is a cooperation of public and private industries built up over time within the nation, but a civil air industry is built on history and evolution through a gradual process. I believe that the aerospace industry cannot be just bought into.

In mid-June, while still blushing over the loss of Emirates' order for 70 A350s, John Leahy (Airbus chief operating officer, customers) was asked about prospects of competition from the China aerospace industry. "I believe China will be a major player," he replied, but said it must allow 20-25 years to establish itself in the market, as Airbus had. "You need a family of aircraft to compete with Airbus and Boeing." He said the same was true for Russia.

On all its civil air projects, China is outsourcing everything: parts, systems, subsystems and test programs (testing is all in North America). A whole new set of commercial-related parameters comes into play when a company wants to compete with the likes of Boeing and Airbus.

As someone whose job it is to follow the aviation industry, I find China's part in civil airliner manufacturing something of a conundrum. There is no middle area. On the one side, COMAC is a multi-billion-dollar registered state-owned aerospace company. A news report in May 2014 stated that 'China is expected to become one of the world's biggest aircraft markets over the next two decades. Boeing forecasts total demand at 5,580 airplanes worth a total of US$780bn.' However, other sources differ.

The first two of the ARJ21-700 regional jets have been completed for Chinese carrier Chengdu Airlines, and are coming to the end of the certification process, according to the company, which says it has 252 orders. The company has also stated that it has received 400 orders from 16 customers, including aircraft leasing company GE Capital Aviation Services. Low-cost carrier Ryanair, as well as British Airways, have also apparently signed memorandums of understanding about their intention to purchase airplanes. However, there is no certification inplace for these orders.

The much-delayed ARJ21 has yet to gain FAA certification (and there is no sign of this happening in the near future), so it must make do with the domestic market for now, and the foreseeable future. Even the task of properly certificating a secondary component supplier under FAA guidelines is unknown to COMAC.

In 2013, *Aviation Week* published a hugely insightful article by business consultant Stanley Chao, who said, "I am sometimes amazed by all the optimism of the dozens of western aerospace executives shuttling in and out of the COMAC headquarters in Shanghai. Most have not made a dime yet on the business, but they continue to send dozens of engineers to China, invest millions to form joint ventures with Chinese aerospace companies, and diligently educate the Chinese on the basics of commercial aircraft-building, hoping one day that these costly efforts will turn into big money. Unfortunately, I do not share the same sentiment."

According to industry analyst Will Horton of CAPA Centre for Aviation, the C919 is an official initiative for China to "recapture the value in aircraft manufacturing that currently goes offshore to Airbus and Boeing". Horton believes, "With such a large objective, accomplishments will come gradually."

Personally, I think it will take longer. Lack of experience in commercial aircraft design, manufacturing, outsourcing and certification instability makes the C919 concept very unsure and the evolution too short. Of course, there will be a domestic market (who would doubt that?!), but taking off across international waters will come long after I could get on a C919.

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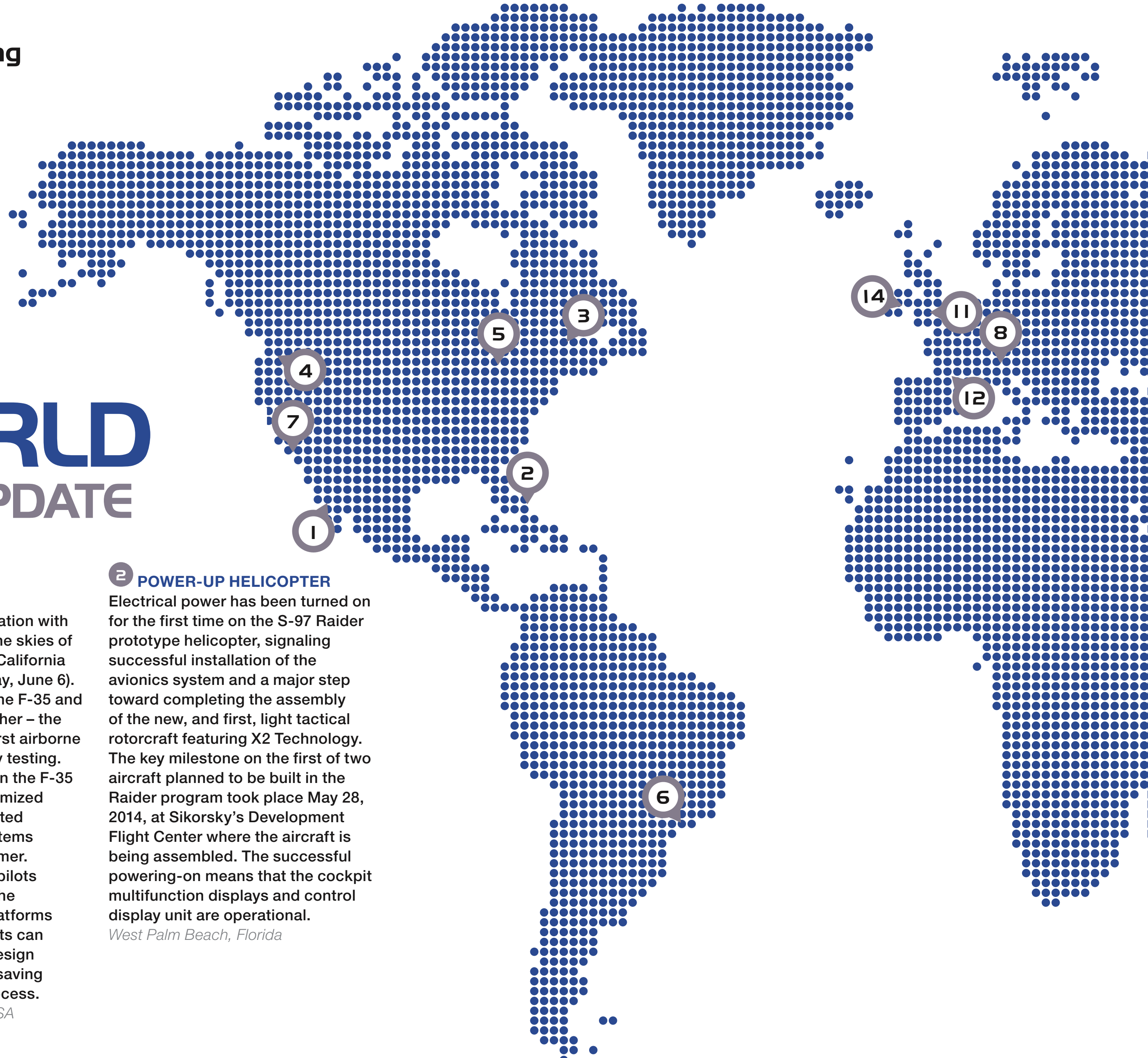


WORLD
TEST UPDATE

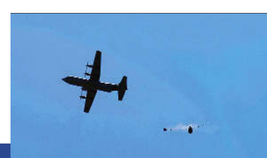
1 F-35 AND TYPHOON WING-TO-WING
An F-35 has flown in formation with two RAF Typhoons over the skies of Edwards Air Force Base, California (the flight took place Friday, June 6). This is the first time that the F-35 and Typhoon have flown together – the aircraft performed their first airborne link during interoperability testing.

Interoperability between the F-35 and Typhoon is being optimized through a series of simulated scenarios led by BAE Systems on behalf of the UK customer. This will allow operators, pilots and engineers to ensure the interoperability of both platforms and means any refinements can be made early on in the design and development phase, saving time and money in the process.
Edwards AFB, California, USA

2 POWER-UP HELICOPTER
Electrical power has been turned on for the first time on the S-97 Raider prototype helicopter, signaling successful installation of the avionics system and a major step toward completing the assembly of the new, and first, light tactical rotorcraft featuring X2 Technology. The key milestone on the first of two aircraft planned to be built in the Raider program took place May 28, 2014, at Sikorsky's Development Flight Center where the aircraft is being assembled. The successful powering-on means that the cockpit multifunction displays and control display unit are operational.
West Palm Beach, Florida

3 BOMBARDIER CSERIES KICK-STARTED
Ground engine testing on Bombardier's CSeries flight test vehicles (FTV) in Quebec, Canada, has restarted. The move comes after the company halted flight testing at the end of May due to a major failure in the FTV1 engine. Bombardier said that the engine was shipped to Connecticut-based Pratt & Whitney for teardown and analysis. Damage on FTV1 from the engine problem was manageable and maintenance teams have begun repairs.
Quebec, Canada

4 787-9 CERTIFICATION
The Boeing 787-9 Dreamliner has been certified by the US FAA and EASA for commercial service. Boeing is now in the final stages of preparing for the first 787-9 delivery to launch customer Air New Zealand. To earn certification for the 787-9, Boeing undertook a comprehensive test program with five airplanes and more than 1,500 hours of flight testing, plus ground and laboratory testing.
Seattle, USA



5 PRECISE CARGO DROP TRIALS
The US Air Force Research Laboratory (AFRL) has awarded Lockheed Martin a contract to adapt its WindTracer wind measurement system to help C-130 and C-17 aircrews make safer, faster and more accurate airdrops of essential supplies to US ground forces at remote locations. Under the contract, Lockheed Martin will design and build a prototype Precision Air Drop (PAD) unit for testing. As part of the demonstration, the prototype unit will be airdropped to the test site and used to measure winds.
Wright-Patterson AFB, Ohio, USA

6 PHENOM 300
Embraer Executive Jets has stated that the Phenom 300 has received certification from EASA for steep-approach operation, which enables increased descent angles of up to 5.5°. "This certification enhances the Phenom 300's operational flexibility," said Marco Túlio Pellegrini, president and CEO, Embraer Executive Jets.
São Paulo, Brazil

7 SOFIA 747 TRIAL
Astronomers are eagerly waiting to begin use of a new instrument to study celestial objects: a high-resolution, mid-infrared spectrograph mounted on NASA's Stratospheric Observatory for Infrared Astronomy (SOFIA), the world's largest flying telescope. SOFIA is a heavily modified Boeing 747 Special Performance jetliner that carries a telescope with an effective diameter of about 8ft (2.5m) at altitudes of 39,000-45,000ft (12-14km), above more than 99% of Earth's atmospheric water vapor.
Moffett Field, California

13 THE WHEREABOUTS OF MH370

A new investigation has shown that the search for Malaysian Airlines Flight MH370 has yet to target the most likely crash site, after being distracted by what are now believed to be bogus signals. British company Inmarsat has claimed scientists told the BBC that they had calculated the airplane's most likely flight path and a 'hotspot' in the southern Indian Ocean in which it most likely came down. Hourly pings sent by the aircraft were received by Inmarsat's spacecraft, leading scientists to calculate its likely path. "It was by no means an unrealistic location, but it was further to the northeast than our area of highest probability," said Chris Ashton at Inmarsat.

Southern Indian Ocean

14 IRISH DEFENCE SYSTEM

Defense and security company Saab has signed a contract with the Irish Defence Forces to provide upgrades to Ireland's RBS 70 air defense missile systems. The order has a value of approximately SKr40m (US$6m) and includes deliveries of improved firing units, new simulators, night vision equipment and associated weapons support. Ireland has requested updates to its RBS 70 systems. The contract provides for new operator training simulators, upgraded fire units to support the BORC night-capable sight and the latest Bolide missile, new external power supplies, plus a four-year support agreement.

Dublin, Ireland

15 MOVING UP A GEAR

As part of business development initiatives, Hindustan Aeronautics Limited (HAL) intends to diversify into civil aviation and is making efforts to re-open HAL Bangalore International Airport. HAL will also take up more activities in unmanned air vehicle (UAV) and unmanned combat air vehicle (UCAV) business segments, the company has stated.

Bangalore, India

8 TEST FLIGHT OF SOLAR IMPULSE 2

Solar Impulse 2, the solar aircraft from the team of Bertrand Piccard and André Borschberg, completed its maiden flight on June 2, departing from the Payerne Aérodrome in Switzerland. Si2 has now been approved by the authorities, and is ready for this summer's test flights. The single-seater aircraft, with which Piccard and Borschberg are attempting to carry out the first solar-powered flight around the world in 2015, flew for 2 hours and 17 minutes, enabling professional test pilot Marcus Scherdel to trial the aircraft's performance in the skies.

Payerne, Switzerland

9 BIOFUEL FROM MALLEE TREE IS VIABLE FOR JET FUEL

A two-year study commissioned by Airbus and partners including Virgin Australia, in 2012, into the practicability of using Australia's mallee trees to make biofuels suitable for powering passenger jets, has reported encouraging results. The report, published by the Future Farm Industries Cooperative Centre, concludes that jet fuel made from the tree will meet strict sustainability criteria determined by the Roundtable for Sustainable Biomaterials and will be suitable for commercial flights, according to the American Society for Testing and Materials.

Crawley, Western Australia

10 FLIGHT SIMULATOR

Deployment of a simulator for the EC135 helicopter developed by Airbus Helicopters Japan has been completed. The system is the first to be granted certification from the Japan Civil Aviation Bureau. The first flight simulator for helicopters in Japan is now operational at a pilot training center close to Kobe airport. The flight model simulation provides highly realistic reproduction of flight dynamics for the EC135 helicopter. This means pilots can practice flying in a range of situations, making complex landings and take-offs.

Tokyo, Japan

11 CHINOOK MAINTENANCE

A new £115m (US$195m) agreement with Boeing Defence UK to maintain the engines of the RAF's increased fleet of 60 Chinooks has been announced; a move that will replace five existing support contracts with one arrangement, saving the taxpayer over £20m (US$34m). The first of 14 Chinook Mark 6 helicopters, which were ordered in 2011 as part of a £1bn (US$1.7bn) program, have now achieved their entry into service on time, and three of the new aircraft have been delivered to the RAF, which has commenced training in the UK.

Odiham, UK

12 A350 XWB COMPLETES EARLY LONG FLIGHT

The A350 XWB MSN2 has successfully completed the 'early long flight' campaign, involving two flights with passengers operated consecutively by Air France and Lufthansa cabin crews. Early long flights are an important achievement toward the A350's entry into service. Although not part of the technical certification program, these flights enable Airbus to assess the cabin environment and systems in flight ahead of final certification, ensuring that airlines will benefit from a fully mature aircraft from day one of commercial operations.

Toulouse, France

MH370 DISASTER: BETTER AIRCRAFT TRACKING REQUIRED

Following its disappearance on March 8, the fate of Malaysia Airlines flight MH370 remains unknown. Despite the biggest ever international maritime search effort, investigators have yet to recover any physical evidence to provide comfort to the families of the 239 passengers and crew. The disappearance of the 275-ton airliner, valued at US$300m, has profound implications for the aerospace industry and is set to be the catalyst for major efforts to improve aviation safety. Until a specific cause is determined, the focus is on improving the tracking of civil airliners and enhancing the ability of searchers to find and recover flight data recorders.

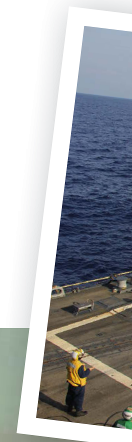
FLIGHT TRACKING

These initiatives kicked off in May, when ICAO held a special meeting on global flight tracking of aircraft at its Montreal headquarters. It was aimed at forging consensus among member states and the international air transport industry on the near-term priority to track airline flights, no matter their global location or destination. The meeting also established a framework for future efforts in this regard for the medium- and long-term.

This set up an industry-led Aircraft Tracking Task Force (ATTF), coordinated by IATA to address the near-term needs for flight tracking.

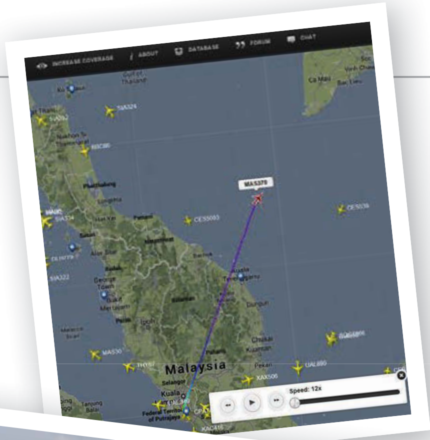
"Malaysia Airlines Flight MH370 was an unprecedented event for aviation, and we have responded here in a similarly unprecedented manner," commented ICAO council president Olumuyiwa Benard Aliu. "While our flight safety work logically focuses the majority of our energy and resources on accident prevention, everyone in our sector also deeply sympathizes with the families of this lost aircraft's passengers and crew." In parallel with IATA's taskforce work, ICAO will begin developing a flight tracking concept for operations, covering how the new tracking data gets shared, with whom and under what circumstances. This, in turn, will require new systems to transmit, store and assess this data.

In the near-term, one answer could be a free global airline tracking service over the Inmarsat network. This service is being offered to all 11,000 commercial passenger aircraft that are already equipped with an Inmarsat satellite connection, representing virtually 100% of the world's long-haul commercial fleet. Rupert Pearce, CEO of Inmarsat, said in May, "We



MH370 FACTS

8/3	Malaysia Airlines flight MH370 disappeared en route from Kuala Lumpur to Beijing on March 8
53,460	The number of flight hours clocked up by the aircraft before its disappearance
7,525	The number of take-offs and landings completed by the aircraft
01:07	The time of the aircraft's last ACARS transmission before the system was silenced
239	The number of people on board when the aircraft vanished (227 passengers and 12 crew)



welcome and strongly support ICAO's decision to place the delivery of next-generation aviation safety services at the heart of the meeting. In the wake of the loss of MH370, we believe this is simply the right thing to do." However, it is not clear yet if the Inmarsat solution will meet all the requirements being developed by ICAO, particularly over the longer term. Possible solutions include a space-based radar tracking system and the fielding of a new constellation of satellites dedicated to receiving tracking data from transponders fitted to every airliner or a combination of both technologies.

Aviation expert Paul Beaver says these ideas throw up several issues for the aerospace testing community: "Installing new antennas and transponders on airliners will require type certification to prove that any transmissions do not interfere with other systems on the aircraft," he explains. "Each type of aircraft is different and will require its own certification process. Installing antennas is not straight forward, particularly when you are putting holes through pressure hulls that have to be able to operate safely at 40,000ft. This clearly would be nice to have but who will pay for satellites? There is insufficient bandwidth at the moment and how far do you go with this? Do you require 30- to 40-year-old aircraft to have it or only new-build aircraft? Some airlines might also not want to have their aircraft tracked everywhere in the world."

FLIGHT DATA RECORDERS

Attention is also starting to be given to improving flight data recorders. The European Aviation Safety Agency (EASA) has announced new proposals for flight recorders and underwater locating devices, which aim at facilitating the recovery of an aircraft and of its flight recorders following an accident.

The new EASA requirements include the extension of the transmission time of underwater locating devices (ULD) fitted on flight recorders from 30 days to 90 days. EASA also proposes to equip large aircraft flying over oceans with a new type of ULD that has a longer locating range than the current generation. Alternatively, aircraft may be equipped with a means to determine the location of an accident to an accuracy of six nautical miles. In addition, the minimum recording duration of cockpit voice recorders installed on new, large aircraft should be increased to 20 hours from the current two hours.

"The tragic flight of Malaysia Airlines MH370 demonstrates that safety can never be taken for granted," says Patrick Ky, EASA's executive director. "The proposed changes are expected to increase safety by facilitating the recovery of information by safety investigation authorities."

CAN WE DO MORE?

The quest for better information recovery in the wake of the MH370 incident is supported by William J McGee – a member of the US Transportation Department's Future of Aviation Advisory Committee. He has been calling for "crash-protected image recorders in cockpits to give investigators more information to solve complex accidents" as one of the "most wanted aviation safety improvements" since 2007.

"Even better would be technology that didn't rely on recovering data from accident scenes," he comments. "In 2010, the Institute of Electrical and Electronics Engineers proposed replacing the 'black box' with a 'glass box' – technology that would transmit data continuously and in real time to a ground-based system. Star Navigation Systems of Canada has already developed such a product. But once again, cost is a factor. One of the most profound changes to evolve from MH370 may be a re-examination of how the airline industry monitors its aircraft."

In addition to its free global airline tracking service, Inmarsat has also offered a 'black box in the cloud' service, under which – following certain defined trigger events, such as an unapproved course deviation – historic and real-time flight data recorder and cockpit voice recorder information could be streamed off an aircraft to defined aviation safety recipients.

The implications for the aviation industry could be profound if it moves forward with these types of technology. It would place airliners and their crews under an unprecedented level of scrutiny. While the benefits for air crash investigators are obvious, the aerospace testing community would also benefit through the collection of huge quantities of raw data, enabling equipment performance to be assessed over time and feed through into new products.

GARNET RIDGWAY

IS MORE OR LESS BEST?

Aerospace testing activities are often accused of being 'process heavy' – too much time is spent on activities that do not directly produce results. Is this accusation fair?

SOPHIE ROBINSON

Although unnecessarily bureaucratic or over-rigorously enforced regulation and processes can undoubtedly be a burden on aerospace testing professionals, the assumption that 'less is more' does not necessarily hold true.

Aerospace testing can, by nature, be extremely hazardous. Well-established processes provide a robust layer of risk mitigation at all stages of the testing lifetime by shifting a portion of the burden of responsibility from individual team members to the process itself. For example, if a key team member is suddenly unavailable, the audit trail provided by a known process having been followed can enable testing to continue without compromising safety. The same audit trail also provides a framework for establishing accountability in the event of an accident, something that is essential in the prevention of further occurrences.

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

Aside from the safety implications, detailed process and regulation can assist collaboration between different organizations for testing activities. For example, it may be the case that such organizations share common or equivalent processes for risk management, test briefing or trials implementation; this reduces the lead time (and therefore cost) of collaborative testing. Such benefits are unlikely to be realized by a collection of individuals developing their own processes outside of a central framework.

Having well-defined processes to follow can also benefit the professional development of team members within a testing organization. Due to the safety issues associated with aerospace testing, the concept of taking charge of such tasks can be somewhat daunting for a junior engineer. Well-thought-out processes can provide a step-by-step guide that means junior team members can take on greater responsibility than may otherwise be the case; and because the process itself takes some of that burden, safety is not compromised.

Although much bemoaned by members of the aerospace testing community (including, on occasion, the authors of this column), a reasonable layer of well-thought-out process and regulation can bring a significant number of important benefits. Surely increased risk mitigation, more coherent collaboration, smoother professional development and less personal stress are worth the inconvenience of ticking a few extra boxes?

The world of test and evaluation is one that is becoming increasingly bureaucratic and overpopulated with middle men, whose role seems to be to make the life of a test engineer more about filling in forms than actually getting out into the real world and testing something (just look at the column on the left). Imagine your working day without bureaucracy. No forms to fill out, fewer boxes to tick – you'd probably have time to actually get things done!

The world of test and evaluation is filled with vastly experienced people. T&E companies should know their people, their capabilities and their experience – and should trust them to do their jobs and do them well. It shouldn't be necessary for engineers to have to prove their capability every time a new task falls on to their desk; if they're suitably qualified and experienced, let them do their thing! Time freed up from documenting competencies and ticking boxes could be used to mentor less experienced co-workers or spent on continued professional development, further returning value to the business.

Reducing regulation and bureaucracy also makes our business more agile and reactive to change. For example, if a small change is required in a test program, maybe to add a test point to the test matrix, it's not uncommon for the form-filling and box-ticking to authorize the new activity to take longer than the activity itself. A five-hour task can rapidly spiral into a 50-hour task when approvals have to be sought and forms rubber stamped.

Increasing the agility of our business will inevitably lead to higher customer satisfaction; jobs are done more quickly and efficiently, with no loss of quality.

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

Leanness is, in general, an attribute that both businesses and their customers find desirable; reducing expenditure of time and money on any activity that doesn't create value should be a target for elimination. The test and evaluation business is no different, and regulation and bureaucracy is a prime target for waste reduction. Customers want results, not neatly filled-in forms.

Of course, it would be impossible to argue for the elimination of all regulation in our industry – we still need some process and guidelines to function safely. But it is essential to maintaining our competitiveness and edge that we must seek to minimize bureaucracy in order to grow and, most importantly, to keep us as engineers happy.

Winning formula

With the first demonstration race having successfully taken place in Spain, Air Race F1 is now set to become a World Series in 2015. We talk to the pilots and the organizer

BY CHRISTOPHER HOUNSFIELD

STEVE TEMPLE

JAY JONES

Over the clear northern Catalan skies, 11 internationally renowned pilots battled it out at Europe's first-ever international Formula 1 class air racing series – Air Race F1 – in Lleida, near Barcelona, Spain. Pilots from the USA, UK, France and Sweden revved up to showcase some of the world's best air racing, in which French pilot Christian Guilie won the overall title on June 1, 2014.

It was not against a clock like in Red Bull Air Racing, or straightforward timed flights. The pilots flew a circuit against each other, vying for lead spot. Imagine F1 car racing, but 3D, and a lot faster.

As the roar of the hugely powerful aircraft has died down, and the champagne has been drunk, the event could mark a totally new era of air racing, which could bring back a golden age not seen for more than 50 years.

This latest air sport needs to be taken seriously. The Reno annual air race is huge, and hundreds of thousands attend, but it is a national sport within the USA. Air Race F1 is global. The results of the first race were ratified by three recognized international air associations from the USA, France and UK, respectively the International Formula 1 Air Racing Association, the Association des Pilotes d'Avions de Formules and the Formula Air Racing Association.

THE AIRCRAFT AND THE PILOTS

Jay D Jones is president of J J Air Works, and happens to be one of the pilots. He came second out of the eight 'Gold' racers, showing an average speed of 239mph. He is adamant that the race brings back the golden age of air sport: "This race in Spain is back to the real air racing that was started in 1947 where eight competitors


MADNESS

BELOW: The air race involved teams from four different nations. Even the demonstration drew crowds above 6,000

RIGHT: Christian Guilie's engineering crew start up the aircraft pre-race

competed with each other at the same time around the pylons. The best combination of pilot and airplane will cross the finish line first."

Aircraft are tested thoroughly and to the same criteria as motor racing: wing area no less than 66ft², empty weight of no less than 500 lb, fuel capacity no less than 5 gallons, and the engine must be a Continental 0-200 with 100hp. Other criteria include height, wheel size, vision requirement and seat height.

On top of this, there are strict technical guidelines on any engine modification or detailing – just the same as for auto racing – such as sweep volumes, compression ratios and carburetor guidelines; and individual parts weights such as cranks, push rods, valves, pistons and connecting rods.

Jones says, "F1 racers are built to go fast, fly low and turn left. But F1 aircraft are also built with love by airplane enthusiasts and designers who think they can make a faster and a better design that can slip through the air better than their competitors.

"I have spent years trying to remove any gram of drag on the aircraft – everything from the wheel parts, intersection fairing, cowling shapes, fuselage, engine cooling and engine induction. Each part added to the airplane is tested over and over, and each variation is test flown to remove any drag, and tested for flutter, vibration and performance."

Steve Temple is another air race pilot who took part in the demonstration race in Spain, and

JEFF ZALTMAN

THE MAN BEHIND IT ALL

Jeff Zaltman, CEO, Air Race F1

HOW DID AIR RACE F1 COME TO FRUITION?

Air Race F1 came about following my years of development of other forms of air racing and air sports events and media projects. I had long identified Formula 1 air racing as a format that could have high growth opportunities, and finally I found the right moment to run with it.

The sport has a lot of history, but has not had the benefit of proper promotion and development, so I decided about 18 months ago to use my 10 years of experience in this area to focus solely on Formula 1 air racing and to take it into the mainstream of the sporting world. So, Air Race F1 is the new international series dedicated to this sport, with a focus on media and commercialization and sustainability.

YOU USED TO BE AN AIRCRAFT TECHNICIAN. DID THAT INFLUENCE THE CREATION OF AIR RACE F1?

My time in the US Navy as an avionics technician on carrier-based attack aircraft certainly contributed to my early inspiration to both fly and develop an aviation career. In particular it helps me to grasp and contend with the technical side of Formula 1 air racing – which is at least as demanding as any maintenance support environment that I saw in the military. I'm still not a very technically minded person, and I don't have a tiny fraction of the knowledge that the Formula 1 air racing support crews have, but at least I can appreciate their expertise, dedication and importance; support is integral to the sport.

HOW DOES AIR RACE F1 DIFFER FROM RED BULL AIR RACE, THE RENO AIR RACES AND THE ROCKET RACING LEAGUE?

It is quite different from any other competition format out there. In the Red Bull Air Race, only one aircraft competes at a time against a clock; Formula 1 is eight aircraft competing directly against each other in a real race. The Rocket Racing League is a fascinating concept but never really took off, and the race would take place thousands of feet away from audiences. It is a sound platform for gaming but it doesn't benefit from having any history or existing fan base. The Reno Air Races are the mecca of the sport and a grand event, but it takes place only once a year and is a US National Championships – not an international series like the Air Race F1. However, we do hope to have a good working collaboration with it in the near future.

HOW DID YOU GET INTO AIR RACING?

As a basic private pilot, I met other pilots who do some amazing things, and I wondered, 'Why don't more people know about this stuff?!' So I decided there might be an opportunity to introduce new audiences to air racing, and air sports in general, as the last frontier of sport yet untapped. I chose air racing as the most audience-friendly format, and off I went!

LEFT AND BELOW: Engine and component checks on aircraft Catch 22 (Jane Jarvis)

YOU HAVE COMPLETED THE FIRST DEMONSTRATION RACE SERIES IN SPAIN. HOW DID IT GO ?

I couldn't be happier with the outcome! There were many hurdles and unforeseen obstacles, but they were quickly overcome by the wide support and motivation of all the people who contributed to the event, including pilots, engineers, racing associations, enthusiasts and even the authorities and governmental organizations. The biggest mark of its success is that everyone – from host city to competing pilots – want to come back for more next year.

HOW DO THE AIRCRAFT PERFORM? ARE THEY ALL DIFFERENT?

Formula 1 airplanes need to meet a certain defined set of criteria to qualify for the race. But pilots can take those criteria and 'connect the dots' however they wish. So although there is a standardized starting point for design and build, there is an impressive variation in design characteristics and use of technology. Each plane is truly different, yet compatible in sporting fairness.

HOW DID YOU ACHIEVE APPROVAL FROM THE VARIOUS FLYING ORGANIZATIONS?

This Air Race F1 event was the first time that all three official Formula 1 air racing associations had come together to organize one international event. This was, if I may say so, historic. The associations had all evolved in different ways over the years, mainly because of operating in different regulatory environments. This meant that there was some discrepancy between rules, airplanes and even perspectives. But everyone came together in a surprisingly seamless and collaborative manner to make this happen because they all recognized the benefits for the growth and development of the sport.

Ultimately, all parties equally wanted a safe event and a fair and fun competition that participants and audiences would enjoy. The airport management team we worked with was also super-helpful and indeed a driving force in the development of the event. It was their vision and effort that kept the event alive. The aviation authorities were also admirably open to analyze this and to study the event.

AS A COMPETITION, HOW DO YOU SEE THE FUTURE?

This event will have a big impact on the aviation industry, on an awareness level and also on a technical level. Formula 1 air racing is an excellent platform for testing and researching new technologies and products. Just like other motorsport events involve manufacturers, this series could be the proving ground for many new technologies. To prove this, we signed an important and respected market-leading sponsor for the event, Continental Motors, which makes aircraft engines. We see a big synergy with such a fine company and product range and I am confident that many new enhancements to their engines and other products will be a result of future testing and research during our racing events. Watch this space…

was unlucky not to complete the last laps because of technical problems. He agrees that the aircraft have to follow stringent guidelines, but that they do vary: "There are some purpose-built racers such as the Boyd GR-7 Panther and the French Arlety [moulded to the pilot's body]. Most are sport flying machines, meaning you can fly them at the weekends from airport to airport and also do some minor aerobatics with them. The most widely accepted racing design is a Cassutt."

THE SETUP

The teams have many support crew and engineers on the ground. Temple explains, "Typically there is one dedicated pilot and a crew chief who functions as the aircraft mechanic. In order to facilitate safe starting, many of the teams have a dedicated starter as many of the aircraft must be hand-started or propped. There is usually one team member dedicated to assisting the pilot in and out of the airplane. So typically pilot, crew chief, starter, pilot assistant."

Jones says that the responsibility of engine testing is entirely down to him, but he has the kit: "I have full telemetry recording equipment on board, designed by MGL Avionics, that monitors engine output, performance, EGT, CHT, rpm, oil pressure, oil temperature and manifold pressure; and all flight characteristics such as speed, altitude, g-load, and GPS tracking."

Temple goes into more detail, but agrees that tests are the responsibility of the pilot in order to keep safe, and

RIGHT: A win from French pilot Christian Guilie, beating the best of the USA, UK, France and Sweden

FAR RIGHT: Pre-race cockpit checks for the US team

things are really fairly simple: "The aircraft are tested using standard home-built stress tests that typically have a load placed on the wing with sandbags to demonstrate the wing-loading capability.

"There is also the requirement of the airplane to demonstrate a 6g pull with a mobile g-meter attached in the cockpit. During the check ride, the pilots must do a full left and right roll, and a half left and right roll, demonstrating the upset recovery capability of the airplane and pilot.

> "AS PILOTS, WE MUST KEEP BOTH OUR BODIES AND MINDS IN SHAPE"

AIR RACE HISTORY

The sport of air racing has over 100 years of rich heritage and has captured the public imagination and inspired many millions of people. Air racing began in Reims, France in 1909 and soon became a global phenomenon, reaching its Golden Age in the 1920s and 1930s. Throughout the past century, air racing was regularly used as a platform to develop technology and improve engineering, as well as for recreation and enjoyment of the public.

Racing took many forms from pylon racing (like the Reno Races and Aero GP) to single-plane time trials (like the Red Bull Air Race) to the long-distance air races (like the Thompson Trophy, the Powder Puff Derby, the Schneider Trophy and many others).

They must also conduct an engine-out landing and a simulated aborted take-off. Typically, a volumetric test is conducted using a liquid measuring device – typically a buret. Load it with Marvel Mystery Oil and test for volume at top dead center of the piston stroke to make sure the engine displacement is standard and there has been no stroking or boring of the cylinder. There is also a cam test conducted using a dial indicator to measure valve rise and fall. These measurements are then loaded into a program to make sure that the camshaft meets lobe measurement formula criteria."

FLYING THE COURSE

Inspections by the pilots, race organizers and ground experts are regular and thorough, but how do the pilots prepare? "You prepare for a race by trying to get as much formation flight time as you can. We say this is an uncooperative formation. There are different ways to fly the course. The high line keeps you out of the turbulent air that is created by the other airplanes. However, most pilots do not fly a high line – they prefer to get as low as possible to best judge the exact distance from the pylon. A constant altitude is the best way to fly the course as no energy is spent either climbing or diving. However, since the entire course is flown by line-of-sight, this is what the pilot finds most difficult and that is where the skill set is – flying at a constant level."

Jones concurs, "Practice, practice and practice; flying in all racing conditions, from flat flying to sharp turns, from quick climbs to controlled descents. Acrobatic safety maneuvers

RACE PLAN

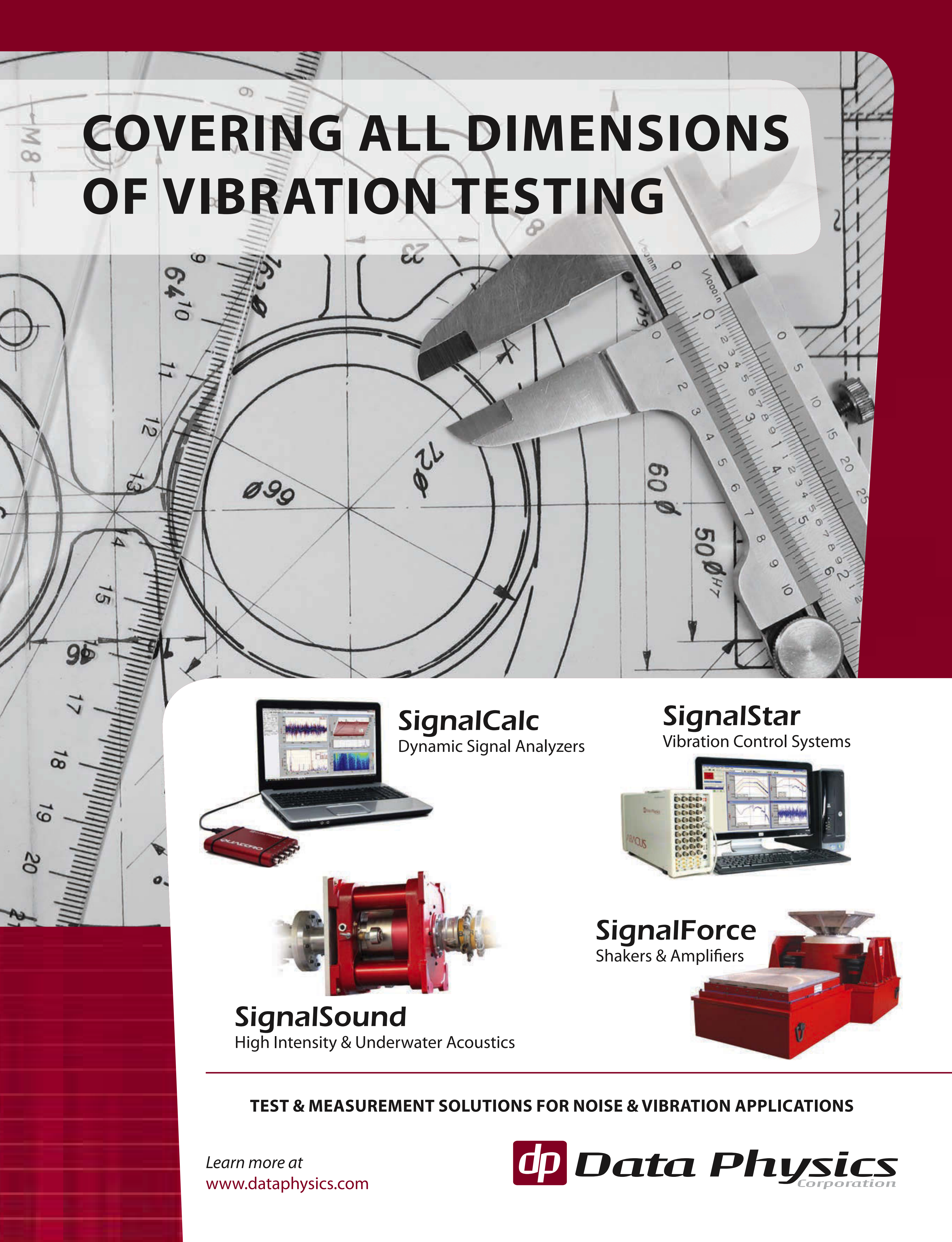
Air Race F1 is motorsport at its fastest. It is a test of pilot skill based upon the long-running historic Formula 1 aircraft class. All airplanes race against each other at speeds of over 450km/h together on a circuit just 2km end to end. The first aircraft to cross the finish line wins.

KEY FACTS:

- **8 aircraft racing together simultaneously**
- **Each race is 10 laps of 5 kilometers each lap**
- **Takes place on a circuit entirely visible in front of crowds**
- **Two days of racing (plus several practice days used in advance)**

are practiced and tested. "As athletes, we train by running, cycling and exercising. As pilots, we must keep both our bodies and minds in shape."

Jones sums up: "I am very optimistic that this joint national event will rekindle the aviation spirit and bring the golden age of flying back to the public." Air Race F1 will hold its first full annual World Series in 2015. Dates are being planned and venues arranged, with announcements to come later in the year. Anyone who has been to a Formula car race, will see and feel cars shoot past every few seconds, but did not really have a clue what is going on. I have a feeling this will be very different – and more thrilling. ∎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AIRBUS
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002

Climatic climax

Exposure of the new Airbus A350 XWB to high temperatures and solar radiation in the United Arab Emirates in June completed hot and cold environmental testing of the new twin-aisle twinjet. Senior Airbus engineers discuss the campaign

BY IAN GOOLD

Initial use of a climatic chamber for whole-aircraft environmental trials has been a major novelty for Airbus as it concludes climatic testing of the new A350 XWB. Accommodating a complete aircraft in such a facility has been "a big first for Airbus", according to flight test work package team leader Stephan Ducarroir.

While the twin-aisle twinjet introduces greater use of carbon fiber composites material – most obviously in application to fuselage skin panels (whose temperature propagation behavior must be tested) – there is otherwise "not much new" in the way of systems or equipment that will require new testing technologies or procedures, says Ducarroir.

In May, Airbus dispatched the second A350, MSN (manufacturer's serial number) 002 and the third example to fly, to the McKinley Climatic Laboratory at the Eglin Air Force Base in Florida, where meteorological conditions can be created artificially in the world's largest climate chamber. This was done to enable Airbus to meet the constraints of a very tight airworthiness certification program that aims to see the airliner enter service later this year, less than 18 months after the first flight in June 2013.

Airbus has used McKinley "to go beyond certification requirements and testing". Over three weeks, MSN002 and its various systems and cabin installations were subjected to three groups of extreme conditions: hot and humid, hot and very dry, and very cold. The tests extended work performed earlier this year with A350 MSN003 in the Middle East and northern Canada to ensure what Airbus describes as "maturity and full in-service readiness from Day 1 for all A350 operators".

Ducarroir explains that the European manufacturer usually uses two flight test aircraft for such work, exposing them to real conditions of

McKINLEY CLIMATIC LABORATORY

The McKinley Climatic Laboratory at Florida's Eglin Air Force Base, in which Airbus tested the new A350 twin-aisle twinjet, is said to be the world's largest such environmental testing facility and offers six operational chambers to both commercial and military customers. Conceived during World War II and completed in 1947, the laboratory primarily accommodates all-weather testing of military weapons and ancillary equipment. Temperatures can be reduced to as low as -70°F (-56°C) or raised to (180°F) 82°C; for example, -45°F (-42°C) can be reached from ambient heat levels in less than 18 hours. Solar panels are mounted in the chamber to simulate heat radiating from the sun. Because of demand for the use of the climatic facility, customers must reserve capacity up to a year in advance, while a day in the laboratory could cost up to US$40,000.

"IN VERY COLD CONDITIONS ONE SINGLE FLIGHT IS ENOUGH, BUT IN HOT, WE DO MAYBE TWO OR THREE"

extreme weather. But to tighten the program as much as possible by avoiding the prohibitive vagaries of global weather, three years ago Airbus booked space at McKinley so that one aircraft could be dedicated to ground climatic testing.

The two aircraft are instrumented differently: MSN003 is equipped for operations in real conditions, while MSN002 has a more sophisticated setup to represent an aircraft in service, including passenger seats, and galleys and toilets, as well as a flight test engineers' station. Ducarroir says it is very important to have all cabin systems installed "to demonstrate performance to both manufacturer and customer".

THE A350 STRUCTURE

The actual behavior of the A350's structure, which involves carbon fiber skin panels fastened to an aluminum-alloy skeleton, is now the subject of continuing analysis. "Initial results suggest the A350 behaved well; there is a massive amount of data to be looked at," Ducarroir told *Aerospace Testing* in June, just a week after MSN002 returned to Toulouse from Florida.

Since temperature propagation through the new technology structure was likely to be different from that of airframes using established materials, Airbus needed to establish the implications for thermal insulation – not just of the passenger cabin, but also for attendant systems and equipment. "It may happen that the outside air temperature propagates into the aircraft during cold and hot soak tests differently from conventional structures. We have the feeling that there is more natural insulation [leading to] longer propagation," says Ducarroir. While that impression remains to be validated, the flight test engineer acknowledges that Airbus anticipates confirmation, having studied models of thermal behavior during the A350 design phase.

Apart from MSN002's dedicated use for ground climatic testing, a major contributor to what Ducarroir dubs "the environmental campaign" was work with the heavily instrumented A350 MSN003. Airbus engineers are careful to differentiate between tests in artificially induced conditions and actual meteorological situations: accordingly, they say MSN003 has

ABOVE: The A350 XWB's various cabin systems – from in-flight entertainment and air-conditioning to its galleys, water and waste systems – were validated during testing at the US Air Force's McKinley Climatic Laboratory in May 2014

been used to conduct 'real' cold-weather climatic tests at Iqaluit on Canada's Baffin Island; and 'real' hot-weather trials, including solar radiation exposure, at Doha (Qatar) in the Gulf.

A further round of high-temperature tests, including exposure to solar radiation, in late June at Al Ain in Abu Dhabi, provided a climatic climax to A350 environmental trials. It is very important, say officials, that airframe heating comes from solar radiation as well as from ambient temperature. Additional aircraft testing at La Paz in Bolivia has covered aircraft high-temperature and high-altitude performance.

THERMAL STRESS

Apart from whole aircraft climate chamber testing, something else that Airbus has done for the first time is much less obvious. The manufacturer needed to understand the thermal stress on major carbon fiber sub-assemblies, such as fuselage 'barrel' sections and wings that were being transported by air.

"Even before the first flight, this was something new we did on this aircraft when we ferried the fuselage

ABOVE: **MSN002 was subjected to multiple climatic and humidity settings from as high as 45°C to as low as -40°C during evaluation**

barrel and wing sections and major components," says Ducarroir. These very large sub-assemblies were delivered aboard the Airbus A300-based Beluga special transport aircraft from different partner factories to final assembly in Toulouse.

Without revealing any conclusions, Ducarroir explains that the shipments were instrumented with thermocouples and strain gauges to measure thermal stress on them under the cold conditions prevailing at high altitude in the unheated, unpressurized cargo compartment. Officials are reluctant to share results of these tests, beyond saying that analysis was completed more than a year ago and findings have been taken into account on the manufacturer's simulation models.

Must airframe manufacturers follow an environmental testing template or can they use pragmatic solutions to meet airworthiness certification requirements? "We have to respect a lot of rules, plus more stringent requirements prescribed by the Airbus design office, but these are not necessarily certification requirements," according to flight test engineer and director of A350 environmental testing Philippe Foucault. "We are verifying how individual components behave when assembled together and fulfilling requirements. McKinley was not a certification item, but was mostly for aircraft operability verification and to see how the aircraft performs in such conditions."

While A350s MSN002 and MSN003 have similar missions, there is not a specific portion of flight test time assigned to them both, according to Foucault. "But for each there is a lot of ground activity, then when doing a campaign in real conditions there are two to five flights, and each is approximately two to four hours," he says.

Climatic testing is "mostly how to get your aircraft up to conditions where you can load passengers and take off safely". Foucault says there might be little flying involved: "In very cold conditions one single flight is enough, but in hot, we do maybe two or three."

IN THE CABIN

After meeting certification requirements, Airbus goes a second mile by considering customers' operability issues: for example, in testing the effect of low temperature on cabin services such as water and waste systems, about which the A350 customer focus group raised many questions. "These are not the most noble items," says Foucault, "but are very important for operators to know how to service the aircraft when arriving at and leaving the gate." In-flight entertainment (IFE) systems hardware is also considered.

Airbus measures the time required for cabin temperatures to revert to 'normal' ambient levels of 24°C from very hot and cold test conditions. Foucault reports customer interest in how long after, say, a 36-hour soak at -40°C OAT (outside air temperature), that makes the whole cabin "about -36°C everywhere", IFE equipment will take to become operational. "It

A350 FLIGHT TEST UPDATE

Airbus expects to achieve European Aviation Safety Agency Type Certification for the new A350 twin-aisle twinjet by the end of September and to hand over the first aircraft to launch customer Qatar Airways by year's end. Since the maiden flight 12 months earlier, the remaining four aircraft have flown, logging more than 2,000 flight hours (FH) in a 2,500 FH flight test campaign. Initial examples of the Rolls-Royce Trent XWB engines for production aircraft were dispatched from the UK in mid-May.

MSN001: Equipped with heavy flight test instrumentation, it is being used for initial handling, natural icing campaign trials, and systems and powerplant testing.

MSN002: This aircraft features the first A350 cabin interior and medium test instrumentation, and is used for related systems testing, IFE and hot/cold cabin tests and early long flights.

MSN003: Having been second to fly, this A350 has a similar flight test equipment installation and has been used for high altitude and hot/cold weather testing, performance measurement, and systems and powerplant testing.

MSN004: This lightly instrumented flight test aircraft is used for external noise and lightning strike tests, avionics development and certification, and customer pilot and maintenance training.

MSN005: The last flight test A350, which flew for the first time on June 20, has a full cabin interior, but only a light flight test installation. It is to be used for cabin operability and training, route proving, and extended twin-engine operations approval.

is not in the avionics rack but in the aircraft tail, which will not warm up as fast as the equipment bay below the cabin, and certainly not as quickly as inside the cabin."

Operators ask how the IFE rack is ventilated and if the system can be active when passengers board. Foucault says that previous generations of long-haul aircraft could take four hours to become operational "when integration of airflow was not taken so seriously". Tests have shown "very satisfactory" results for IFE media loading in hot cabins when there is no air-conditioning, according to Foucault. Another consideration after a long cold soak is how soon food can be loaded and passengers embarked. For Airbus, it is part of getting to know the aircraft. "When and how to load galley items are very practical questions based on very long experience," says Ducarroir. Such parameters can differ according to the temperature propagation rates of airframe materials.

A350 FLIGHT TEST STATION

Despite the entire cabin of Airbus A350 MSN002 being part of climatic testing, with 220 seats fitted, there is also a dedicated flight test engineers' station in the center of the economy section. This is linked to all the aircraft systems, and several fixed and portable computer screens display measured and recorded information. The cabin features numerous temperature and sound-level probes and sensors to monitor the environment.

Indeed, Airbus suggests the cabin can be considered as equipment for testing everything, from LED lighting to seat recline functionality, and from IFE to coffee makers.

McKINLEY LABORATORY

McKinley has provided Airbus with "a wonderful tool" that Ducarroir is convinced the European manufacturer will use again future aircraft development work. He says that the company had to prepare carefully well in advance to instrument the aircraft for the environmental testing, which involved "hundreds of measurements" to create a real-time recording of its exposure to varying conditions.

Ducarroir emphasizes the need for good preparation and robust test equipment capable of coping with hot and cold. "All those things have to be measured by instrumentation that must cope with the same conditions. Very, very specific care has to be taken long, long in advance on how systems are rigged to cope with such conditions," he says. "When we mention battery items, how long it takes the battery area to cool to -15°C, it means hundreds of similar measurements all along the aircraft interior that were permanently measured, all night and all day, all the time we were in the McKinley chamber. So there was a full-time recording of 10 days' exposure to hot and cold."

Foucault explains the need to expose the entire A350 cabin to climatic testing: "It is a very complex system – not just a carbon fiber pipe with wings. Behind the panels and linings you have hundreds of kilometers of wiring and pipes, air-conditioning, electrical supply, hot air, waste, and water systems – particularly the water system.

"Every point that can freeze will make the system inoperative, so whether close to the aircraft skin or in warmer areas, it is very, very important that all components are properly isolated when run through cold areas."

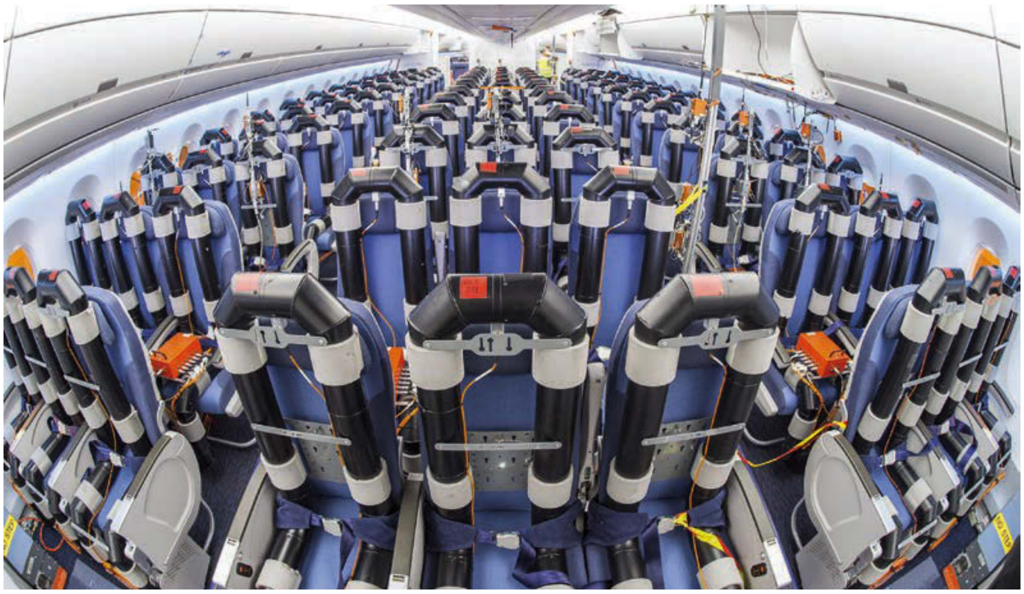
Airbus offers optional cold-weather packages for the water system and can provide additional heaters where people may move in door areas. "When you start at -40°C and are raising the cabin air temperature to 24°C, it could still feel freezing at floor level, so some areas have electrically heated floor panels."

Climatic testing usually involves aircraft with empty underfloor cargo bays "so that we have the biggest volume of air to be replaced and redistributed", says Foucault. "No one will leave an aircraft in cold conditions with a hold filled with precious materials, so these have to be unloaded for exposure to cold soak tests."

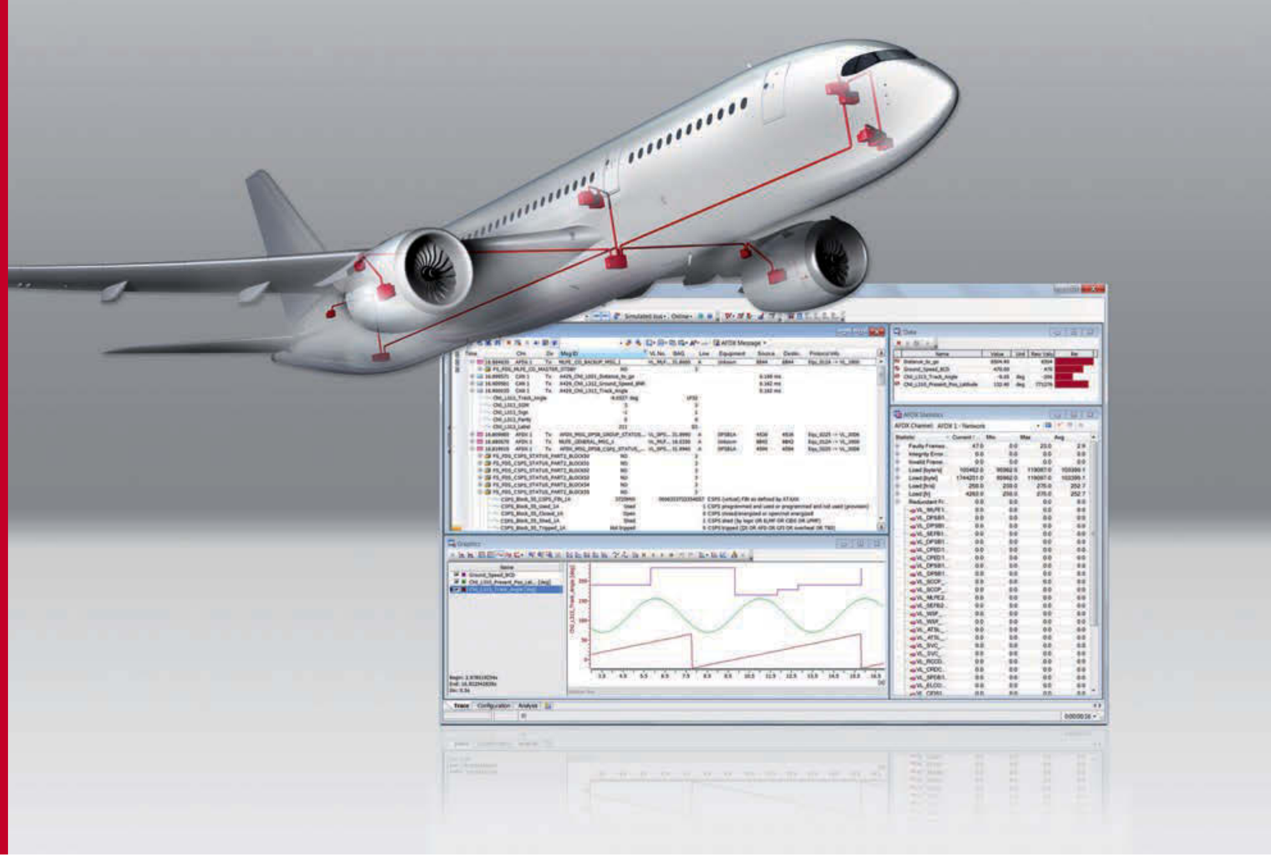
Since normal turnaround times on long-haul flights require no more than two to three hours to refuel, clean the cabin and replenish food trolleys, the aircraft is not exposed to low temperatures for very long, explains Foucault. "So cold soak testing is rather exceptional when aircraft stay cold for a long time, but it is contractual for certification requirements."

Is A350 environment testing on schedule? "We're progressing very well," reports Foucault. "We have most of the results. We are on time, but didn't have any other choice because, for the tests in the McKinley chamber, we had a slot booked three years ago that was not movable because the chamber is always full." Results from McKinley have been "very positive and very satisfactory" – some fine-tuning will be needed, says Foucault, "but nothing that calls for major change". Fine-tuning? "We have a few snags – mostly software-driven – so we are reviewing the retrieved data and thinking about fixes for minor anomalies. Nothing we found was detrimental to certification, but we need to be absolutely sure that we understand correctly all the data we have…" concludes Foucault. ∎

Ian Goold is a UK-based writer for Aerospace Testing International, *and also a freelance writer specializing in the aviation industry*



BELOW: The test cabin. The development cabin interior, installed on flight test aircraft MSN002, underscores the flexibility and comfort in economy class



ACCESS II alternatives

It was an impressive formation of jets, whichever way you looked at it: a pair of Dassault Falcon bizjets, specially outfitted with research equipment, following in the wake of a four-engine Douglas DC-8 airliner, escorted by a diminutive, 1960s-vintage Canadair T-33 jet trainer

BY THOMAS NEWDICK

The unique four-ship mentioned above was incredible but the reason for the get-together was somewhat more serious. The aircraft assembly was also responsible for a joint research campaign that could have far-reaching implications for the global aviation community. It is all part of efforts to better understand the emission characteristics of biofuels. Alternative fuels such as these offer the potential not only to greatly shrink the overall carbon dioxide footprint of aviation, but also to reduce the potentially harmful climatic effects of particle emissions and aircraft-generated cloudiness.

Between May 7-17, 2014, NASA, the German Aerospace Center (DLR) and the National Research Council of Canada (NRC) joined forces to begin a series of trials of alternative aviation fuels. The flight tests studied the atmospheric effects of emissions from jet engines burning both conventional and alternative fuels.

Known as Alternative Fuel Effects on Contrails and Cruise Emissions (ACCESS II), the flights were undertaken from NASA's Armstrong Aircraft Operations Facility in Palmdale, California, with most of the flying conducted within restricted airspace near Edwards Air Force Base. The NASA-led flight campaign involved more than 100 participating scientists and technicians, including a contribution from NASA facilities at Armstrong, Langley and the Glenn Research Center in Cleveland.

THE ACCESS PROJECT

The ACCESS project dates back to 2009. In 2013, the ACCESS I tests revealed that biofuel blends may substantially reduce emissions of black carbon, sulfates and organics. However, the scope of the studies conducted in 2009 and 2011 were necessarily limited by having the DC-8 test article parked on the ramp at the Palmdale facility. Ground-based instruments were then used to measure the exhaust emissions as the aircraft burned alternative fuels.

ACCESS I showed that soot emissions from blended fuel were reduced by 40-60% compared with JP-8 fuel by itself, according to Bruce Anderson, NASA's principal investigator for the ACCESS program. "We saw big changes in soot emissions from the DC-8, but we weren't able to make clear ties between the type of fuel burned and the formation of contrails. So for ACCESS II we really wanted to dig into that," Anderson said.

THE CONTRAIL MYSTERY

For Anderson, understanding more about contrail formation is of critical importance. The contrail phenomenon is considered an essential variable in discussions about climate change. Contrails consist of ice particles that are created when water vapor from the jet exhaust condenses and freezes on nuclei.

1500	The number of commercial flights that have taken place using 50% or more biofuel
4895	The distance in miles between Amsterdam and Aruba, the world's longest biofuel flight (10 hours) to date (flight KL767)
250	times more oil can be produced for aviation fuel by algae than from soybeans
19	The number of airlines that have used a biofuel mixture
80	The percentage reduction in fuel emissions compared with fossil fuel

What is unclear is the source of these nuclei. Candidates include soot from the jet engine exhaust, in which case the use of alternative fuels might lead to a reduction in contrail formation. Another possible source is the sulfur found in standard jet fuels, suggesting that a low-sulfur or non-sulfur fuel might also have an effect on contrail formation. The presence of normal background aerosols in the atmosphere could also be a factor.

"It could be any or all of those things. Some people say there's so much water vapor in the exhaust of an aircraft that any particles at all will seed the formation of ice," Anderson says.

In the latest tests, the NASA DC-8 flew ahead of the two Falcons, at typical cruising altitudes of between 9,000m and 12,000m, its engines burning a combination of biofuel and conventional kerosene. Scientists on board the DLR Falcon 20-E5 and NASA HU-25C Guardian (originally a Falcon derivative for the US Coast Guard, now based at NASA's Langley Research Center in Virginia) measured exhaust gas composition at distances between 100m and 20km from the airliner and observed the formation of contrails. Meanwhile, the NRC's CT-133 research aircraft was equipped with sensors to monitor the dynamics of the DC-8's wake, beginning with the airliner's initial climb out of Edwards.

Before the trials began in earnest, it was necessary to practice the intricate formation flying and separation required for the demanding scientific mission. The conventionally fueled DC-8 took off first, followed by the T-33. While the practice flight, which took approximately three hours, saw the NASA Falcon taking off first, once in the air, positions were swapped with the DLR jet and different formations familiarized. The Falcon pilots paid particular attention to transitioning between a study position just behind the DC-8, the 'near-field', and a study position about 16km away, the 'far-field'.

During the research flights, the four CFM56 engines of the DC-8 alternated between using regular JP-8 jet fuel and a 1:1 mixture of JP-8 and the biofuel HEFA (hydro-processed esters and fatty acids). Although on a chemical level HEFA is identical to the hydrocarbons found in jet fuel, it is obtained from feedstock containing vegetable oil, in particular the oil of Camelina plants. In order to test the role of sulfur in contrail generation, the JP-8 was provided in low-sulfur and high-sulfur grades.

TOP: Cabin of the DLR Falcon 20-E5. DLR researchers focus on measurements of the biofuel exhaust emissions of soot and sulfur particles, as well as the size and shape of the ice crystals in the contrails (Photo: DLR)

ABOVE: The research aircraft flew at altitudes between 9 and 12km during the experiments (Photo: NASA)

EMISSIONS

In measuring the biofuel exhaust gases, particular focus was given to the emissions of soot particles and sulfur compounds, and the size and shape of the ice crystals in the contrails. Using alternative fuels, such as HEFA, it is expected that soot and sulfur particles will be considerably reduced, as well as providing a better carbon dioxide balance. An effect of lower soot emission levels could be the formation of larger ice crystals in the contrails, in turn reducing the impact of aviation on the climate in the form of additional

TEAMWORK

"For NASA, partnership with DLR and NRC is a means to combine our expertise and resources as we work together to solve the challenges common to the global aviation community", says Jaiwon Shin, NASA's associate administrator for aeronautics research.

NASA project manager Bruce Anderson of the Langley Research Center welcomes the international support provided by the German contingent: "DLR's expertise and measurement capabilities are making an important contribution to the ACCESS II campaign." Indeed, these latest efforts are the culmination of 15 years of cooperation between DLR researchers and their NASA colleagues in the area of atmospheric research. "For the DLR scientists, working with NASA on this research mission is a real benefit," says Hans Schlager.

The results of the latest joint flight tests will be discussed at the next meeting of the International Forum for Aviation Research (IFAR). Thereafter, DLR will continue to focus on alternative fuels under the ECLIF (Emission and Climate Impact of Alternative Fuels) initiative. "Under ECLIF, our research focus is on various types of alternative fuels, and we will investigate both the combustion in the engine and the resulting emissions," says Patrick Le Clercq from the DLR Institute of Combustion Technology. Initial research flights for Project ECLIF, using the DLR's A320 ATRA (Advanced Technology Research Aircraft) and Falcon, are planned for 2015.

cloudiness. "Measurements in aircraft exhaust plumes and contrails require a great deal of experience and proven measuring equipment," notes the head of the DLR mission, Dr Hans Schlager from the Institute of Atmospheric Physics in Germany. "In recent years, DLR has built up expertise and measurement instrumentation in airborne sampling experiments in the wake of aircraft." Since 2000, the DLR's Falcon has been used in various measurement campaigns to examine emissions and contrails behind commercial aircraft.

TURBULENCE AHEAD

In another innovation, the latest ACCESS mission also investigated the role of wingtip wake vortices – the turbulent, twisting air that streams for miles behind the wingtips of aircraft. This involved flying the research aircraft into the vortices themselves, which required NASA to conduct detailed studies of the DC-8 wake vortices at various altitudes and flight conditions with the Guardian following closely in trail. "Before, it was a mission rule to avoid flying into the wingtip wake vortices because of the potential structural hazards for the research chase plane," says Brian Beaton, NASA's ACCESS II integration manager.

Therefore the chase plane pilots first had to know exactly where it was safe to fly through the vortices. To select suitable trailing distances, the team made use of extensive analysis, including computer simulations. Then, once in the vortices, the two Falcons made observations of exhaust composition and contrail characteristics. At a separation of 14 miles, for example, the Falcon was found to be severely buffeted by the wake vortices, but was tough enough to withstand any damage to the airframe. "Our Falcon is an extraordinarily robust research aircraft and ideal for taking measurements in the exhaust plume and in condensation trails," said DLR test pilot Philip Weber. "Heavy structural loads that not all aircraft are designed for can occur in aircraft take turbulence."

another set of probes is used to measure ice crystals in the contrails. Using the scattered light of a laser, not only the number but also the size of the ice crystals can be determined. Ice crystals ranging in size between 0.5µm and 100µm can be measured using the underwing instruments while in free flow. In addition, researchers in the cabin study the ice water content of the crystals with a hygrometer, which is connected to a forward-facing heated air inlet on the roof.

Once the number of particles and the amount of carbon dioxide within the vortices had been assessed, these figures could be compared with the quantity of fuel burned.

While the DLR Falcon was on hand to analyze the chemistry side of the experiment, the Canadian CT-133 was used to study the aerodynamics

> **"MEASUREMENTS IN AIRCRAFT EXHAUST PLUMES AND CONTRAILS REQUIRE A GREAT DEAL OF EXPERIENCE AND PROVEN MEASURING EQUIPMENT"**

TEST PAYLOADS

The DLR Falcon is also equipped with various instruments to measure trace gases and particles. These are also robust enough to withstand flying in the turbulent wake of another aircraft.

The Falcon is able to detect airborne particles in sizes ranging from around 5nm to 3µm. The larger particles are gathered using probes carried under the port wing. The smaller particles are gathered via an opening in the cabin roof that is served with stainless steel tubes that conduct them into the measuring instruments on board. Under the Falcon's starboard wing,

and physics of the wingtip wake vortices themselves, providing data to complement the measurements gathered by NASA's Guardian. The latter aircraft was also earmarked to study 'targets of opportunity' – depending on weather conditions, the NASA Guardian could coordinate with air traffic controllers and airliner pilots and take measurements while trailing airliners flying in the southern California region. These missions were flown from a safe distance of five miles [8km] or more. ∎

Thomas Newdick is an aviation and defense writer and editor based in Berlin

RIGHT: The NASA Guardian seen at Palmdale, California, for the measurement campaign (Photo: DLR)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Engine driver

Boeing is developing the 737 Max, the fourth iteration of its famous single-aisle twinjet, but 50 years of evolution have left few options to improve airframe efficiency. Ian Goold discovers that the economic gains are essentially driven by a new, more efficient powerplant

BY IAN GOOLD

Six years after CFM International (CFMI) launched the new Leap engine, and nearly half a century after establishing the Model 737 twinjet project, Boeing is working on a fourth generation of its short/medium-haul workhorse. With a more efficient aerodynamic and structural design, lower engine thrust and reduced maintenance requirements, the planned 737 Max will offer great cost advantages, claims chief project engineer Michael Teal.

US low-cost carrier Southwest Airlines launched the Max-8 sub-variant in 2011, followed by a -7 order last year. Now almost 40 customers have ordered over 2,000, nominally worth over US$200 billion (at list prices) and Boeing has 'commitments' for another 250. While the new variant is very much driven, literally and metaphorically, by its Leap-1B powerplant, "The Max offers a new engine and more," says program general manager Keith Leverkuhn. "The Max also combines advanced aerodynamics including advanced-technology winglets, and large-screen flight deck displays."

Powered by the Leap-1B engine, the Max will be 14% more fuel efficient than current 737NGs, according to Boeing, which plans to begin final assembly in mid-2015, fly the aircraft in 2016 and deliver the first example in the third quarter of 2017. Engine design freeze came in April 2013 (following that for the -1A and -1C variants in 2012) and parts manufacture began soon afterward, accelerating as CFMI prepared for first engine assembly.

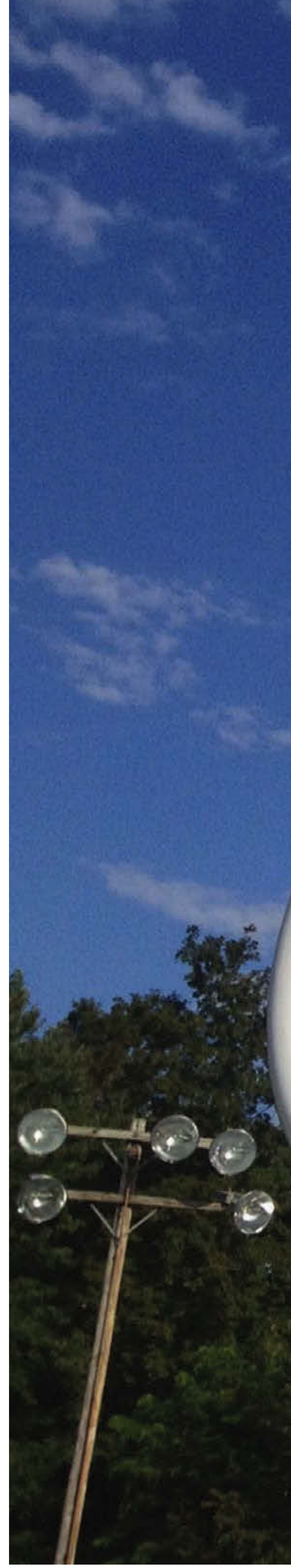
LEAP-1B

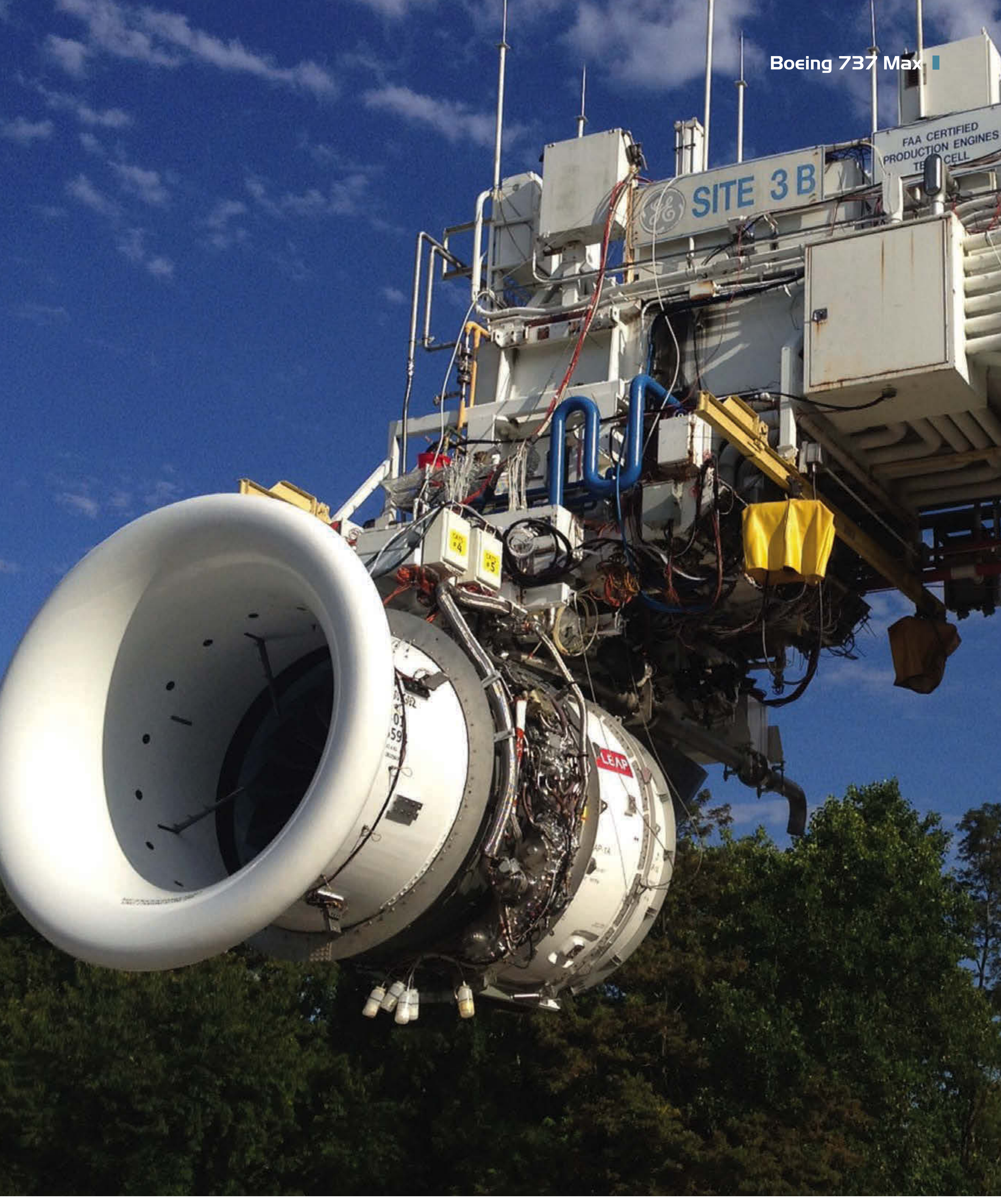
The Leap-1B, optimized with a more efficient core and 69.4in diameter fan (up from 61in on the 737NG's CFM56-7 powerplant), is the major source of increased efficiency, reducing fuel consumption by about 11% after drag is calculated. The result is increased range, more than 3,500 nautical miles (6,480km), an improvement of up to 580 nautical miles (1,075km), or a higher payload, than competing designs.

"Among design changes from the 737NG, a new engine pylon is integrated into the wing, on which a new spoiler fly-by-wire system aims to improve reliability and reduce weight and stopping distances," says Teal. Another change is substitution of titanium for composites in thrust-reverser inner walls. Titanium is heavier, but overcomes requirements for heat-insulation blankets. Exposing reverser walls to heat is less of a concern and allowed Boeing to enlarge the nacelle, which has been 'sculpted' to enhance laminar flow.

The larger engines are mounted slightly higher, and to maintain ground clearance, Boeing has lengthened the nosewheel leg by 8in and modified the local structure to accommodate it. Early design iterations also showed a small bump in the nosewheel door, but this has now been eliminated and high- and low-speed wind tunnel tests have shown cleaner aerodynamic lines at the front of the aircraft.

Aft-body aerodynamics is also improved through adoption of an extended tail cone and redesigned

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PRODUCTION ENGINES
SITE 3 B
LEAP

> "A PHYSICAL MOCK-UP OF THE REDESIGNED FORWARD-FUSELAGE LOWER LOBE HAS BEEN USED TO CONFIRM SYSTEMS LOCATION"

auxiliary power unit inlet, with a thickened section above the elevator to improve airflow stability. This reduces drag by 1% and eliminates the need for tail vortex generators.

A physical mock-up of the redesigned forward fuselage lower lobe has been used to confirm systems location and maintenance ergonomics. It permits external viewing through transparent skins that show, for example, that Boeing has moved the electronics aft bulkhead 4in rearwards.

SEAT CAPACITY

Mirroring an Airbus move to increase the competing A320neo's capacity to 189 seats (ultimately dictated by emergency exit requirements), Boeing is understood to be considering up to nine additional places over established 737 configurations through use of 'slimline' seating and internal changes.

Adding seats enhances fuel/seat performance, but Leverkuhn has claimed that the manufacturer is happy with established layouts, although he conceded last year that Boeing would talk with customers, suggesting that minds are not completely made up. Larger flight deck displays offer improved reliability and reduced spares, weight, and lifetime maintenance and upgrade costs.

THE ENGINE

CFMI, a partnership between General Electric (GE) and Snecma, launched the Leap engine with no specific application until China's Comac chose the Leap-1C as the sole Western powerplant for the C919 jetliner five years ago. Airbus followed in 2010, adopting the -1A engine as an option on the A320neo, before Boeing selected the -1B a year later as the sole 737 Max powerplant. As Boeing studied a fourth-generation 737 variant, "the engine really became our focus," says Leverkuhn.

737 MAX COMMONALITY

Current Boeing 737s will enjoy operational commonality with the new Max variants. The fuselage and wings, for example, are similar, but they and the landing gear will be strengthened to carry heavier, more powerful engines. The Max will use the 737NG support system and maintenance program and retain a high degree of spares commonality.

ABOVE: The 737 Max will incorporate the latest quiet engine technology to reduce the operational noise footprint of the airplane by up to 40%

RIGHT: Wind tunnel tests. Boeing claims the 9ft winglets will give 1.5% fuel burn improvement over current technology

The manufacturer took a good, hard look at the Pratt & Whitney (P&W) geared turbofan (GTF) engine and also worked with Rolls-Royce. Several years of potential new and re-engined aircraft studies preceded Boeing's selection of the Leap-1B (initially with a 68in diameter fan).

"We're very happy with the selection and CFMI's assurance that we will get what we need for the customers," says Leverkuhn. "Given our familiarity with GE's GEnx, we are confident CFMI can precisely tune the engine to the airplane and the airplane to the engine." It's a remark that suggests the existing airframe and landing gear setup has been a limiting factor. Leverkuhn says the nacelle dimensions are "pretty close to current size" through thrust-reverser sculpting. The Leap-1B uses a carbon fiber-

AERODYNAMIC WINGLET

As well as new engines, a Boeing 737 Max airframe change claimed to contribute a minimum 1.5% improvement in fuel burn is a 'winglet' designed to provide increased lift from a wingspan limited by the requirements of airport terminal gates. "The effective wingspan increase is balanced between the upper and lower parts," says chief project engineer Michael Teal. Composite 'feathers' slope sharply upward and downward from the wingtip, complemented by a third flatter element.

Boeing integrated 'rake-tip' technology with the 'dual-feather' winglet, while taking advantage of natural laminar flow. Outboard of the ailerons, the wing will incorporate a split trailing edge to transmit load into the winglet, "making it work harder", says Boeing flight sciences chief aerodynamicist Robert Gregg. A modified 737NG winglet has been test flown to prove "profile and assembly tolerances", according to Max structural design engineer Philipp Witte.

"AN 'UNPRECEDENTED' LEVEL OF TESTING IS PLANNED TO INVOLVE 28 DEVELOPMENTAL LEAP-1 ENGINES"

composite fan and fan case, 3D aerodynamic airfoils, twin-annular, pre-swirl combustor, advanced cooling and coatings in the high-pressure turbine, and materials such as ceramics matrix composites (CMCs) and titanium aluminide. Thrust ratings are in the 20,000-28,000 lb range (about 1,000 lb higher than the 737NG's equivalent CFM56 ratings).

"Engine/wing integration has been improved," says Teal, "with the powerplant higher and further forward on the wing to retain ground clearance. This reduces drag, contributing about 0.5% of fuel efficiency."

Advanced aerodynamics, environmental, and materials technology development will contribute to a 15% saving in both fuel consumption and CO_2 emissions (compared with the best CFM56), with "dramatic" noise and emissions reductions, claims CFMI.

The engine company began running the Leap-1A (for the A320neo) on GE's testbed in Ohio last September, with the Max's Leap-1B scheduled to run in mid-2014. Initial Leap testing with the -1A began with 50% power achieved immediately and full power within "a few hours" after necessary "break-in" runs; the 30,000 lb full-rated thrust was exceeded within 48 hours.

Early testing was essentially problem-free, says CFMI, which has run four iterations of the core. The manufacturer believes this validates its module-testing strategy, which included the fan, different components, and engine-level testing with the fan.

An "unprecedented" level of testing is planned to involve 28 developmental Leap-1 engines: 20 (including 15 -1As) by the end of 2014, seven more next year, and a final Leap-1C variant with tests thought to involve a 'blade-out' check in 2016. CFMI would not say how many engines are allocated to each airframe.

COMPLIANCE ENGINES

CFMI will also test 32 'compliance' engines that will be sent to Airbus, Boeing and Comac for flight test before certification. "We'll have 60 engines and 42,000 cycles combined – equivalent to about 15 years' simulated revenue service. This tremendously aggressive and robust program is necessary to achieve the reliability customers expect," states CFMI.

Leap-1A icing tests in Winnipeg, Canada, in early 2014 will be followed in September and October by 'block tests', measuring operability in extreme conditions, such as extended running at maximum fan and core speeds and maximum exhaust-gas temperature. The Leap-1B is scheduled for June ground testing at Safran (Snecma) in

PRODUCTION STRATEGY

Boeing has released about 25% of the Max airframe design and completed 150,000 hours of systems, flight deck and spoiler fly-by-wire development work. "We're doing a lot of mock-up work alongside detailed design because we have to produce this airplane at high rates," says program general manager Keith Leverkuhn, explaining that it must enter production without interrupting flow times in the Renton factory, near Seattle.

Accordingly, Boeing has to inaugurate Max manufacture, accelerate overall 737 production to 47 a month to reduce order backlog as the Max enters service in 2017 and replace 737NG assembly, which will cease in 2019. Southwest Airlines should receive the first stretched Max-9 in 2018 and the smaller -7 the following year.

"We have to weave Max into [already running] production at a high rate; it's not about technology, but about proving production capability," says Leverkuhn. This means, for example, that Boeing will perform both detailed design and manufacture of the Leap-1B engine inlet at its new assembly site in Charleston, South Carolina.

Tooling for Max systems installation (SI) is under way at Renton, where fuselage SI positions alongside the two 737NG final-assembly lines are being cleared to establish a "Max transition line" accommodating a third line as Max airframes gradually infiltrate existing production areas. Managing Max integration is 737NG general manager Beverly Wyse, who talks of the "strategic application of automation" to describe the challenge.

Each 737NG assembly line can complete 21 aircraft/month, a rate Boeing should reach by July as production accelerates. The Max transition line will allow slower initial assembly and could be used to introduce subsequent Max variants and will facilitate installation of flight test equipment and employee training. Following completion of initial airframes, Max training will shift to main assembly lines. Later, the transition area could support higher production rates.

Villaroche, France, where extensive instrumentation will track more than 1,500 engine parameters, while other Leap-1C and -1B work this year includes aeromechanics (blade-vibration tests) and hail, ice and rain ingestion.

Certification and first flights of the -1A and -1C (on the A320neo and C919, respectively) are scheduled next year and for -1B (on the Max) by mid-2016. Flying testbed (FTB) work on GE's Boeing 747-100 with the Leap-1B will have begun in early 2015, following the -1C and -1A at GE's facilities in California.

Ahead of expected Leap-1B certification, expected in February 2016, simultaneous approval for the Leap-1A and -1C has been scheduled for June 2015 – recent delays to C919 airframe development not withstanding (CFMI previously said that -1C certification was "pending a pragmatic approach of potential adjustments in the C919's schedule"). The Leap-1C remains first to fly but last to enter service, CFMI saying that the schedule is based on requirements from the three airplane companies and the ultimate entry-into-service dates. "There are hardware requirements to fulfill the schedule for the FTB, so we're just going to go ahead and fly the -1C first. This is how we laid out our schedule. We like to stick to our plan," says CFMI. "The -1C and -1A are very similar, although installation is not exactly the same. But from an engine perspective, everything we learn on the -1C is applicable to the -1A," says CFMI. Experience with the -1A, which has different turbo-machinery (the differences lying in the nacelle/pylon interface) has validated technologies used in, for example, fan blades that are made with three-dimensionally woven carbon fibers, titanium aluminide alloy low-pressure turbine blades, and engine shrouds employing ceramic matrix composite (CMC) material.

The CMC reduces part weight by two-thirds and can withstand high temperatures. Some Leap low-pressure turbine vanes use additive-layer manufacturing in titanium alloy, while production engines will sport fuel nozzles partly made via 3D printing with nickel alloy. Leap-1 first-stage HPT blades and a ceramic shroud (to GEnx dimensions) have been tested on two GEnx ground test engines, with CFMI aiming to complete 6,000 cycles.

With three Leap-1 variants entering service from 2016 to 2017, CFMI faces a steep production ramp-up: "The goal is to get there in less than three years, from zero to 1,700 engines per year by the end of 2018 or the beginning of 2019," the organization states. Current annual production is about 1,500 engines.

LEAP COLD TRIALS

CFM International, which is developing the Leap-1B engine for the Boeing 737 Max, completed initial icing tests on the basic engine earlier this year, 12 months ahead of certification testing. The engine ran for more than 20 hours at GE Aviation's Testing, Research and Development Centre (TRDC) in Winnipeg, Canada, completing the "most severe certification-level test points". CFMI also evaluated various icing-mitigation configurations under an overall risk-reduction process. The engine behaved "very well" in extremely harsh conditions.

Initially designed to handle jet-engine cold-weather and ice testing, the 122,000ft² TRDC site has been expanded to include all-weather development and test cycles for engines. The facility, built in 2012 and owned by GE and operated by Standard Aero, now incorporates additional equipment and a concrete base to allow wind tunnel movement to accommodate different types of testing.

Digital "temperature-catching" equipment and turbulence-control structures (to "straighten" air entering test engines) have been introduced. "The facility will be a critical part of new-engine development," says GE Aviation design and systems integration engineering manager Kevin Kanter. AG has been working with five partners (iSAM AG, Cassidian, GOM – Gesellschaft für Optische Messtechnik mbH, Electro Optical Systems (EOS) and Eurocopter) on the development of an applicable process chain for the rapid, automatic and reproducible repair of high-performance fiber composite materials.

Leap-1 engine family

Variant	Platform	Thrust
Leap-1A	Airbus A320neo	24,500-32,900 lb
Leap-1B	Boeing 737 Max	23,000-28,000 lb
Leap-1C	Comac C919	27,980-30,000 lb

RIGHT: **By the end of June, the first full Leap-1B engine will begin ground testing at Snecma facilities in Villaroche, France**

ALTERNATIVES

A Honeywell electronic engine bleed-air system should reduce fuel burn by optimizing cabin pressurization and ice-protection systems. The supplier says it will enable operators to monitor aircraft diagnostics electronically, simplifying troubleshooting and making maintenance less time intensive. ∎

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

ENVIRONMENT AND THE 737 MAX

The 737 Max will have a lower environmental impact than current similar jetliners, according to Boeing. The company says that annually a Max-8 subvariant will emit just over 3,000 fewer tons of CO_2 and burn about 975 tons less fuel, saving more than US$1,120,000 (assuming US domestic rules, 500 nautical mile mission, two-class seating, and fuel at US$3.50/US gallon). The aircraft will have an up to 40% smaller noise footprint and about 50% lower NOx emissions than ICAO environmental protection limits.

Watch this space

SPACEX DRAGON VERSION 2

Dragon Version 2 (V2) lands using its SuperDraco rocket engines, but it has parachutes if the rocket engines fail to fire. When it lands using its rockets, four landing feet extend downward through the heat shield. Dragon V2 is designed to be reusable and will carry seven astronauts and has a glass cockpit control panel, with some buttons for emergency related systems. It is launched by SpaceX's Falcon 9 rocket. SpaceX's original Dragon spacecraft, also launched by Falcon 9, is carrying cargo to the ISS under a NASA contract.

NASA's commercial crew program is heating up this summer, with a number of critical testing milestones either planned or underway

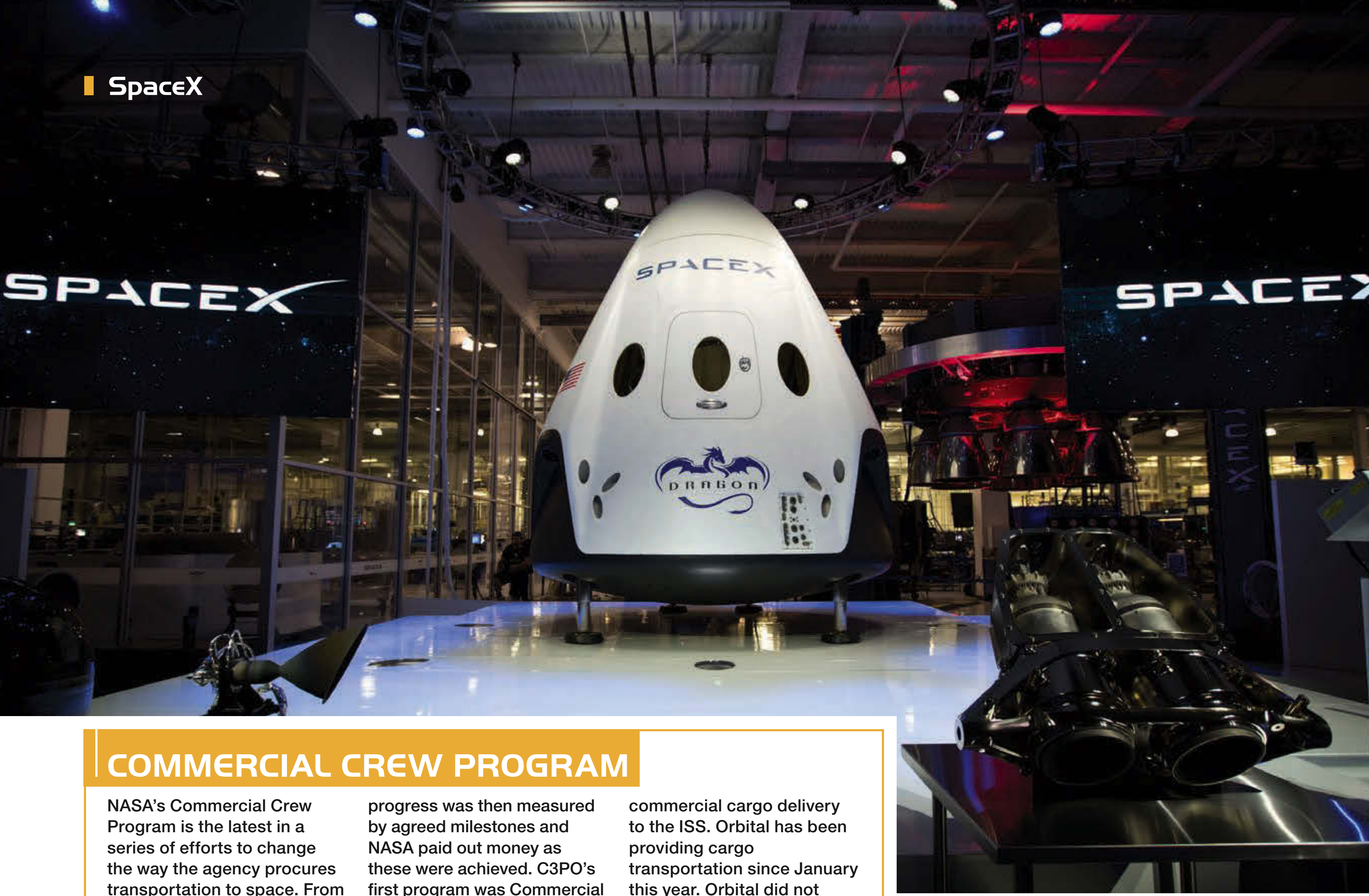
BY ROB COPPINGER

At the end of June 2014, a spacecraft will launch at Cape Canaveral in Florida for NASA's Commercial Crew Program, which will see the US space agency buy seats for its astronauts for orbital trips from 2017. The purchase of US spacecraft has come into sharp focus with the Ukraine crisis because, for now, NASA has to buy seats on Russian spaceships to get its astronauts to the International Space Station (ISS) as the agency has no transportation system of its own since the space shuttle fleet was retired in 2011. The aim of the program is to utilize private companies to ferry astronauts to and from the ISS as part of the stepping stone to the human exploration of Mars.

The June launch will test Space Exploration Technologies (SpaceX) Dragon Version 2 (V2) spacecraft's SuperDraco thrusters, which will propel a capsule from the top of the Falcon 9 rocket, which was also built by SpaceX. Based in California, SpaceX is one of three US companies that were selected in August 2012 for the final stages of NASA's Commercial Crew Program. The other two companies are: Boeing, a company with a long space flight history; and Sierra Nevada Corporation (SNC), which is based in the state of Nevada, USA. Two of the companies have a conventional rocket and capsule type system, while Sierra Nevada has a space plane it calls Dream Chaser. This space plane is launched on top of the Atlas V rocket, which is manufactured by Lockheed Martin and launched by the Lockheed/Boeing joint venture United Launch Alliance (ULA). Boeing also uses the Atlas V for its capsule spacecraft, the Commercial Space Transportation (CST)-100.

LAUNCH ABORT TESTING

The SpaceX June launch abort is one of the Commercial Crew Program milestones agreed between the firm and NASA. All of the companies have milestones against which NASA links funding. According to a presentation given in April by the crew program's manager Kathy Lueders, who was appointed to the position that month,



ABOVE: Toward the base of the capsule but outside the pressurized structure are the Draco thrusters, Dragon's guidance navigation and control (GNC) bay and Dragon's advanced heat shield

COMMERCIAL CREW PROGRAM

NASA's Commercial Crew Program is the latest in a series of efforts to change the way the agency procures transportation to space. From the Mercury Project to space shuttles, NASA had, with private industry's help, designed, developed and operated its own space transportation systems.

Cargo transportation began in 2012 and crew services are expected from 2017. The Commercial Crew and Cargo Program Office, also known as C3PO, has managed the development and contract programs. The new approach would mean companies had to provide their own funds that were matched against NASA's funding. The companies' progress was then measured by agreed milestones and NASA paid out money as these were achieved. C3PO's first program was Commercial Orbital Transportation Services (COTS).

Starting in 2006, COTS was formed to help companies develop and demonstrate cargo space transportation technologies. Two companies were selected: Space Exploration Technologies (SpaceX), and Rocketplane Kistler. This led to Cargo Resupply Services (CRS) in 2008, but by that time Rocketplane Kistler had dropped out and was replaced by Orbital Sciences. The ISS Transportation Office managed CRS. In late 2012, SpaceX made the first commercial cargo delivery to the ISS. Orbital has been providing cargo transportation since January this year. Orbital did not move on to the next stage, the Commercial Crew Development Program.

NASA requirements for the spacecraft are: be able to carry four astronaut crew members and equipment to the ISS and return them to Earth at least twice a year; assure crew safety in the event of an emergency on the launch pad and during launch and ascent to orbit; demonstrate that the spacecraft can serve as a 24-hour safe-haven during an emergency in space; and be able to stay docked to the ISS for at least 210 days.

SpaceX will also have an inflight launch abort test in August. This means the Dragon will separate from the Falcon 9 rocket 73 seconds into its ascent into space.

According to an October 2013 NASA statement, SpaceX's Dragon will be outfitted with about 270 sensors for the launch abort test to measure a wide variety of stresses and acceleration effects on the spacecraft. An instrumented mannequin, similar to a crash test dummy, will be inside. The spacecraft's parachutes will deploy for a splashdown in the Atlantic, where a ship will be pre-positioned for simulated rescue operations. The test spacecraft will be returned to Port Canaveral by barge so data can be retrieved and incorporated into the system's design.

The SuperDraco rocket engines that are being tested in the on-pad and inflight aborts passed their qualifying firing testing in May at SpaceX's Rocket Development Facility in McGregor, Texas. That testing involved multiple starts, extended firing durations, and what SpaceX calls "extreme off-nominal propellant flow and temperatures".

The SuperDraco is a development of the Draco engine of the Dragon spacecraft being used for ISS cargo transportation. The SuperDraco has much higher thrust at 16,000 lb and features a 3D printed combustion chamber made from Inconel, a high-performance nickel chromium superalloy.

Like SpaceX, Boeing has a pusher escape system for its CST-100 and, like SpaceX, a launch abort will mean a sea landing in the Atlantic Ocean. So that the CST-100 can cope with this, Boeing has been working with Bigelow Aerospace, a US company that has developed an inflatable space habitat that can act as a space station or be part of such an orbital outpost. Boeing explains, "There has already been robust testing conducted at Bigelow Aerospace of our airbag system in case of a water landing." The airbag is for flotation and keeping the capsule upright in the water.

Boeing's most recent important test was its February flight control software system design review. This demonstrated spacecraft control with a pilot in the loop. Boeing says, "The CST-100 is fully autonomous; the pilot serves almost as a backup system for

SIERRA NEVADA DREAM CHASER

The Dream Chaser is described as a reusable lifting-body spacecraft that is based on NASA's Horizontal Lander (HL)-20 and it can carry seven astronauts. The HL-20 has years of research behind it at NASA's Langley Research Center in Virginia. For example, under its Personnel Launch System research, Langley engineers built a full size 8.84m engineering model. Launched from NASA's John F Kennedy Space Center (KSC) at Cape Canaveral, Florida, by the Lockheed Martin-built Atlas V rocket, provided by United Launch Alliance, Dream Chaser would land at KSC's runway, which had been used by the space shuttle.

"IN OCTOBER 2013, SIERRA CONDUCTED ITS FIRST FREE-FLIGHT TEST OF THE DREAM CHASER SPACECRAFT AT ARMSTRONG FLIGHT RESEARCH CENTER"

the spacecraft, so developing robust flight control software is critical."

The CST-100 may be fully autonomous, but it is yet to fly. Sierra Nevada has flight tested its Dream Chaser, but it was only a low-speed landing approach test with a prototype. In October 2013, Sierra conducted its first free-flight test of the Dream Chaser spacecraft at Armstrong Flight Research Center, formerly Dryden Flight Research Center, in California. During the test, the company says it demonstrated "excellent performance of our flight software in the controlled descent and landing phase of flight". It also confirmed that "flight software development is continuing and will be further demonstrated as part of the future flight tests", and assured that flight software development is "on schedule".

However, that flight test saw the Dream Chaser prototype's left landing gear fail and the spacecraft skidded to a halt on the Armstrong Center runway.

KEY PLAYERS

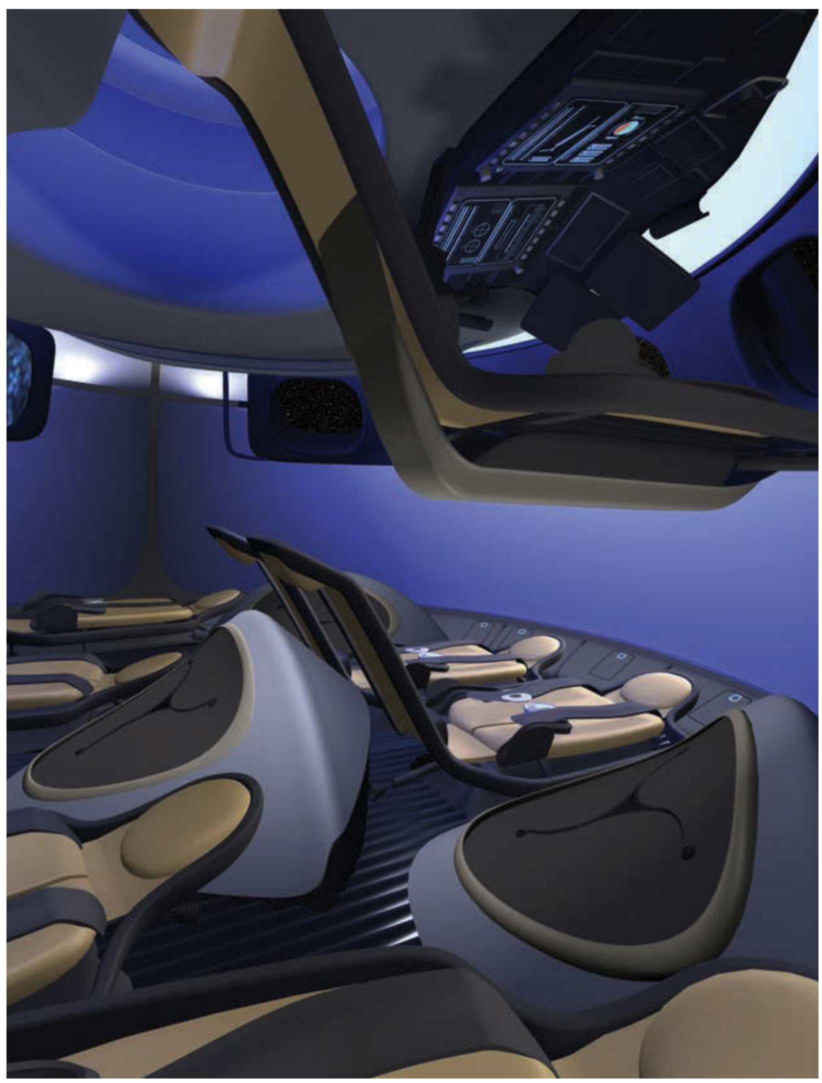
The Commercial Crew Development Program has had phases one and two, known as CCDev and CCDev2. CCDev started in 2010 and the companies involved were: Blue Origin, which is owned by Amazon.com founder Jeff Bezos; Boeing; Sierra Nevada; Paragon Space Development Corporation; and United Launch Alliance. SpaceX was not part of this first phase of CCDev.

CCDev2 started in April 2011 and involved Boeing, SpaceX, Sierra Nevada and Blue Origin. Under CCDev2, Blue Origin received US$22m, Sierra Nevada US$80m, SpaceX was awarded US$75m, and Boeing US$92.3m. This was the last stage Blue Origin was selected for, but it is continuing to develop its launch system of a two-stage rocket with a reusable first-stage and a biconic space vehicle capsule, which will also be reusable and carries seven astronauts. It is called biconic because of its shape, which provides for greater flight control during re-entry than a conventional Apollo-style capsule. Once separated, the first-stage booster will descend to perform a powered vertical landing, while the space vehicle returns to Earth where it will land using parachutes.

CCDev2 led to the Commercial Crew Integrated Capabilities (CCiCap) initiative, for which three companies were selected: Boeing, SpaceX, and SNC. NASA has paid out more than US$1.4bn so far on its CCDev, CCDev 2 and CCiCap agreements.

Following CCiCap is the Certification Products Contracts, for which USS$30m has been paid out. This will lead to a crew version of ISS resupply services. The first commercial crew flight is expected in 2017.

BELOW: Illustration of Boeing's CST-100 interior



BOEING CST-100

An Apollo-style capsule – the Commercial Space Transportation (CST)-100 – will be launched on the Lockheed Martin-built Atlas V rocket provided by United Launch Alliance. The CST-100 will carry seven astronauts and is expendable. Through its acquisitions, Boeing represents the bulk of US human space flight experience: from North American, which developed the Apollo command module, to Rockwell International, which built the space shuttle.

WIND TUNNEL TESTING

Sierra's most recent milestone test was its April wind tunnel testing of a Dream Chaser scale model. Three major wind tunnel tests were used to evaluate the integrated Atlas V and Dream Chaser dynamics during their ascent through the transonic and supersonic flight regimes. This was for Sierra's agreement with NASA for its Commercial Crew integrated capability (CCiCap) phase of the crew program. On April 15, 2014, Sierra presented data from those tests to NASA. Mark Sirangelo, corporate vice president and head of Sierra's Space Systems, says the data confirmed "that the integrated launch vehicle and spacecraft stack performs very well".

The next step for Boeing for its CCiCap agreement is a critical design review and a safety review in July. For Sierra, the next important area of testing is for the Dream Chaser's main propulsion system and its reaction control system, which consists of small rocket engines that enable the spacecraft to maneuver in orbit.

Sierra has agreements with many NASA research centers. The US space agency is made up of one headquarters building in Washington DC and nine research centers and other facilities dotted around the USA. As well as the Armstrong Center, Sierra has worked with five other NASA centers: Ames Research Center in Moffett Field, California; Langley Research Center in Hampton, Virginia; Marshall Space Flight Center in Huntsville, Alabama; Johnson Space Center in Houston, Texas; and Kennedy Space Center in Cape Canaveral, Florida. Langley is where the Dream Chaser wind tunnel testing took place.

Boeing is also using four of the centers – Langley, Ames, Kennedy and Johnson – as well as the NASA facility at White Sands, New Mexico.

204	The number of astronauts who have spent time on the ISS
1.5 billion	The miles on the odometer that the ISS had completed on its 10th anniversary
924,739	The weight of the station in pounds
174	The number of spacewalks completed from the ISS
1.5 million	Lines of software code run on 44 computers communicating via 100 dat networks
2	Bathrooms

ABOVE: To ensure a rapid transition from cargo to crew capability, the cargo and crew configurations of Dragon are almost identical. This commonality simplifies the human rating process, allowing systems critical to crew and space station safety to be fully tested on unmanned cargo flights

THE BOTTOM LINE

All of this testing costs hundreds of millions of dollars – SpaceX declined to answer any questions, but Boeing revealed it has been awarded US$580.2m so far, and Sierra has been given about US$330m.

For Sierra Nevada's Dream Chaser, it won two CCDev awards, totaling US$100m; a CCiCAP award worth US$212.5m; and a Certification Products Contract for US$10m. NASA also awarded Sierra Nevada an additional milestone funding, totaling US$15m. Neither company will reveal how much funding they have put into the Commercial Crew Program.

With only three years before NASA will make its decision on what will ferry its astronauts from the USA, and other countries, to the ISS, it should become clear in the next 18 months whether it is space flight veteran Boeing, cargo resupply winner SpaceX, or Sierra's reusable shuttle that will maintain human access to outer space, and with that ultimate goal to allow humans to live on other planets. ■

Rob Coppinger is a UK-based postgraduate engineer and spaceflight writer

INVESTIGATION: TEST SITE

In this second installment of our in-depth look at test sites, *Aerospace Testing International* gains exclusive access to space test sites. Our reporters look at some of the leading rocket test locations around the world and talk to those that run them, including: JAXA, NASA; ESTEC, the Netherlands; and ISRO, India.

- At ESTEC, the intensity of the artificial sun available in the space simulator has to be increased fivefold to represent the environment that it will see when it will be observing Mercury
- JAXA has international offices in Washington DC, Houston, Paris, Moscow and Bangkok
- NASA Armstrong researchers on the ground have the data-handling resources to track two major flight experiments simultaneously
- The Italian San Marco launch platform in the Indian Ocean is a former oil rig
- India's Chandrayaan-2 is being developed to complete a landing on the lunar surface as early as 2016

AEROSPACE TESTING INTERNATIONAL EXCLUSIVE

NEXT ISSUE: ROTORCRAFT DEVELOPMENT TEST SITES

Indian Space Research Organization

Location: Satish Dhawan Space Centre (SDSC), Andhra Pradesh, India

Coordinates
Latitude: 13.717
Longitude: 80.1665
Elevation: 6.0m

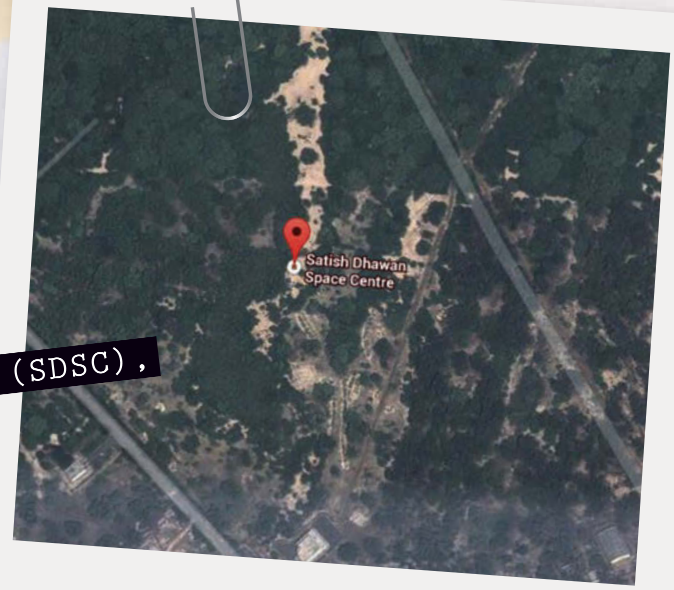


Image: Google Maps

India began a fledgling scientific space program in the early 1960s, initially putting small sounding rockets into the upper atmosphere and ionosphere. Under the guidance of Dr Vikram Sarabhai, the Indian space program took shape, with a focus of indigenous development of communications and surveillance satellites for national use.

The Indian Space Research Organisation (ISRO) was formed in 1969. Overall space policy is directed by India's Space Commission. The Department of Space is in turn responsible for implementing programs through the ISRO, as well as through other, smaller organizations including the Physical Research Laboratory (PRL), National Atmospheric Research Laboratory (NARL), North Eastern Space Applications Centre (NE-SAC) and Semi-Conductor Laboratory (SCL).

The prime objective of ISRO is to develop space technology and apply it to various national needs. The original remit of providing a national service is continued by current ISRO chairman Dr K Radhakrishnan. "The Indian space program is people-centric and application-centric. That's our USP," Radhakrishnan explained recently. "Whatever we do, it should finally find a place for the common man and society."

GROUND FACILITIES

ISRO's space launch facility is the Satish Dhawan Space Centre (SDSC) at Sriharikota in Andhra Pradesh. The facility is equipped to launch satellites into low Earth orbit, polar orbit and geostationary transfer orbit. Also provided is infrastructure to launch sounding rockets for atmospheric research. For large-scale launch vehicles, two launch pads are provided to ensure redundancy and quick turnaround times.

Headquartered at the Spacecraft Control Centre in Bangalore, ISRO Telemetry, Tracking and Command Network (ISTRAC) provides mission support to low Earth orbit satellites as well as launch vehicle missions. It includes a network of ground stations at Bangalore, Lucknow, Sriharikota, Port Blair and Thiruvananthapuram in India; as well as stations in Mauritius; Brunei; Bear Lake, Russia; and Biak, Indonesia.

The ISRO is also responsible for the National Remote Sensing Centre (NRSC), which acquires, processes and disseminates remote sensing data from satellites and other aerial sensors, and provides decision support for disaster management. The NRSC data reception facility is at Shadnagar, near Hyderabad.

Other key installations include the Liquid Propulsion Systems Centre (LPSC) with locations in Bangalore and Mahendragiri. The LPSC is responsible for development of liquid stages for launch vehicles, including cryogenic stages. Meanwhile, the Space Application Centre (SAC) in Ahmedabad is responsible for sensors used in communications and remote sensing satellites.

SATELLITES

ISRO pursues two discrete satellite programs, which represent its major space efforts. Hardware for these systems is produced at the ISRO Satellite Centre (ISAC) in Bangalore. The two systems comprise the Indian National Satellites (INSAT) family for communications, broadcasting and meteorological services, and the Indian Remote Sensing (IRS) satellites for monitoring and managing natural resources.

The IRS constellation of remote sensing satellites began with the launch of IRS-1A in 1988. Today, it includes 11 satellites that provide imagery in a variety of spatial resolutions from better than 1m up to 500m. The most recent of these was an Indo-French project, the Satellite with ARGOS and ALTIKA (SARAL), intended for oceanographic studies. SARAL studies ocean circulation and sea surface elevation using two primary payloads built by the French National Space Agency CNES: ALTIKA, a Ka-band altimeter, and the ARGOS data collection system. The French payloads are carried on satellite bus built by ISRO.

The primary INSAT and IRS series of satellites have been complemented by a handful of meteorological satellites, including the latest geo-stationary INSAT-3D, and the Indian Regional Navigation Satellite System (IRNSS), a regional navigation system providing accurate position information within India and up to 1,500km from its borders.

LAUNCH VEHICLES

ISRO has developed the PSLV primarily for launching IRS satellites, and the Geosynchronous Satellite Launch Vehicle (GSLV) for launching INSAT payloads. Both types of launch vehicle are products of the Vikram Sarabhai Space Centre in Thiruvananthapuram.

Thanks to the PSLV series of rockets, which represent ISRO's first operational launch vehicles, the Indian space program is broadly self-reliant in terms of satellite launch vehicles. PSLV is capable of launching 1,600kg satellites into 620km sun-synchronous polar orbit and 1,050kg


The Payload Fairing is positioned on top of the stacked vehicle and its integrated payload

satellites into geosynchronous orbit. PSLV is a four-stage rocket using both solid and liquid propulsion systems. As of April 2014, the PSLV had achieved 25 successful flights in succession.

While the PSLV is primarily intended for launching IRS class satellites into polar orbits, the GSLV is primarily used for launching communications satellites into geosynchronous transfer orbit. GSLV Mk I and II can thus carry a 2,000-2,500kg INSAT payload. The three-stage GSLV rocket also uses a combination of solid and liquid motors. First tested in April 2001, the GSLV has since recorded six more launches, most recently on January 5, 2014, (carrying the 2,000kg GSAT-14 communications satellite).

In the future, ISRO will add the GSLV Mk III to its fleet. This will enable India to become fully self-reliant in launching heavier communications satellites, weighing 4,500-5,000kg. The vehicle is planned to put payloads into geosynchronous transfer orbit, low Earth orbit, polar, and intermediate circular orbits. The three-stage GSLV Mk III uses a combination of solid-propellant, re-startable liquid, and LOX/LH2 cryogenic stages.

With its promise to dramatically improve thrust and efficiency, the indigenous cryogenic upper stage of the GSLV Mk III is an important program for ISRO. Trials of this new technology have made use of a newly built high-altitude test facility (HAT) at LPSC in Mahendragiri. "A simulated high-altitude condition was created with high-capacity pumps in a vacuum chamber and the test proved successful," says M C Dathan, director of LPSC. The HAT facility was completed in a record time of one year. "This facility is a unique one in the country for testing cryogenic engines, simulating the high altitude conditions," notes Dathan. An initial sub-orbital flight of the GSLV Mk III, carrying an experimental crew module, was due to take place in July 2014.

Beyond conventional rocket launch vehicles, ISRO is also working on a Two Stage To Orbit (TSTO) fully reusable launch vehicle. As part of the technology demonstration phase, a winged Reusable Launch Vehicle Technology Demonstrator (RLV-TD) has been designed. This will test technologies including hypersonic flight, autonomous landing, powered cruise flight and hypersonic flight using air-breathing propulsion.

PLANETARY AND MANNED MISSIONS

On October 22, 2008, India launched Chandrayaan-1, its first mission to the Moon, from Sriharikota. The spacecraft orbited at a height of 100km from the lunar surface and conducted chemical, mineralogical and photo-geologic mapping. The spacecraft carried scientific equipment built in India, the USA, UK, Germany, Sweden and Bulgaria.

This is to be followed by Chandrayaan-2, which will complete a soft landing on the lunar surface. Chandrayaan-2 is configured as a two-module system comprising an orbiter craft (OC) and a lander craft (LC) carrying a lunar rover developed by ISRO. Launch is expected at the end of 2016 or the beginning of 2017.

ISRO has also embarked on a mission to Mars, using a craft that will complete an elliptical orbit of the planet. The Mars Orbiter mission was launched from Sriharikota on November 5, 2013, carrying five different scientific payloads. The craft is expected to enter orbit around Mars on September 24, 2014.

Most ambitiously, ISRO's human spaceflight program aims to carry a crew of two to low Earth orbit in a fully autonomous orbital vehicle and return them safely to a predefined destination on Earth. Currently, the organization is developing technologies required for critical subsystems, including a crew module, environmental control and life support system, and a crew escape system. ∎

Titov Main Test and Space Systems Control Centre

Coordinates

Latitude: 48.39
Longitude: 41.0
Elevation: 55m

Bearing the official title G S Titov Separate Command and Measurement Complex of the Main Test Centre for Space Systems Trials and Control, this organization falls under the control of Russia's Space Command. The latter organization is itself subordinate to Aerospace Defence Forces, and as well as the Titov Space Centre, Space Command includes the Main Centre for Missile Attack Warning headquartered at Timonovo, and the Main Space Intelligence Centre at Noginsk-9.

While the headquarters of the Titov Space Centre are located at Krasnoznamensk, around 40km southwest of Moscow, it also maintains subordinate units at locations throughout Russia, befitting its role as the primary Russian military and commercial satellite control center. Originally established in 1957 and known as Golitsino-2, the Titov Space Centre is responsible for collecting and analyzing all data gathered by Russia's spy satellites. As well as military satellites, however, the facility also serves as a control center for Russia's commercial satellite activity.

In its original role, the center was tasked with the command and control for the Soviet Union's first satellites. Until today, the military retains responsibility for tracking orbital systems, whether scientific, commercial or military. Since the 1970s, Golitsino-2 coordinated and managed the network of ground-based, sea-based and airborne control facilities across the Soviet Union. The center also contributed to the Soviet and Russian manned space programs, including space stations. This role continues with its work on behalf of the International Space Station.

NASA Armstrong Flight Research Center

Location: Edwards AFB, California, USA

Coordinates

Latitude: 34.95

Longitude: -117.88

Elevation: 700m

Image: Google Maps

A May ceremony formally rededicated and renamed the Neil A Armstrong Flight Research Center about 90 miles north of Los Angeles, California. Part of the Edwards Air Force Base complex, the former Hugh L Dryden Flight Research Center remains at the forefront of atmospheric flight science.

Armstrong's deputy director of programs, Joel Sitz, explains, "It's our breadth of flight resources and how we can apply them, coupled with some of the unique ground facilities we have here." The NASA Center made historic contributions with the X-15 hypersonic research aircraft, F-8 fighters with fly-by-wire flight controls and supercritical wings, and solar-powered aircraft. The current research fleet includes supersonic F-15s and F-18s, high-altitude ER-2s and the SOFIA (Stratospheric Observatory For Infrared Astronomy) Boeing 747. Among other unmanned aircraft at Armstrong, the X-56A Multi-Use Technology Testbed will explore active aeroelastic control technologies while the big RQ-4 Global Hawk flies earth science missions. "With our fleet of aircraft, we have the ability to do unique things with unique resources," summarizes Sitz.

SPACE RESEARCH

Armstrong research aircraft fly most of their carefully monitored missions on the Dryden Aeronautical Test Range, itself within the restricted airspace of Edwards Air Force Base. According to associate mission director for aeronautics Tom Horn, "Our telemetry, our communications, are all NASA-owned. We have the only research-quality tracking radar on the base. When the Air Force needs tracking, the Air Force hires us." Sitz adds, "We have a strong alliance with the Air Force Test Center now. We use their facilities, and they use ours."

Armstrong's researchers on the ground have the data-handling resources to track two major flight experiments simultaneously with telemetry, radar and high-definition video. "We have one operational control room with multiple telemetry receivers reconfigured day-by-day," says Horn. "Our support airplanes, our chase aircraft, are all configured so that we can put a videographer in the back seat and stream live video down from those airplanes. We're constantly upgrading our capabilities. One of the areas we're currently working on is virtual control room capabilities that will allow us to stream our communications over the internet to anyone who needs to join in our flight research."

Real research aircraft are backed by modular, quick-change simulators. According to Horn, "Our engineering simulators have very high-fidelity aircraft models operating in them, so engineers can use them in their analysis tools to understand our vehicles out at the edge of the envelope." He adds, "We have simulators for all our aircraft here, including the F-18s and F-15s. The engine that drives our sims is common among all of them." Sitz adds that the simulators are being networked into a live virtual construct. "It's a way to integrate simulated aircraft in flight with real aircraft in flight to better use unmanned air vehicles in the National Air Space."

JOINT JOBS

Armstrong Flight Research Center undertakes reimbursable and non-reimbursable research projects for NASA mission directorates, other government agencies and private industry partners under the Space Act. "If we are partners in whatever research, they will contribute and we will contribute," says Sitz. "If they provide an aircraft, we can provide the simulator of that aircraft collaboratively." In collaboration with the Air Force Research Laboratory, NASA Armstrong flies its Gulfstream III business jet with Adaptive Compliant Trailing Edge flaps to determine if the flexible, seamless controls can enhance aircraft efficiency and suppress airport noise. Under a reimbursable Space Act agreement, Sierra Nevada Corp. will return its Dream Chaser reusable space plane to Armstrong this fall for a second round of helicopter drop tests.

Separate agreements with the German Aerospace Center (DLR) and the National Research Council of Canada (NRC) sponsor ACCESS II (Alternative Fuel Effects on Contrails and Cruise Emissions) tests to study the atmospheric effects of alternative jet fuels. Armstrong DC-8 and HU-25 research aircraft will burn different fuel blends while the DLR Falcon 20-E5 and NRC CT-133 measure emissions and observe contrails.

The Armstrong Research and Engineering Directorate has six branches: aerodynamics and propulsion, aerostructures, dynamics and controls, flight instrumentation, flight systems, and systems engineering and integration. "They all contribute as necessary to the project teams that conduct the research," says Sitz. "Everyone has to wear different hats at different times." ∎

The HiMAT subscale research aircraft, seen here during a research flight in December 1980, demonstrated advanced fighter technologies that have been used in the development of many modern high-performance military aircraft

European Space Research and Technology Centre (ESTEC)

Location: Noorwijk, Netherlands

Coordinates
Latitude: 52.240
Longitude: 4.45
Elevation: 1.2m

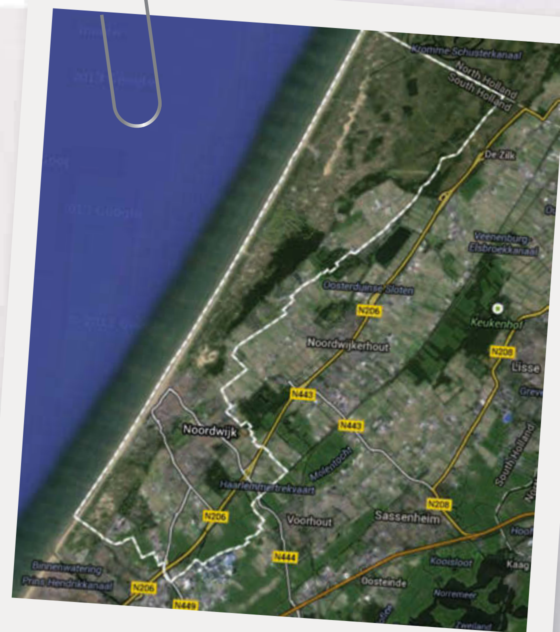


Image: Google Maps

The European Space Research and Technology Centre (ESTEC) is the European Space Agency's largest site and its technical heart. Founded in 1968, and based in the Dutch town of Noordwijk, it employs more than 2,500 staff. ESTEC is the incubator of the European space effort, where most ESA projects are born and guided through the various phases of development. ESTEC also hosts a suite of highly specialized technical laboratories necessary to support space technology development as well as the ESTEC Test Centre.

"The tests we carry out here are to guarantee that all space hardware will survive the launch and their subsequent life in space," says Gaetan Piret, head of the ESTEC testing division. "Almost all the satellites that ESA launches are tested to some degree at ESTEC. As the biggest spacecraft test center in Europe, we can accommodate the large satellites that smaller centers are unable to cope with. We are familiar with the needs of very complex missions and their verification processes. Most other centers have been designed to handle more classical telecommunication satellites. For us, each test is usually unique and complex."

THE FACILITIES

The test center includes all necessary testing facilities to verify the proper operation of spacecraft: shakers, acoustic chamber, mass properties measurement facilities, electromagnetic compatibility facilities and thermal vacuum chambers. Most of these facilities are unique not only in terms of size (largest acoustic facility, largest vacuum facilities, largest shaker facility) but also in their performance. As a result, its roster of past projects is highly impressive: BepiColombo, Herschel, SMOS, LISA PF, ATV, METOP, comet-chasing Rosetta, GOCE, Planck, Envisat, Integral, XMM, VEGA and Ariane5 to name a few.

"Each of these tests was special and challenging," says Piret. "For example, the intensity of the artificial sun available in the space simulator has to be increased five times to represent the environment that BepiColombo will encounter when it observes Mercury. The satellite needs to survive and operate under a solar flux higher than 10,000W/m². A new large vibration facility has been built to cope with the increasing size of space projects, such as Envisat and ATV. Special instrumentation has been developed to capture the small deformations that antennas can suffer when submitted to temperature extremes, and high-temperature measurement systems have been adapted to work under vacuum. Gravity compensation systems have been engineered to be able to test the large appendages on the ground."

ESTEC is currently involved in testing the Galileo navigation satellite constellation. The first four Galileo satellites are already in orbit, with 22 more being readied to join them over the next two years. All these satellites will undergo testing at ESTEC in advance of the launch. Two flight models have already passed all their tests and departed from ESTEC in May of this year. Number three satellite has already arrived and is being prepared. The center also recently completed the testing of the protective sunshield of the Solar Orbiter mission. Set for 2017, Solar Orbiter will observe our parent star from as close as 42 million kilometers away – a little more than a quarter of the distance to Earth.

The first two of a total 22 fully operational satellites

NEXT STAGE CHALLENGES

The challenge for the ESTEC Test Centre is to keep all these facilities ready for upcoming missions from ESA and to adapt them to the needs of future missions. Piret believes that one of its current challenges is the reduction of vibration generated inside satellites.

"Future satellites will need to be controlled to a much more precise degree than before," he says. "Satellite pointing accuracy and attitude stability will be very important for optical communication. Therefore it is essential to have the means to verify on the ground that there are no vibrations generated inside the satellites. To do this we need to create a measurement platform that is able to reduce the vibration injected by the satellite support and have state-of-the-art instrumentation to measure acceleration.

In order to be ready for this next generation of satellites, ESTEC is creating a micro-vibration measurement facility. It was started two years ago and is expected to be complete by the end of this year.

"What makes us different and special is the sheer scale of what it is we can offer," concludes Piret. "I hope we will be able to remain the unique test center we are in the future. I don't see why not."

Spaceport Africa

Location: Luigi Broglio Space Centre (BSC)

Coordinates
Latitude: -3.0
Longitude: 40.195
Elevation: 8.5m

Image: Google Maps

Off Kenya's western coast is perhaps the world's least known spaceport. The site was opened in the 1960s and saw the launch of 27 vehicles into outer space until flight operations 'paused' in 1988.

The Luigi Broglio Space Centre (BSC) is an Italian-owned spaceport near Malindi, Kenya, named after its founder and Italian space pioneer Luigi Broglio, who died in 2001. He is known as the father of Italian astronautics and is sometimes referred to as the 'Italian von Braun'. Broglio oversaw the building and sending into orbit around Earth of Italy's first satellite. Italy was the first country to set up an equatorial launch pad and to successfully launch a rocket from it.

The site began life in the 1960s through a partnership between the University of Rome La Sapienza's Aerospace Research Centre and the US National Aeronautics and Space Administration (NASA). It served as a spaceport and test facility for the launch of Italian and international satellites. The center comprises a main offshore launch site, dubbed the San Marco platform, as well as two secondary control platforms and a communications ground station on the African mainland.

In 2003, a legislative decree handed the Italian Space Agency (ASI) formal management responsibility for what was then the San Marco Equatorial Range. A year later the name was changed.

The San Marco launch platform is a former oil rig to the north of Cape Ras Ngomeni on the coastal sublittoral of Kenya, close to the equator, which makes it an energetically favorable location for rocket launches. Launches from the platform were controlled from the Santa Rita platform, a second former oil rig southeast of the San Marco platform, and the smaller Santa Rita II houses the facility's radar. A ground station on shore forms the center's primary telemetry site.

EQUATORIAL LAUNCH PLATFORM

The San Marco launch platform complex was in use from March 1964 to March 1988, with a total of 27 launches, including the Nike Apache, Nike Tomahawk, Arcas and Black Brant rockets. Low payload orbital launches were also made, using the solid-propellant Scout rocket (in its B, D and G subvariants). The first satellite specifically for x-ray astronomy, Uhuru, was launched from San Marco on a Scout B rocket on December 12, 1970.

The ground segment remains in use and continues to track NASA, European Space Agency and Italian satellites. However, the two platforms fell into disrepair during the 1990s. Recently, the ASI has conducted a feasibility study to reactivate it for the Russian START-1 rocket, but to date there have been no contracts signed.

The San Marco program was an Italian satellite launch program conducted between the early 1960s and the late 1980s. The project resulted in the launch of the first Italian-built satellite, San Marco 1, on December 15, 1964. With this launch Italy became the third country in the world to operate its own satellite, after the Soviet Union and the USA. San Marco was a collaboration between the Italian Space Research Commission (CRS) (a branch of the National Research Council), led by Luigi Broglio, Edoardo Amaldi and NASA. Five satellites were launched during the program, all using American Scout rockets. The first flew from Wallops Flight Facility in Virginia and the rest from the San Marco Equatorial Range. The last satellite, San Marco-D/L, launched on March 25, 1988.

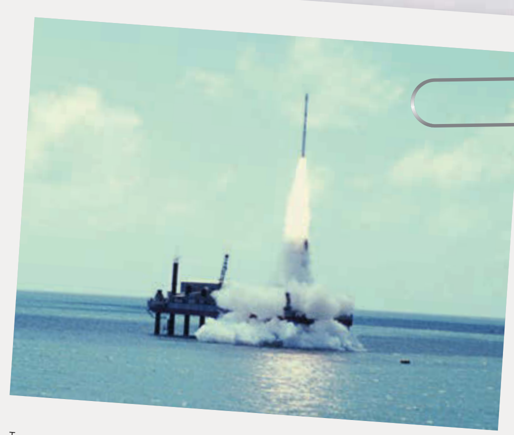
IDYLLIC LOCATION

The BSC's land site currently covers an area of 3.5ha on the coast of the Indian Ocean, 32km from Malindi. While the site is a property of the Republic of Kenya, the day-to-day management is entrusted to ASI. The main facility is a ground station of series of antennas, including:

- An S-band antenna, equipped with a 10m long parabola used for the ASI programs;
- An S/X/L band antenna, equipped with a 10m long parabola used for the control of launch vehicles (Arianespace, Titan) and to give test support to the first phases of commercial satellite flights (LEOP);
- A band-X antenna equipped with a 6m long parabola used to receive remote-sensing data (ERS2, Spot, Landsat).

Italy operates the BSC under an inter-governmental 15-year renewable agreement, which was renewed in 2010. This involves launch activities, data acquisition from satellites, remote sensing and training activities in Kenya and Italy.

In July 2013, a further agreement was reached on a collective bargaining agreement with local representatives of Kenyan workers. ASI's director general, Fabrizio Tuzi, commented that the conclusion of the negotiations for the renewal of the Kenyan BSC staff's contracts represented "a positive basis for the strengthening of activities carried out at the base, which sees in this period the installation of a new antenna that will increase the operational capabilities". ▮



Lancio Ariel 5 launched from Malindi space port (photo: ASI)

Stennis Space Center

Location: Mississippi, USA

Coordinates
Latitude: 30.362764
Longitude: -89.600226
Elevation: 7.66m

Image: Google Maps

Protected in the southwest corner of Mississippi, Stennis Space Center has long given NASA an expansive test site for propulsion hardware, ranging from small thrusters and turbopumps to very large thrust chambers, engines and fully assembled rocket stages burning a variety of fuels. "We have a large buffer zone, a 125-acre donut hole around here," explains Stennis director of engineering and test Randy Galloway. "You can't develop in that. You can't build in it. A lot of the centers built in the Apollo era have lost their ability to test large things because the local economy can't stand the noise."

The Stennis Engineering & Test Directorate manages, maintains and modernizes the multicell rocket test complexes. The Stennis A-1 test stand, for example, is being readied for the first hot-fire tests this summer of the huge RS-25 core engine of NASA's up-and-coming Space Launch System (SLS). The uprated SSME (Space Shuttle Main Engine) will generate 512,000 lb of thrust in a vacuum. "That's going to be the biggest thing we've tested since the MPTA [Main Propulsion Test Article] for the shuttle in 1989."

NASA Stennis fired SSMEs from 1975 to 2009. The MPTA simulated a shuttle stack with three engines in a flight-weight aft fuselage fed by an external tank. "That proved out a lot of the countdown procedures at KSC [Kennedy Space Center], and a lot of the operations were adequately proved out on our test stands," observes Galloway. Stennis test stands also fired all but one of the Saturn booster stages that launched Apollo missions.

The Space Shuttle main engine is being repurposed as the RS-25 core engine of the new Space Launch System

PROPULSION TESTS

The historic space center still has unique resources for propulsion testing in support of NASA and private-industry space programs. "The first thing is our workforce," says Galloway. "In the core disciplines of propellants and testing, most are civil servants. We augment them as we need to with contractors. Our technician workforce is very experienced, and they are all contractors."

Stennis test complexes are likewise unique. Galloway notes, "Most of our test stands are either active or have recently been active." In February 2014, NASA engineers used Test Stand E-3 for a series of tests of the HD4B-LT liquid oxygen and methane engine for the Morpheus vertical take-off and landing test vehicle. NASA, Orbital Sciences Corporation (OSC), Lockheed Martin and Aerojet Rocketdyne engineers conducted a hot-fire test of the AJ26 engine for the OSC Antares rocket on the E1 test stand in March 2014. According to Galloway, "E1 can go the gamut from components like a thrust chamber to a full-scale rocket like the AJ26."

ROCKET SIMULATION

Various combinations of Stennis facilities can test components, engines or complete stages. A turbopump or engine would be connected to test stand run-tanks. "We're essentially simulating the rest of the rocket," says Galloway. "We gather a lot more data than you can with an operational vehicle." A complete stage test includes vehicle fuel tanks. "We fill it up and do the same thing. When you have the full stage, you're generally not doing the kind of extreme testing you're doing with an engine. Most people don't want to put their full stage assets at risk."

Current US government emphasis on commercial launch developments has resulted in new customers for Stennis. Tests of the methane-fueled Raptor engine for the new Space X Heavy Falcon launch vehicle began in May 2014. Galloway says, "Generally speaking, industry gives us the test article and the interface requirements we have to meet to play well with the system." He adds, "Most of the time, they bring in a well-thought-out test plan and what kind of data they want. We produce a design for the test system that can meet those requirements. Then we provide the test procedures, execute the test and provide the data – in real time or in a combination of real time and fully processed data that you ship over the internet or on a disk."

Test data collection has evolved dramatically. "Back in the Apollo days we had a place called the Data Acquisition Building that was full of cables and reel-to-reel tape recorders." Tapes would be trucked under police guard to the massive NASA computer processing facility in Slidell, Louisiana. "Today, we can do everything they could do with the acquisition and processing in pretty much just a few racks." Each of the Stennis test stands now has its own data collection and processing capability. ∎

JAXA: Japan Aerospace Exploration Agency

Location: Tsukuba Space Center (TKSC), Japan

Coordinates
Latitude: 36.08349
Longitude: 140.077
Elevation: 31.4m

The Japanese Aerospace Exploration Agency (JAXA) controls a major, multifaceted space research, development and test program through multiple facilities. Kyoko Fukuda of JAXA's main public office revealed details of the test programs for Japan's burgeoning space industry.

Japan's interests in space and related technology are explored, promoted and protected by JAXA through facilities administratively grouped under the Space Transportation Mission Directorate, headquartered at the Tsukuba Space Center (TKSC).

Rocket engine research and test work is primarily tasked at the Noshiro Testing Center (NTC) and Kakuda Space Propulsion Center (KSPC). Operational since 1962, when it was formed in affiliation with the University of Tokyo's Institute of Space and Astronautical Science (ISAS), NTC ground tests rocket engines and other propulsion system components. Kakuda's lead role is research and development, primarily based on liquid-fueled rocket engines for domestically designed spacecraft.

Key infrastructure and development projects are underway at KSPC, including work to develop a reusable engine and an air-breathing combined-cycle engine for atmospheric use. The latter employs the facility's high-enthalpy shock tunnel, while a high-altitude test stand will accommodate rocket testing in what JAXA terms a 'quasi-space environment'.

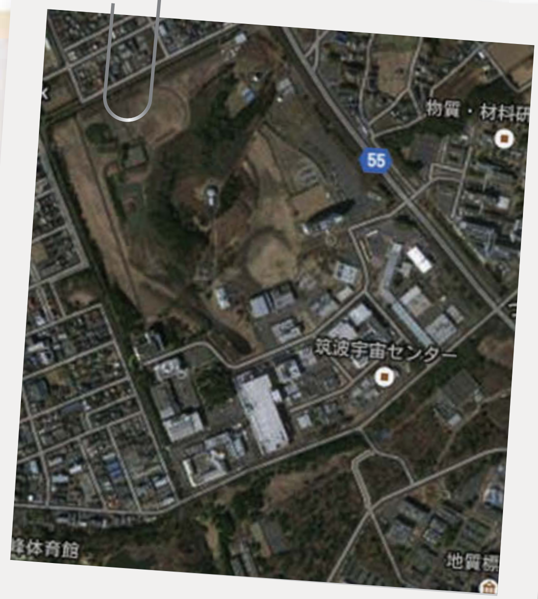
Research and development for space vehicles – launch rockets and satellites – occurs at the Tsukuba Space Center (TKSC), which also has an important test function, alongside its ability to control and track satellites. The center of Japanese astronaut training, TKSC also houses the human spaceflight Mission Directorate and research, development and test functions for the Institute of Space and Astronautical Science. A number of smaller sites across Japan house tracking and observation facilities, while the Sagamihara Campus combines the educational requirements of ISAS with a range of functions including test and, previously, the monitoring of Japan's Shuttle astronauts. JAXA has international offices in Houston and Washington, DC, USA; Paris, France; Moscow, Russia; and Bangkok, Thailand.

VEHICLE PROGRAMS

The Space Transportation Systems division manages vehicle launches from the Tanegashima and Uchinoura Space Centers. A number of key vehicles are the focus of JAXA's work, including the Epsilon, H-IIA and H-IIB launch vehicles and the H-II transfer vehicle (HTV), known as Kounotori.

Epsilon is an attempt to simplify space launches using a 24m-long solid-fuel rocket, testing and verifying technologies and procedures for a next-generation system that JAXA says will use a combination of autonomous checks and operator monitoring via the internet to make rocket launches 'just like daily events'. The Epsilon test program is proceeding after a successful maiden launch in September 2013.

The 53m-long H-IIA is Japan's primary launch vehicle, capable of placing a 4 metric ton payload into geosynchronous transfer orbit at an altitude of 36,000km. Using a liquid fuel first stage, H-IIA was developed from the H-II platform, but its simplified design and improved performance have, according to JAXA, halved launch costs compared with similar available systems. Mitsubishi Heavy Industries has held responsibility for launch services since flight 13, with JAXA taking overall control and managing safety. The 24th H-IIA launch placed the Advanced Land Observing Satellite-2 into orbit on May 24, 2014.



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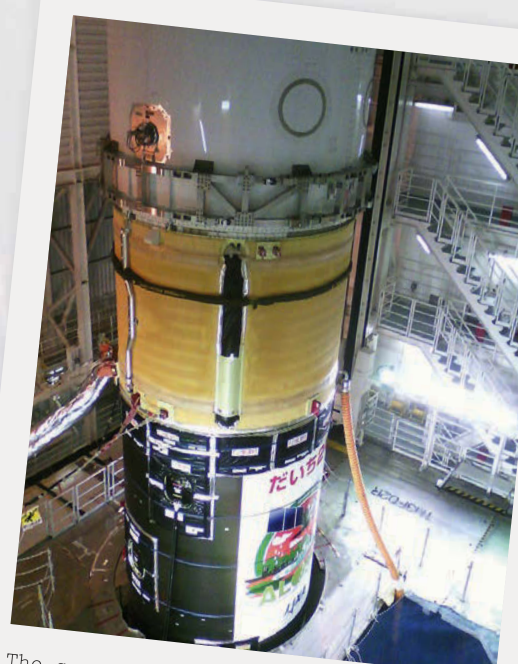


The second stage of H-IIA launch vehicle No.24 mating with the first stage

JAXA is in charge of launch safety management of the HIIA

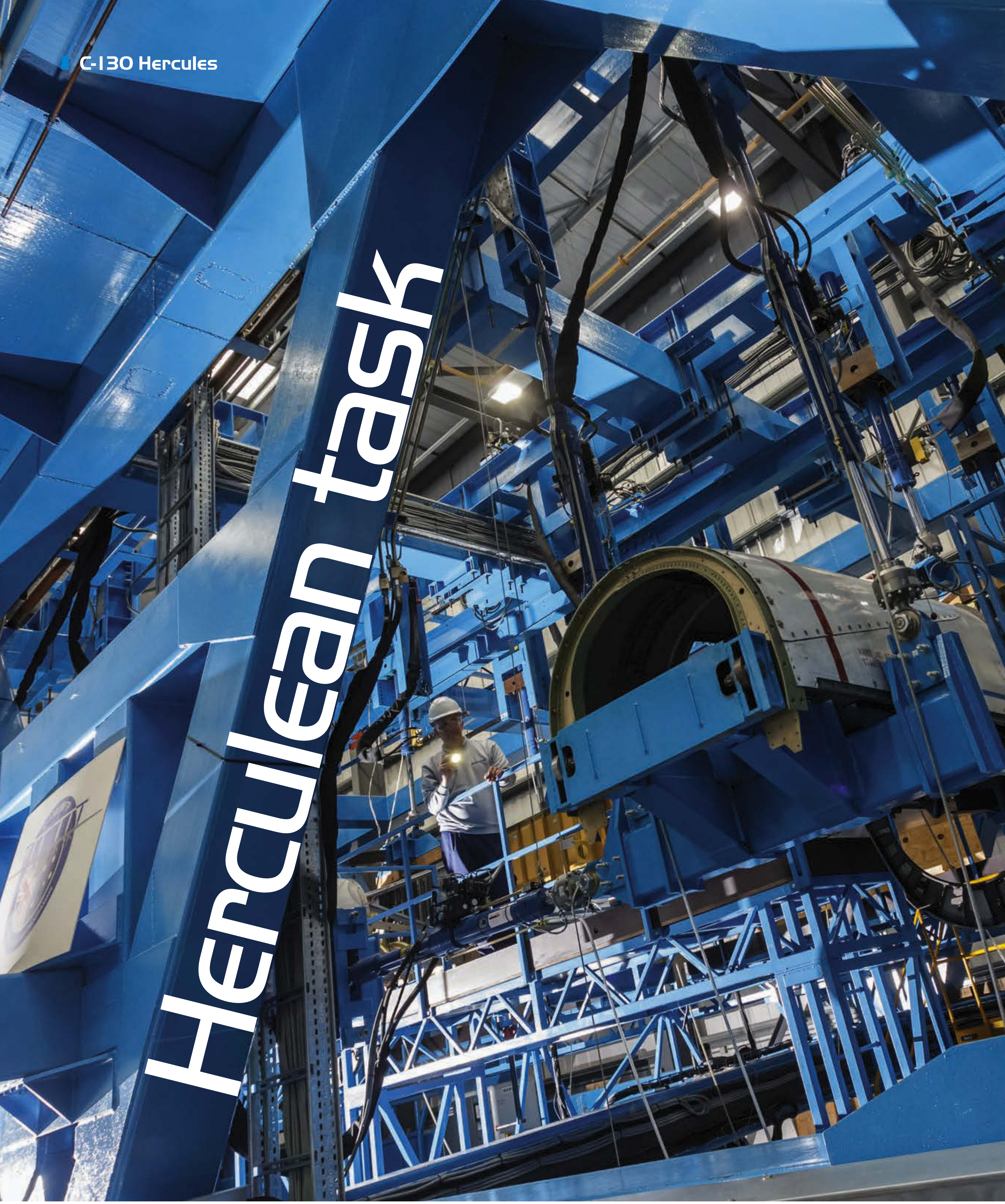
H-IIB builds on H-IIA to provide a more capable launch platform for the future, offering the potential for twin satellite launches, as well as carrying the Kounotori HTV into space. JAXA and Mitsubishi successfully launched H-IIB F4 from the Tanegashima Space Center on August 4, 2013, with the Kounotori 4 spacecraft separating from the rocket 14 minutes 59 seconds after lift-off.

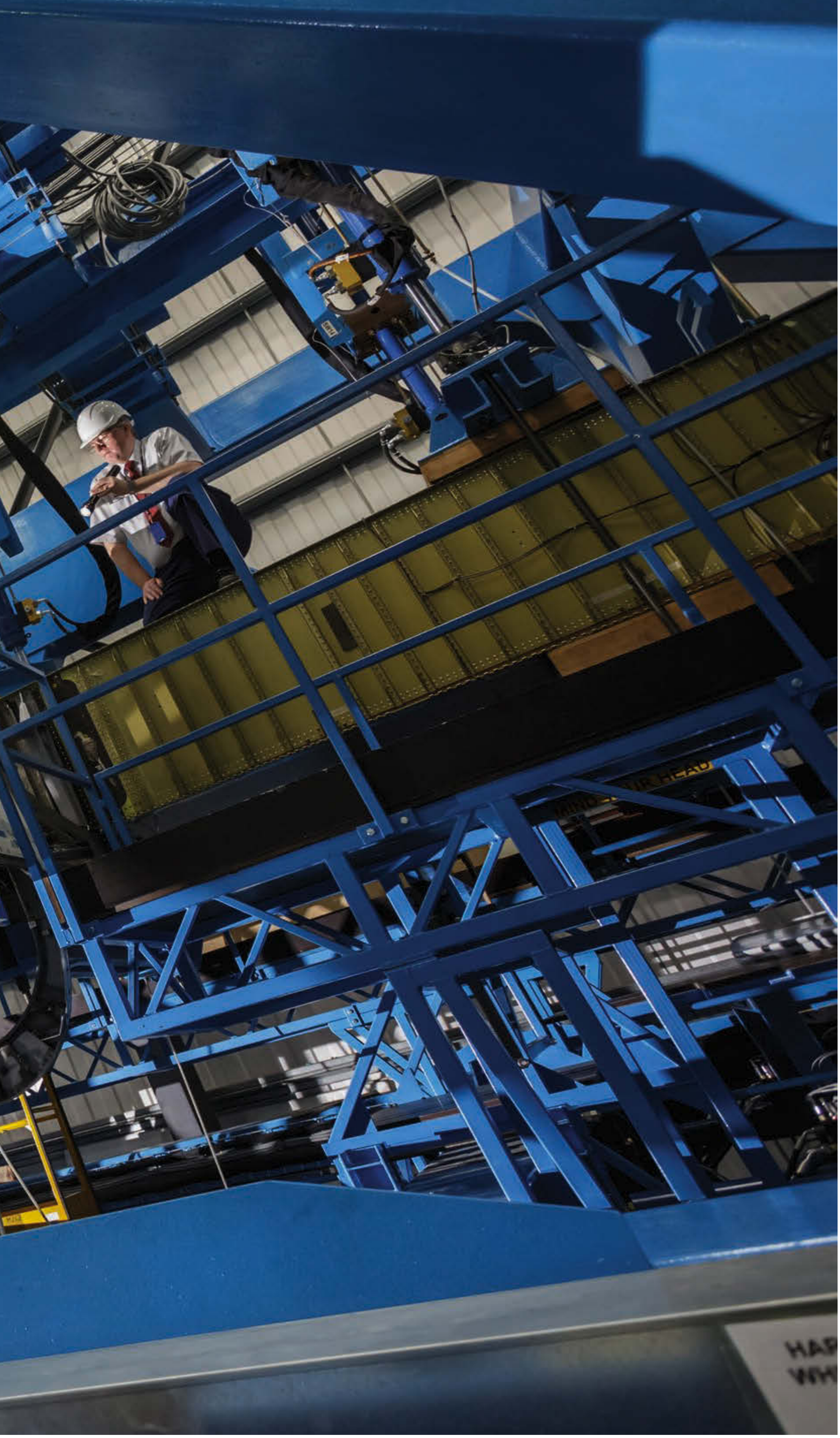
KOUNOTORI HTV

The Kounotori HTV is effectively an unmanned cargo module developed specifically to support the International Space Station (ISS), while H-IIB was initially created as its dedicated launch vehicle. It complements Russian and European Space Agency resupply craft, delivering essential supplies, including food and mission equipment, to the six ISS personnel. Kounotori benefits from experience gained in the research and engineering effort to develop Kibo (Hope), the Japanese Experiment Module that forms a section of the ISS.

Kounotori automatically docks with the ISS orbiting at around 400km, where cargo is offloaded and the craft reloaded with waste material. It separates from the station to be destroyed by kinetic heating as it re-enters Earth's atmosphere. Its 6 metric ton capacity, 10m length and 4.4m diameter, enable Kounotori to form the basis of research and testing for future transfer craft. JAXA is considering the possibility of an HTV-like vehicle delivering supplies to the moon and continues to collect data from Kounotori's operations to inform basic technologies for future projects, including manned space transport craft. ∎

Herculean task





The C-130 Hercules has been in service for almost 60 years and Marshall Aerospace has been associated with it for most of that time. The company continues to test the Hercules from its base in Cambridge, UK

BY PAUL E EDEN

Marshall Aerospace and Defence Group has been providing Lockheed C-130 Hercules modification and maintenance services for almost five decades. Well known as a Lockheed Martin-licensed Hercules MRO center, Marshall has supported Royal Air Force Hercules operations since the UK's first example arrived at the company's Cambridge base in 1966.

The work continues today, with RAF machines sharing hangar space with those from several other operators. Marshall's comprehensive engineering, fatigue and flight test capabilities are less obvious. A dedicated test hangar houses ongoing fatigue measuring work running simulated RAF flight profiles ahead of the fleet. The facility also has simulator capability and dedicated flight test engineers and pilots.

Among its C-130 'products', Marshall offers a cockpit upgrade (CUP) based on commercial off-the-shelf equipment and tailored to individual operator requirements. Mark Johnston, director of engineering, explains how the CUP was developed against a Dutch contract, combining the best available individual avionics items and integrating them into the cockpit. "We design the system to integrate into the aircraft and do considerable work to make sure the various systems will talk to each other, then use a rig to test the integration.

"This tests the architecture, but then we have to test the operational aspects. Because we have a flight test crew we can work with the customer and understand how they wish to operate the aircraft and the concept of operation can be clearly understood. It helps with equipment selection and

RIGHT: **The C-130 fuselage fatigue test rig in Marshall's test hangar**

once we have the configuration, we can put together cockpit working groups to get the HMI right."

Marshall pilots work with customer pilots on the HMI, using a cockpit simulator produced to support the Europrop TP400 Flying Test Bed program. Initial tests are very simple, using a dummy instrument panel and cardboard cut-outs representing equipment. Because the simulator retains standard yokes and other fittings, crews can immediately identify the most basic issues – yokes obscuring displays, for example.

Following the simulator experience, Johnston says that 3D models are produced for further test and analysis. The combination of testing on the rig, in the simulator and in a virtual 3D model ensures that the system architecture is working and the upgraded cockpit has been proved to meet customer requirements through testing by operational crews long before metal is cut.

FLIGHT TEST FACILITIES

Marshall has four test pilots from a wide variety of military backgrounds, their experience including air-to-air refuelling and low-level operations. Adding these pilots to its dedicated flight test engineers, and considering that its test crews and full engineering facilities are available at the Cambridge base, the capability displayed by Marshall is impressive.

During April 2014, Marshall Aerospace was presented with a Boeing Supplier of the Year Award for its fuel tank work on the P-8 Poseidon. Johnston notes that fuel-system testing is undertaken at Cambridge. In fact, when Marshall was modifying Lockheed TriStar airliners as inflight refueling tankers – work that naturally followed from its connections with Lockheed, the Hercules and the RAF – a complete 'iron bird' fuel rig was built to test the aircraft's tanks, refuel transfer system and other fuel-related equipment.

The dedicated test hangar currently houses a C-130K fuselage and C-130J wing fatigue test rigs. (The C-130K was the RAF's legacy Hercules model, retired in 2013.) Both are impressive pieces of engineering, the wing rig

MARSHALL'S TESTING LEGACY

The first Hercules for the RAF, XV177, was delivered direct to Marshall's at Cambridge on December 19, 1966. A similar pattern was followed for subsequent aircraft, all of which underwent detail design completion to RAF requirements before a pre-delivery flight test. An RAF crew tested XV177, but Marshall's personnel converted onto type to undertake future work.

Remarkably the C-130 had been designed for a limited service life sufficient for the decade or so that it was expected to remain on the frontline. It became quickly apparent the type was destined for a useful career far beyond the late 1960s, however, and fully aware that this would have wing fatigue implications, Lockheed developed a wing center-section replacement package.

Keen to understand the economics of replacing or reinforcing the center sections of the British Hercules fleet, the Ministry of Defence commissioned Marshall to build and operate a center wing test rig. Its simulation of RAF flight profiles revealed that replacement was the better option.

On April 15, 1982, Marshall was ordered to provide a Hercules inflight refueling probe installation with all possible haste. The first modified aircraft completed initial flight testing at Cambridge 14 days later and the capability became operational on May 5. Marshall then turned its attention to a Hercules tanker conversion, performing extensive ground tests, as well as the majority of the design and engineering work, during May.

Before the tanker took its first flight on June 8, dump, bowser, emergency disconnect and surge pressure tests were completed, and the drogue was successfully deployed inflight on that initial sortie. Flight testing continued with the cabin pressurized on June 10, before the aircraft was passed to the military for further work. Back at Marshall for refueling equipment issues to be overcome, the Hercules transferred fuel to a Blackburn Buccaneer jet on June 21 before returning to military testing. It was in service by July 15.

SNOOPY

In 1971, Marshall modified Hercules XV208 for weather reconnaissance work. The aircraft gained a long instrumented test boom on its nose and podded weather radar, as well as the nickname 'Snoopy'. Careful trials were undertaken, since the requirement was for minimal changes in performance.

30	vendors supplied equipment for the Dutch CUP, all of it integrated and tested at Marshall's site in Cambridge, UK
2	Hercules fatigue test rigs are operational in Marshall's test hangar
4	Hercules test pilots are on Marshall's staff
70	The number of C-130s lost in the Vietnam conflict, although it has a low accident rate
164,000	C-130J maximum take-off weight in pounds

OEM TESTING TODAY

Lockheed Martin's continuing Hercules test effort covers not only pre-delivery checks on C-130Js emerging from the production line, but also J-model and legacy work in support of customer requirements. Pre-delivery air testing is scheduled for a single flight per aircraft and essentially consists of regular functional test-flight activity.

Testing is an integral part of upgrade work and is completed at Lockheed Martin facilities, or certified service or heavy maintenance centers. The company has C-130J integrated systems test labs and an engineering flight simulator at its Marietta, Georgia, site and also deploys aircraft globally as test schedules require.

holds a full-span Hercules wing set, minus engines, which can be rotated vertically so that its leading edge is aligned roughly parallel with the hangar floor.

The RAF needs to understand the effect that its flying regime, which might differ from that for which the Hercules was designed, has on the aircraft. Operational load measurements on in-service aircraft provide data that is mapped onto the fatigue specimens in the rigs. This data is used to generate test procedures that accelerate real-world operations in the hangar. "It helps us determine what's going to go wrong in the future, what repair schemes are needed and what parts might need to be replaced early. It allows forward planning and for a potential out-of-phase problem to be scheduled into maintenance," Johnston says.

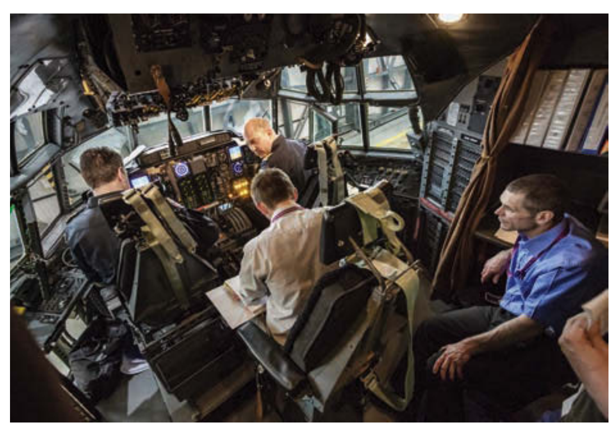
The fuselage rig has been running for approximately 10 years, as the first test function to occupy the dedicated hangar. C-130K tip-to-tip wing testing had been accommodated elsewhere on site, but the J-model wing rig is conveniently located just a few meters from the fuselage rig.

Alongside its ground and air test facilities, Marshall has extensive experience gained through the modification of an ex-RAF Hercules as a flight testbed for the Europrop TP400 and execution of the subsequent engine test program. It also offers test support to customers working through development, verification and certification programs on the C-130 and a variety of other civil and military aircraft platforms.

Almost 50 years since the first Hercules arrived at Cambridge, the type remains at the heart of Marshall's military operations. The Hercules has in many ways driven – and in others benefited from – the company's expertise, ranging across single component testing to full system analysis. The future is likely to see similar test work come to Cambridge, most likely on the Hercules, where 10 air forces are currently served and the company is looking at a French contract, but also on other platforms. ∎

Paul E Eden is a UK-based freelance writer for Aerospace Testing International

LEFT: The TP400 Flying Test Bed mounted the subject engine inboard on its port wing



BELOW: Marshall originally created its C-130 cockpit simulator for the TP400 program

Target acquired

An integrated test team evaluates the conversion that turns the familiar F-16 fighter into a full-scale aerial target for training and testing – the QF-16

BY FRANK COLUCCI

As a testing and training opponent, the QF-16 Full Scale Aerial Target (FSAT) is expected to be more agile, less detectable and easier to maintain than the unmanned QF-4 Phantoms that get shot down today.

Boeing Global Services & Support (GS&S) integrated and tested the unmanned control system that enabled the QF-16 to fly without a pilot for the first time in September 2013. Chief engineer Paul Cejas says, "This is the first fly-by-wire airplane that's been converted this way. This is a small airplane, so getting all the extra wiring in there was a big challenge. Our goal was to not disrupt and to remove as few systems as possible to retain full capability."

Tests of the full QF-16 capability culminate in live-fire engagements this year at Holloman Air Force Base (AFB), New Mexico, and Tyndall AFB, Florida. The scope of the test program was developed by an integrated test team (ITT) that included the QF-16 Program Office, the 96th Test Wing, and Detachment 2 of the US Air Force Operational Test and Evaluation Center, all at Eglin AFB. The ITT also included the FSAT end user 53rd Weapons Evaluation Group at Tyndall, and White Sands Missile Range in New Mexico. QF-16 Initial Operational Capability at Tyndall AFB is expected in 2016, and production plans call for 210 QF-16s to be converted through FY2022. The Air Force QF-16 program office resides within the aerial targets branch within the test and training division of the Armament Directorate at Eglin AFB, Florida. The branch has managed the QF-4 target program since the early 1990s for fighter aircrew training, research, development and test projects. A QF-4E, for example, was one of two test targets killed by the Medium Extended Air Defense System at White Sands in November 2013.

The optionally manned Phantoms typically fly several missions before their demise. However, the Air Force counted just 60 of 314 QF-4 conversions remaining late last year. According to Paul Garvey, materiel leader, aerial targets at the Air Force Armament Directorate, "The QF-16 is much more maneuverable than the QF-4, and is capable of

pre-programmed maneuvers such as high-g turns, barrel rolls, split-s, etc. This provides the warfighter with an enhanced ability to respond and react to new threats and tactics. Additionally, the QF-16 will have a lower radar cross section (RCS) than the QF-4, which will provide a more realistic RCS for US fighter aircraft in test scenarios. Finally, the QF-4 is becoming more difficult to sustain. The QF-16 will be easier to maintain and generate sorties to support warfighter test efforts."

Like the QF-4, the QF-16 will fly either manned or unmanned. NULLO (not under live local operation) flights launched from Tyndall AFB are routed over the Gulf of Mexico under the Gulf Range Drone Control System (GRDCS). The telemetry/command system tracks and controls the FSAT to a distance of 120 nautical miles. At Holloman AFB, unmanned fighters work with the adjacent US Army White Sands Integrated Target System (WITS). Ground control stations, antennas, command and control architecture, and other QF-4 infrastructure at both locations will support the QF-16.

TESTING PIECES

Boeing GS&S headquartered in St Louis, Missouri received a pre-engineering and manufacturing development (pre-EMD) contract for the QF-16 in March 2010. As the prime contractor, Boeing maintains six test aircraft, performs simulation support, and qualifies QF-16 software in concert with suppliers. The company is responsible for the qualification testing of all systems, authors all flight test cards for developmental test and evaluation (DT&E), and performs data analysis of all flight test events. Additionally, Boeing provides QF-16 drone controllers and pilots for the DT&E flight test program.

Equipment installation on the six EMD test aircraft was performed by Boeing Global Maintenance, Modifications and Upgrades at Cecil Field, Florida. In addition, Boeing GS&S also drew on rapid prototyping expertise from Boeing Research and Technology. X-ray backscatter scanning provided a clear picture of the integration space inside the compact airframe. The company also

MAIN: A pilotless QF-16 FSAT from the 82nd Aerial Targets Squadron flies over the Gulf of Mexico on its first unmanned flight in September 2013. Boeing Global Services and Support integrated and tested the QF-16 systems

US AIR FORCE

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LEFT: An F-16 explodes during tests of the QF-16 Flight Termination System in 2010. The test demonstrated that the FTS design could terminate the flight of a QF-16 immediately with a controlled debris footprint

integrated near-miss scoring, smoke-generating visual augmentation, and command flight termination systems into the new FSAT.

Subsequent hardware-in-the-loop testing at the BAE Systems Integration Laboratory (SIL) in Endicott, New York, tried the new QF-16 autopilot and computer with the modified transponder/vehicle interface (TVI) from Kratos Advanced Drones and Target Systems and other equipment. Corin Beck, BAE Systems fixed wing control solutions product line director, explains, "The SIL was used for the software qualification testing and has a remote control workstation rather than a regular F-16 cockpit."

SIL displays show flight instruments, the outside world, and the aircraft in simulated flight with moving control surfaces. "That was the first time we integrated hardware with software in the integrated system," explains Cejas. Details of the QF-16 integration remain proprietary. "It's all done electronically by the fly-by-wire system except for the throttle. For that we replace the existing throttle with an auto throttle with actuators." He adds, "These is no intrusion in the cockpit. Full manned capability is maintained and we keep all the F-16 maneuverability."

Boeing translated the QF-16 system performance specification into a requirements verification matrix, a test and evaluation program plan, test information sheets, test plans and procedures, and individual test cards. The EMD aircraft underwent hangar and ramp system verification tests, functional check flights, and GRDCS-controlled flights. QF-16s flew over 100 test sorties during pre-EMD risk reduction at Cecil Field. During the EMD portion of the test program at Tyndall AFB, the new FSAT flew approximately 80 test sorties.

Government engineers meanwhile took a basic F-16 flight control computer and aircraft simulation and plugged it into the GRDCS architecture to simulate the new FSAT. They developed the guidance, navigation and control systems to track and control the unmanned fighter and adapted the command landing algorithm from the QF-4 to the QF-16, where the Phantom snags an arresting cable, the QF-16 flares, lands and brakes. Initial GRDCS up-and-away flights checked flight control modes, pre-programmed maneuvers, loss of carrier-signal recovery routines, and take-off abort/automatic take-offs and landings.

EMD testing included two each of the F-16A Block 15 and F-16C Block 25 configurations with Pratt & Whitney F100 engines and two F-16C Block 30 aircraft with General Electric F110 propulsion. The retired fighters pulled from desert storage by the 309th Aerospace Maintenance and Regeneration Group (AMARG) underwent structural and corrosion inspections and received new engines.

Recertified for flight (the F-16A for 200 hours, and the F-16C for 300 hours), each unmodified aircraft was ferried to Boeing. "We take it, remove the gun and other items, and install our avionics packages at Cecil Field," explains Cejas. "The brains of it go into the ammo bay. We remove the ammo drum, the gun and the gun loader." Two redundant TVI boxes fit in the main QF-16 avionics bay.

9	The *g*-force the aerial target is now capable of maintaining
40,000	The height in feet achieved on first flight in September 2013
15	The number of years the converted F-16 had been retired before first flight
6	The number of months it takes to train an existing pilot to become a controller of the target drone
98	The total number of F-16s intended to be converted

NEXT STEP LOCATION

QF-16 (DT&E) and integrated testing (IT) at Tyndall AFB stretched from December 2012 through September 2013, and culminated in the first successful unmanned QF-16 flight for the program on September 19, 2013. Once DT/IT at Tyndall AFB was complete, all six QF-16 test aircraft were ferried to Holloman AFB in December 2013. Detachment 1 of the 82nd ATRS has continued DT/IT at Holloman AFB through until April 2014.

Subsequent operational test and evaluation (OT&E) will ensure that the QF-16 is effective in its operational environment. OT&E is performed by the 53rd WEG without the involvement of the QF-16 Program Office or the 96th Test Wing. DT and OT&E culminate in full military flight release and a milestone C decision for low-rate initial production. According to the QF-16 program office, the first regenerated F-16 of Production Lot 1 flew its functional check flight in January 2014. QF-16 production conversions begin in September 2014.

US AIR FORCE

US AIR FORCE

COMBAT ARCHER

It is expected that QF-4 missions will be phased out in 2015 and their pilots to be trained to transition to QF-16s immediately afterward. The unit at Holloman AFB will continue to fly QF-4s until 2017.

The 53rd WEG is responsible for conducting the Air Force's air-to-air weapons system evaluation program, known as Combat Archer, and the air-to-ground version, known as Combat Hammer. For future Combat Archer exercises, the 82nd will use the QF-16 in full-scale aerial target role along with its BQM-167 in a subscale aerial target role.

An explosive flight termination system is distributed in smaller QF-16 equipment bays. The 780th Test Squadron blew up an F-16 hulk on the ground at Eglin AFB in August 2010 to validate the damage done by the termination charge with slow-motion video and subsequent inspection. "It's obviously a fairly pricey test to conduct. You only do it once," observes Cejas. "There was a lot of analysis up-front. We had to predict probability of kill, if you will."

With QF-16 systems installed, Boeing engineers put their test jet on jacks at Cecil Field for systems verification testing with a portable ground control station. "We have a test set that drives the airplane," says Cejas. "We can simulate commands to the jet through the flight control computer like the ground station would do." Commands dropped the landing gear and moved flaps and control surfaces to scale the control response. Boeing led the contractor testing with a pilot in the cockpit. "With the pilot there, you can always take over if something happens."

TESTING TEAM

The first QF-16 manned flight test at Cecil Field in May 2012 used a mobile GRDCS trailer and portable datalink towers from the 96th Range Control Squadron. The Kratos TVI modified from that in the QF-4 telemeters 126 QF-16 parameters to the ground. Cejas explains, "Obviously, since we've got the ability to remote-control fly the aircraft, you're down-linking a lot of parameters, the aircraft systems, to the ground control station. That was our primary source of data and will be in the production jet." Boeing engineers also installed an AMPEX flight data recorder to collect over 2,600 data points. "We were recording everything that's on our databus. If we had any issues, we could dig into the flight control capability and do whatever was needed. That won't be in the jet for production."

An ITT mixed Air Force and Boeing resources for DT&E. Boeing provided QF-16 drone controllers and pilots, maintained the six test aircraft, provided simulation support, and qualified QF-16 software. The Air Force program office assigned the test manager and additional test and engineering expertise to execute and monitor the program. The 96th TW at Eglin provided the test range and approved the test cards to ensure safety requirements were met. The 53rd WEG provided pilots and controllers to the test team.

An FAA Certificate of Authority permitted unmanned flights only in segregated airspace off the Gulf coast. "We did normal envelope expansion testing and then worked our way up through altitude, supersonic speed, different maneuvering, all the way to 9g." A similar unmanned clearance will be issued for Holloman AFB and the adjacent White Sands Missile Range, where the first live-fire test occurred in the first quarter of 2014.

According to Garvey, "During DT&E, all aspects of the QF-16 program are tested and evaluated to ensure they comply with USAF performance specifications. During early DT&E, test points are evaluated, and as deficiencies are found they are addressed and corrected. During the final phase of DT&E, performance is evaluated to ensure that the QF-16 meets or exceeds required the performance specification. The scope of the DT&E test program is formally documented in the test and evaluation masterplan (TEMP), signed by all test organizations and program stakeholders. Once the program has completed DT&E, it is evaluated for entry into operational test and evaluation (OT&E)."

Garvey explains, "The purpose of OT&E is to ensure that the QF-16 performs as per USAF requirements in its operational environment. This involves test by the 53rd WEG without any involvement from the QF-16 Program Office or the 96th TW, and is intended to evaluate the system meets warfighter suitability and effectiveness requirements, and ultimately provides a threat-representative 4th generation aerial target that meets warfighter needs. The scope of the OT&E test program is formally documented in the AFOTEC Initial Operations Test and Evaluation (IOT&E) Test Plan."

The Air Force expects to wrap up QF-4 missions at Tyndall AFB in 2015. Holloman AFB will continue to fly QF-4s until fiscal year 2017. ∎

ABOVE: The first QF-16 arrives at Tyndall AFB in November 2012, escorted by a QF-4. The new FSAT will provide a 4th-generation fighter threat to challenge fighter pilots and air defenders

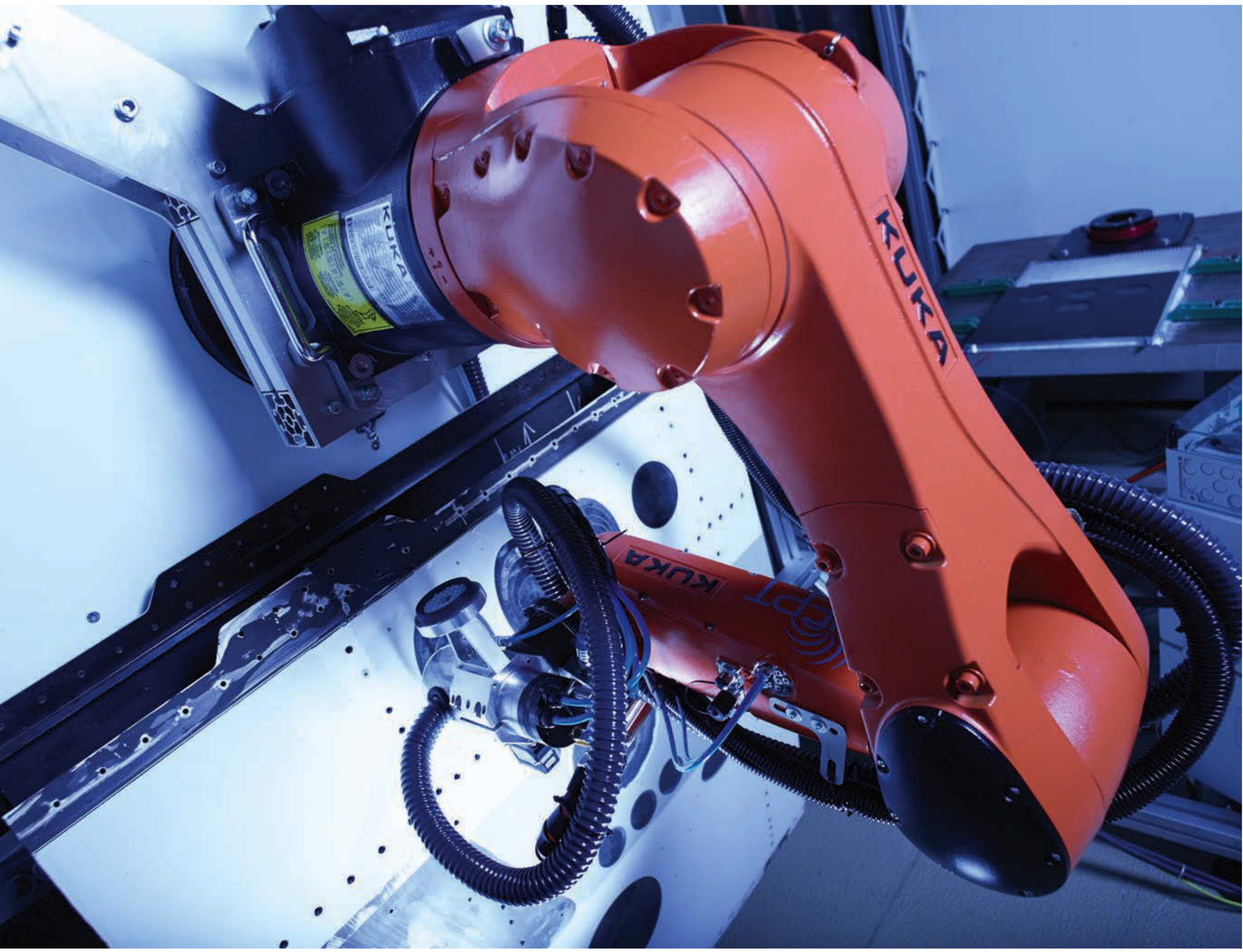
ABOVE LEFT: The QF-16 will be controlled in unmanned flight by the same Gulf Range Drone Control System as at Tyndall AFB. Here, a development console at Eglin AFB enables GRDCS engineers to adapt the telemetry and control system to the new FSAT

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

On a wing and a CAIRE

A revolutionary robot-based CFRP material repair procedure is now ready for mobile deployment

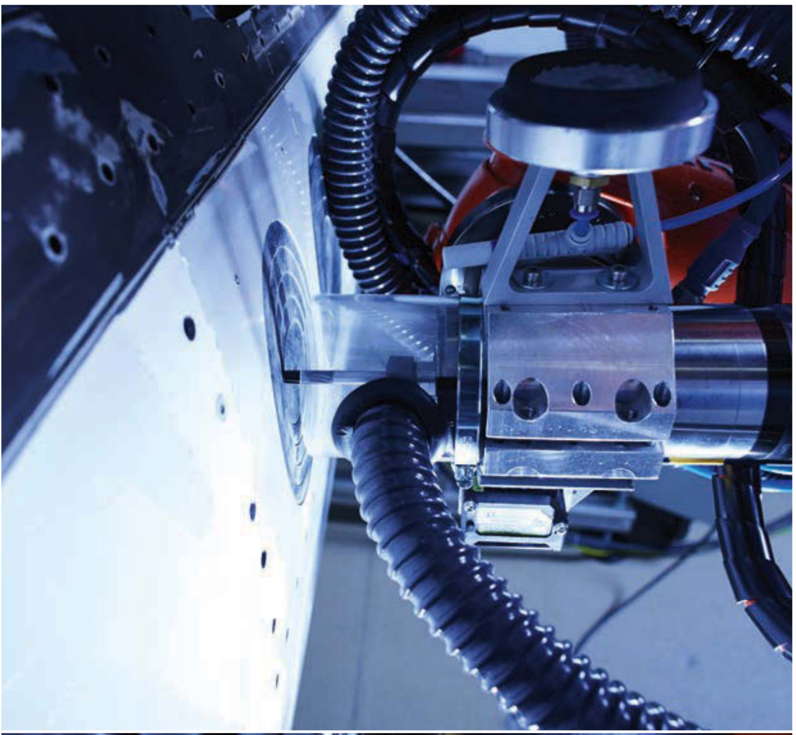
BY SUSI DEBUS



FAR LEFT: A mobile robot is placed on a stand attached to the CFRP component with suction cups

BELOW: After the damage has been scanned and the surface modeled, the form of the scarfing and the milling path are calculated

BOTTOM: A special software is needed to recognize free-form 3D surfaces



Over recent years, carbon fiber reinforced polymers (CFRPs) have evolved into an essential material in a large number of modern structural applications. Corrosion and fatigue are virtually unknown for CFRPs, making the materials ideal for building cars, ships, wind turbines – and aircraft.

The positive characteristics of the materials, combined with their low weight, make modern CFRPs almost indispensable for the demanding aviation industry. Thanks to CFRPs, fuel consumption and the emission of pollutants will continue to drop dramatically with the next generation of aircraft and beyond. Already fuselage and wing structures in the latest generation of civilian wide-body aircraft consist mostly of high-performance composite fiber materials.

The increased use of these high-tech materials, however, also demands the simultaneous development and application of highly efficient diagnostic and repair processes. This is essential if CFRPs are to contribute to cost reductions in civil aviation. "We have to develop completely new repair methods if we are to exploit the impressive potential of these materials," says Jan Popp, project manager and engineer at Lufthansa Technik AG.

RAPID REPAIR

As part of a specific research project called Rapid Repair, initiated in January 2009 and concluded in April 2012, Lufthansa Technik and several network partners succeeded in developing a complete process chain for the rapid, automated and reproducible repair of CFRP materials.

The Rapid Repair system is now in use on large surface areas with monolithic and sandwich structures, the same as currently found on fuselage and wing structures.

Until now, damage to these skin surfaces has meant intensive diagnostics and complex repair work in a maintenance shop or similar environments at airports.

The Rapid Repair procedure kicks in as soon as damage to a CFRP component has been identified and the component has been fully cleaned. Initially, the outer surface and the contour of the affected component are scanned and modeled using structured light projection. Every damaged component requires a complete, individual surface and contour scan, because as a rule no two damage occurrences are the same. The scanning and modeling of the component is precise to a hundredth of a millimeter. Software was specially developed for Rapid Repair to make it possible to create a scarfing with bespoke contours for the damaged surface. A computer calculates the milling paths in the material for optimal preparation and tailoring of gluing surfaces.

A special milling robot is then used. It has a working zone of around $3m^3$, allowing it to be deployed even on particularly large fuselage and wing elements. It is in a separate milling room in the workshops and is controlled from an adjacent room to isolate and safely extract the dust that results from the milling process. After the milling, the new CFRP component is scanned again to determine the quality of the scarfing. The existing scarfing data and the structured light scan are superimposed, making it easier to identify any deviations. In addition, the data acquired in this way is used in the development of new repair tools.

ROBOTIC PROCEDURE

With the help of a ply cutter, similar to a textile guillotine, the precut fittings

> **"SPECIALLY DEVELOPED SOFTWARE ENABLES THE MOBILE ROBOT TO PROCESS SURFACES UP TO 1,000 x 1,000mm IN SIZE"**

for the composite layers are produced and applied to the component to be repaired. The layers have a 100% accurate fit. Finally, the individual layers are glued together with the primary structure and then cured in an autoclave. As the majority of the Rapid Repair process is performed by robots, the procedure was initially only possible in stationary installations.

CAIRE

The goal of Lufthansa Technik's current follow-up project, CAIRE (Composite Adaptable Inspection and Repair), is a repair procedure that is fully independent of a location, feasible even in places without infrastructure comparable to that of a maintenance shop. For it is only when airliners can be repaired anywhere in the world, and quickly, that airline operators have a guarantee that those aircraft are financially viable.

CAIRE has further enhanced and extended the original stationary milling robot for mobile repairs. "In the laboratory, the mobile robot already works faultlessly," Popp explains. "Only smaller parts can be repaired, though. The task now is to develop a successor model for mobile deployment, capable of repairing large areas of damage on the fuselage. We want to develop and build the machine by summer 2014."

Building on the latest monitoring of Rapid Repair, and funded by the German Federal Ministry of Economics and Technology (BMWi), a mobile robot is currently being developed, equipped with the software needed to recognize free-form 3D surfaces. For mounting, the robot is placed on a stand attached to the CFRP component with suction cups. Specially developed software enables the mobile robot to process surfaces up to 1,000 x 1,000mm in size, along with thick CFRP structures such as wing connection zones. After the damage has been scanned and the surface modeled, the form of the scarfing and the milling path are calculated. The robot then first grinds out the damaged material, after which the precut fitting of the repair layers is produced. Finally, the new part is manually inserted, glued and cured in the 3D mounting surface created by the robot.

The new robot enables mobile teams to diagnose and repair large areas of fuselage and wing damage 'on wing'. Repairs that were inconceivable just a short time ago are now possible. With the help of CAIRE, pure gluing repairs to critical high-performance composite fiber structures can now be made certifiable.

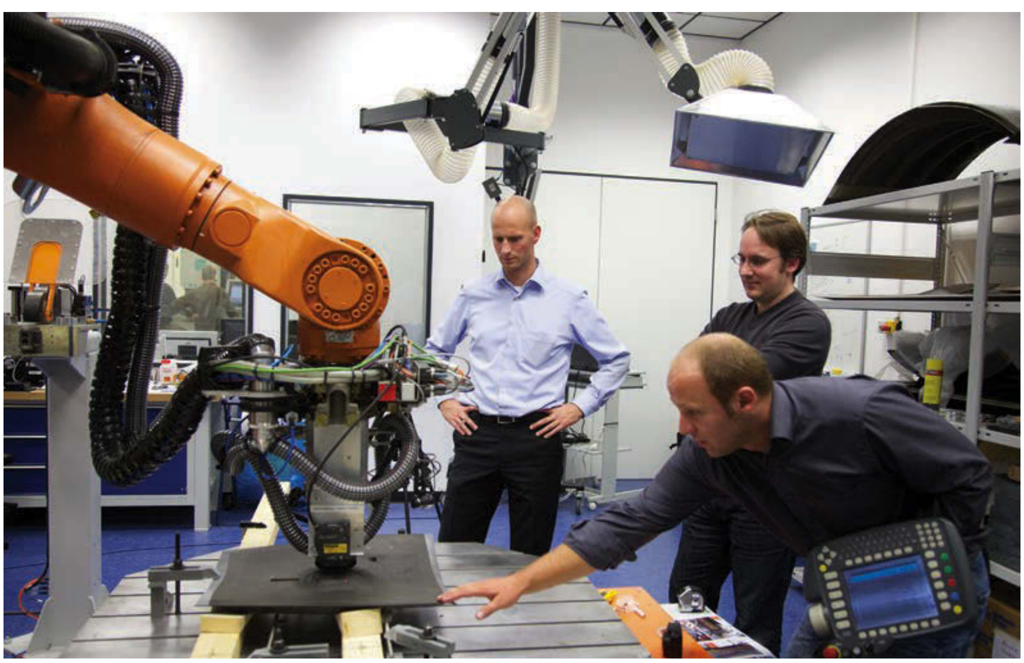
By avoiding flights to a maintenance base and by virtue of shorter ground times and the minimal transport times of individual components, automated repair away from maintenance bases can result in great cost reductions. The new procedure has already attracted a lot of attention in the aviation industry, and the major aircraft manufacturers are now showing interest. The impressive potential of composite fiber materials can come into its own on such modern passenger aircraft as the Airbus A350 and Boeing 787, with up to 80% of the fuselage and wing structures made using these materials.

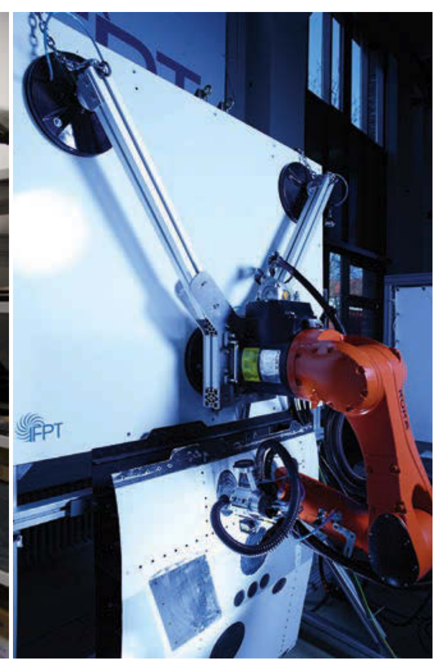
"Our robots don't only save time and money," explains Popp. "There is a lot more at stake. Mobile repair procedures mean that the deployment of CFRP airliners is finally economically feasible." Technology is now in place to deal with the inspectioin of complex CFRP. ▮

Susi Debus is from Lufthansa Technik and works as the company's editor

CARBON COOPERATION

From January 2009 to April 2012, Lufthansa Technik AG has been working with five cooperation partners (iSAM AG, Cassidian, GOM – Gesellschaft für Optische Messtechnik mbH, Electro Optical Systems (EOS) and Eurocopter) on the development of a generally applicable process chain for the rapid, automatable and reproducible repair of high-performance fiber composite materials.





30,000 HOURS AND COUNTING

Air France Industries KLM Engineering and Maintenance finds a low-cost solution for stringent FADEC overhaul requirements

To overhaul or to not overhaul. That was the question facing Air France Industries KLM Engineering and Maintenance as the engine control units of its Boeing 737 Next Generation fleet neared the 30,000 flight hour mark. Outsourcing the overhaul of these units would mean great expense, long turnaround times and loss of revenue. But AFI KLM E&M didn't have equipment that would allow it to meet the ECU vendor's stringent testing requirements.

Fortunately, through thorough investigation and some clever engineering, AFI KLM E&M discovered a low-cost solution that would enable it to do the overhaul itself.

A LETTER FROM THE MANUFACTURER

As the first of KLM's Boeing 737 NG aircraft approached 30,000 hours of flight time, AFI KLM E&M looked into the overhaul of the engines and ECUs. What it found was surprising. A service information letter from the ECU vendor, FADEC International, laid out requirements for a 30,000-hour overhaul and recertification. AFI KLM E&M found that it would have to perform a complete wiring integrity check on the more than 2,000 pins of the unit's front and back panels.

The magnitude of the circuit connections and measurements involved was unlike anything AFI KLM E&M had done before. It needed some sort of automated system, but had nothing of the kind at hand.

"We really didn't have anything capable of doing that," says Zafar Haji, a software development engineer in KLM E&M's avionics department. "You have a lot of solutions where you can switch measurements. And you have instruments that can do high voltage. But the combination was very difficult.

"At first I was hoping the solution could be found with our own systems," says Haji. "Could I write the program and organize the system with hardware we already had? Unfortunately we couldn't, because we were missing some testing points. Also, the high voltage switching was a problem. So, I started looking outside for other systems. But really, at that point I didn't have any idea in which direction to go."

Finally, after investigating many tools and options, Haji got a break. He found the solution in his own department.

"We do some repair for the military on AWACS aircraft, and they had provided us with a system called the DIT-MCO model 2115," says Haji. "My colleagues told me there were a lot of test points, and we could do high-voltage testing. So I looked over the specs."

The DIT-MCO 2115 is a low-cost circuit analyzer that provides speed, power, reliability and ease of use in a benchtop configuration. Testing up to 1,500V and 2A, the model 2115 tests wiring and components for leakage, resistance, voltage, capacitance and dielectric breakdown. All parameters are programmable, so you can use high voltage up to 1,500V or low voltage down to 0.225V. Safety limits ensure that no excessive voltage will be used in situations where it may be hazardous, and interlocks enable you to incorporate safety barriers.

Looking at the specification, Haji could see that the model 2115, out of the box, could do 90% of what he needed. And because of its flexible, expandable design, he realized that he could easily modify the system to cover the rest of the requirements.

FEW SERIOUS COMPETITORS

Having found the system he thought he needed, Haji decided to see if there were other systems that could do the same job. Ultimately, the decision came down economics: DIT-MCO simply offered the better deal.

As soon as his model 2115 was delivered, Haji was ready to begin modifications. All the additional equipment he needed was already in-house. "You can add external resources to the system and get measurements from outside," says Haji.

NEW CAPABILITY, NEW REVENUE

Haji likes the model 2115's intuitive programming interface. And he really appreciates how the system is built to automatically set up and run tests and protect against overvoltages. "Because it is designed for high voltage, continuity testing and things like that, you don't have to do a lot of additional programming yourself," he says.

The main benefit for AFI KLM E&M is that it has a valuable new capability. It can now perform a full overhaul on its B737 ECUs very quickly, and at a major saving over outsourcing. It also has an additional service it can offer customers.

DIT-MCO International makes a wide range of circuit testers. But Haji says that those systems also provide many capabilities he didn't need. "For my purposes, I could do everything I needed with the model 2115," he explains. ∎

TOP RIGHT: **Zafar Haji developed the test solution for the engine control unit using the DIT-MCO model 2115. AFI KLM E&M can now perform a complete overhaul of their B737NG ECUs**

RIGHT: **The overhaul of the 737 Next Generation engine control unit requires a complete wiring integrity check on the more than 2,000 pins**

DAMAGE LIMITATION

A new system demonstrates an improvement in vibration testing, based on the forces between the shaker and the item being tested

A major cause of overtesting of space vehicles during vibration testing is associated with differences between the mechanical impedance of the shaker and the mounting fixture, and the standard practice of regulating the input acceleration to the frequency envelope of the flight data. The result is artificially high shaker forces and responses at the resonance frequencies of the test item, which can damage payloads.

To alleviate the problem of overtesting, it is common practice to notch the input acceleration in order to limit the responses in test to those predicted for launch. 'Notching' means reducing the amplitude of the shaker input near the resonant frequencies of the test item. However, this creates a paradox, because there are multiple resonant points on complex structures and determining them is very much dependent on analysis, which the vibration test is supposed to validate.

Another challenge in vibration response testing is placing accelerometers on the test item at all critical locations, each having its own unique resonant response, with many locations inaccessible. Since each location will have a different resonant frequency and exceed the control limits at some point during the test, it is often difficult to determine from which accelerometer the test engineer should control the shaker.

Force limited vibration testing (FLVT) is an alternative that improves the vibration testing approach based on measuring and limiting reaction forces between the shaker and the test item. By using this method, the acceleration input is automatically notched at the equipment resonances by limiting shaker force values to those predicted for actual flight. Notching is based on the premise that mechanical impedances of payloads and mounting structures are typically comparable for lightweight space vehicles. FLVT testing provides the test engineer with an opportunity to mirror structural response as seen during actual flight.

With FLVT, the force measurement signal is sent to the shaker control loop and compared with preset force limits. At frequencies where the measured force approaches limits, the controller notches the shaker. By reducing input to the shaker at these frequencies, forces between the shaker and the space vehicle are maintained within limits.

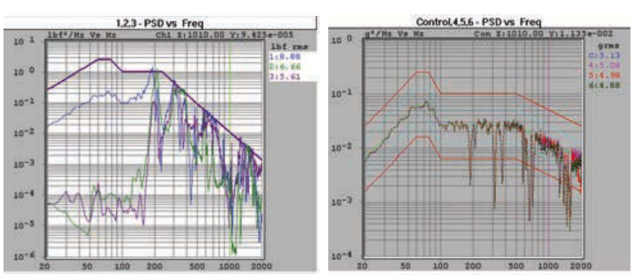
Accelerometers also feed the control loop and limit shaker excitation at frequencies other than resonances for which force limiting prevails. In order to accomplish this, the shaker control system must have 'extremal control' capability. Extremal control is the ability to control with respect to the greater of several inputs, either force or acceleration, as a function of frequency.

FLVT was performed on the James Webb Space Telescope Near Infrared Spectrograph (JWST NIRSpec). The graph below left shows the force-limiting curve (the bold purple curve) and that the force sensor responses of Fx, Fy, Fz (the thin lines) stay within the limits of the curve, obtained during a bracket assembly test. The right-hand graph shows the notching that took place in the random base input to the spacecraft. Notching was automatic, based on feedback from the force sensors; response limiting from the accelerometers attached to the bracket was not required.

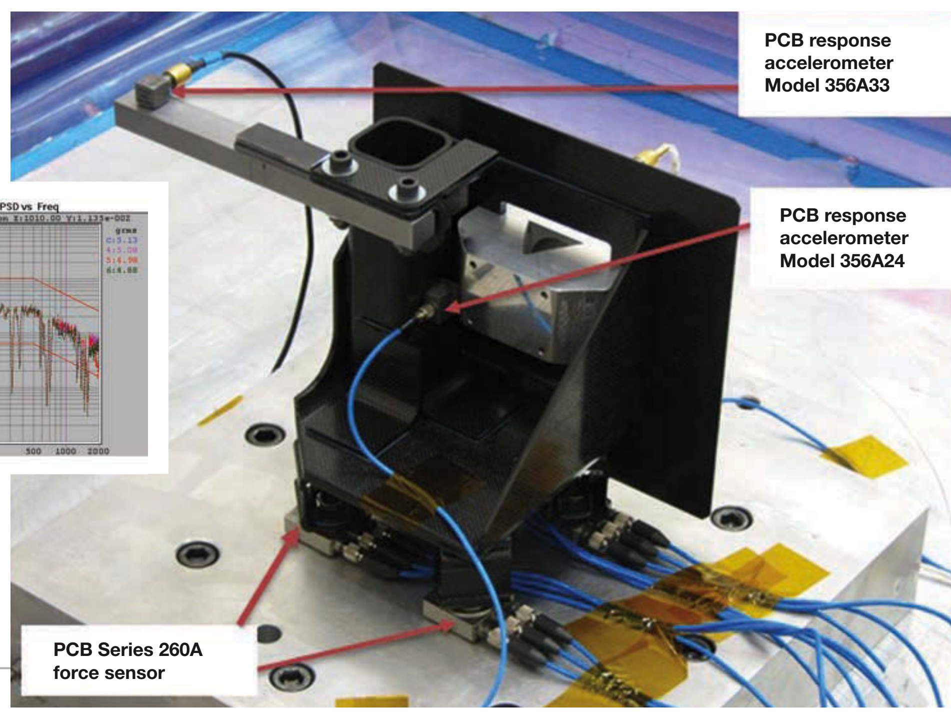
Multiple force sensors are mounted between the shaker and the test item. The figure shown below illustrates three-component piezoelectric charge output force sensors mounted between the shaker and the unit under test. The sensor outputs are summed and then fed into the shaker controller. Also visible are accelerometers placed at critical points on the structure, to monitor structural response.

The same ICP technology used for accelerometers is also available for PCB Piezotronics three-component force sensors. The benefits are easier cable management, hermetic sealing, simplified summing amplifiers, and reduction of labor cost. Each ICP three-component force sensor may be connected via a single cable to a summing amplifier that provides power, conditions the sensor signal, and sums each axis of force input.

To help keep your satellite safe, FLVT offers an improved vibration testing approach based on measuring and limiting reaction forces between the shaker and the test item. The practical use of three-component force sensors to control the shaker via notching reduces the chance of overtesting and damage to space vehicles or other lightweight aerospace structures. Using the same ICP signal conditioning that is used for accelerometers, it is now possible to provide pre-summed ICP force signals to the shaker controller, resulting in a properly notched acceleration input to the space vehicle. ∎



ABOVE: **JWST NIRSpec response data. Image: Space Dynamics Laboratory, Utah State University**



RIGHT: **JWST NIRSpec FLVT bracket installation. Photo: Space Dynamics Laboratory, Utah State University**

SHAKE, RATTLE AND ROLL

Force limited vibration testing limits the upper vibration level on any number of control or measurement channels, thus minimizing overtesting of the structure

The phenomenon of vibration overtesting was first observed in the aerospace industry in the 1990s. It occurs when vibration tests subject a test item to unrealistically severe – and potentially damaging – forces arising at resonances present in the component or fixture. This can result in components being unnecessarily overdesigned to survive conditions they will never encounter in operation.

The most effective solution available today is force-limited vibration testing. The outputs from force transducers, installed at the fixing points of the unit under test, are used to reduce (notch) the vibration excitation at resonances of the test item/fixture to more closely simulate the real-life environment of the combined system in the flight mounting configuration. Tri-axial force transducers are usually employed and accommodate different directions of the vibration excitation without the need to change the transducer. The combined output of each transducer is also used to measure the overturning moment.

THE CHALLENGES

Force-limited vibration testing demands a large number of measurement channels: there may be 5-10 fixing points per component, and each will require three measurement channels for the x, y, z outputs from the force transducers, with additional inputs from accelerometers, etc.

Traditionally, the total force per axis is derived by adding the forces on that axis from each force transducer using summing amplifiers. However, this method is incapable of detecting failed transducers, so the applied force may be underestimated and the force limit exceeded. In addition, when testing large structures, monitoring the overturning moment requires a measurement of the force vector at each fixing point, which is not possible when directional outputs are combined via external summing amplifiers.

M+P INTERNATIONAL SOLUTION

These issues have been overcome by m+p international's VibRunner hardware and VibControl software, which have proved highly successful for force-limiting vibration control.

m+p VibRunner units are designed specifically for noise and vibration engineering applications; self-contained, low-profile units can be combined for high channel counts with synchronization across all channels. All communications are via Gigabit Ethernet so that m+p VibRunner units can be located close to the measurement point to minimize transducer cabling. This unique hardware design enables both frequency and time domain data to be displayed simultaneously in real time, even while controlling the vibration system on high channel count systems.

m+p VibControl software products can be configured to tackle a full range of excitation modes, test control and safeguarding, including notching for sine and random vibration testing, time domain displays, data storage, and support for multiple monitors and remote workstations.

INSTRUMENTATION

For force-limited vibration testing, tri-axial force washers are inserted at the fixture and the correct pre-load applied by tightening the fixing bolt. To calculate the overturning moment, measurements of the physical geometry of each transducer must be taken from a datum. Each of the three force outputs is connected to a separate channel on the m+p VibRunner unit and the output of every force channel is measured and stored; time domain data can also be stored for further analysis using m+p SO Analyzer software. All force sums and moments are calculated by the software and displayed in real-time, overlaid with user-defined test limits.

During tests, the system applies a predetermined sine or random vibration excitation to the assembly, but this is limited if the sum of individual forces in the excitation axis, the root sum square of the acceleration vector at each point, or the overturning moment exceed their set limits.

Measurement channels can be displayed in the time or frequency domain to verify that each force washer is working correctly. Each channel has alarm and abort limits set to detect faults and protect the system from overtest. If the m+p VibControl software detects an open force channel, it immediately aborts the test.

Notch profiles are defined for each measurement parameter and can be calculated and imported from Matlab or a similar program. m+p VibControl also offers the facility to fine-tune notch specifications based on prior test runs at lower test levels. ▮

RIGHT: **m+p international's VibControl software and VibRunner hardware for high-channel count vibration testing**

INFLIGHT VIDEO

Recording a full flight has become more important than ever, and in conjunction with high-speed video can be incorporated into flight data recorder systems

A video system that gives complete coverage of a complete flight from take-off to landing saves money and provides an insight into unexpected occurrences. A cost efficient way to achieve this is by recording test objects with rugged electronic cameras that stream data to local storage for later playback and analysis. Such systems can run standard 30 frames/sec cameras as well as high-speed streaming cameras.

An airborne worthy camera that reliably records all image data under severe environmental conditions, as experienced in a high-vibration unpressurized cold ambient environment, is the core element of any video recording system. Preferably the camera will have a single MIL connector, avoiding wiring multiple cables across the aircraft for power, data transfer as well as other synchronization. A good solution is to run these cameras under the GigE Vision standard. This standardized protocol eases their integration into existing flight data recording systems and offers the user easy exchange of camera types. The cameras must have a good and well-balanced electronic design to avoid image degradation under rapidly changing temperatures as experienced during flight.

A solidly built and well-proven flight data recorder assures safe storage of the image data. Multiple cameras may be connected to these recorders for lengthy recording of events. Having a large amount of non-volatile storage in the recorders absorbs even the most demanding frame rates and resolutions. These recorders often come with software for parameterization of the cameras for framing speeds, resolution, shutter time, etc, making the image data acquisition just as the user wants it.

NEED FOR HIGH-SPEED RECORDING AND STANDARD 30FPS RECORDING?

Some cameras may record at standard speed while there are no fast movements, if there is simply the need to monitor a scene of interest during a complete mission in order to have full coverage and to capture unexpected events. Later, after the tests, the image data provides additional information about what happened or may be imminent, for analysis of additional events discovered during the flight.

However, certain tests demand that a specific event be recorded at high speeds of 200 or even 500 frames/sec, for example in store separation tests during the release phase. In that case there is often the need for a second camera that offers those capabilities.

Such cameras are mounted in the aircraft solely for this purpose. Here a newer generation of cameras combined with suitable controllers can – when triggered by an external signal – switch from standard-speed to high-speed recording for a user-preset time. Subsequently, the camera reverts to standard speed for the rest of the mission, unless another such high-speed sequence has been programmed by means of the software in the controller.

The question remains: How does the camera know when it is time to record at high speed? Here, a single discrete signal (e.g. from the start of store separation) initiates the switch to high-speed recording. Alternatively, without such a signal, the controller is programmed so that the high-speed recording starts at a certain system time. The controller can accept multiple signals to set the camera for high-speed recording again.

CONCLUSION

Modern camera and controller infrastructure that adopts to the needs of different aircraft types speed up in-flight video taking procedures substantially. Moreover, it helps to eliminate the need for additional camera equipment and eases the burden on the budget. ▮

RIGHT: **AOS Technologies' H-EM 501 is a MIL810 tested camera with a single MS27473 connector. The camera runs on a Gigabit Ethernet interface for data transfer and is fully GigE Vision compliant**

FAR RIGHT: **A compact, self-containing recorder from AOS Technologies for up to four cameras. Parameterization of cameras is by means of software**

A350XWB SUPPLEMENTAL COOLING SYSTEM

The new Airbus A350 testing system has been launched by Test-Fuchs, having been verified and approved by the aircraft manufacturer for use on the aircraft itself.

Test-Fuchs has been working with its customers to develop a completely new generation of supplemental cooling system testing equipment, which consists of a fully automatic fill-drain device, plus a top-up unit and adaptor kit for the A350.

The intended use is to drain, fill, bleed and top-up the Airbus A350XWB in accordance with the ATA21 supplemental cooling system with the appropriate propylene glycol water-cooling fluid PGW60/40-DowCal N60/40 or BMS3-20.

The SCST1-FD fill-drain device is simple to operate, with only two buttons, one potentiometer and a 5.7in display. The system is fully automatic and has been designed to minimize service times. Outdoor operation is possible in extreme environmental conditions from -30°C to +50°C.

Several adaptors, hoses, cables and accessories are stored within the waterproofed and UV-resistant GRP cover caps. The chassis is equipped with brakes, full rubber tires and optional springs, and can be towed at up to 25km/h.

The ergonomically designed SCST-TU top-up unit is driven by a hand pump and therefore completely independent from any electrical supplies. The manual valves are mounted on the front panel, where a simplified hydraulic schematic is illustrated for self-explanatory operation. All hoses and adaptors are stored on the unit and provide excellent accessibility to the filters and the removable waste fluid reservoirs. The unit can be moved by hand or by towing the vehicle with the tow bar.

The SCST1-AK350 adaptor kit is a set of adaptors that connects one of the GSEs to the Airbus A350XWB SCS cooling units. This system is necessary only to enable service actions at the basic component level. The normal and standard adaptors for testing the whole system are, of course, already included within the entire GSE itself.

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TRIALING STANAG3910 OVER ETHERNET

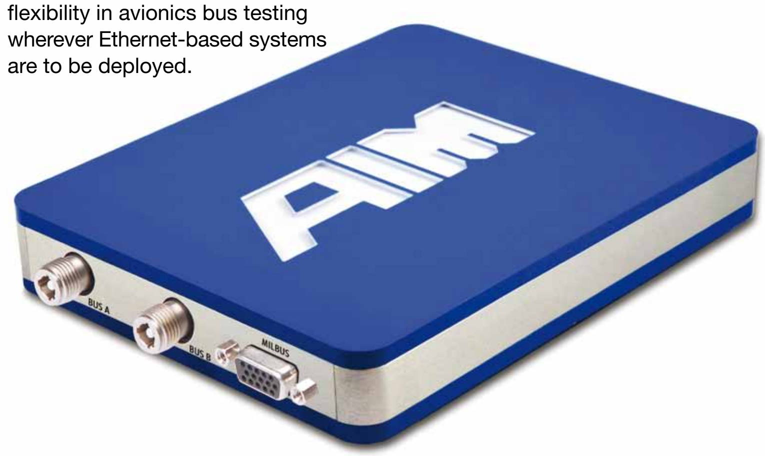
Avionics testing for STANAG3910/EFAbus Express (EFEX)-based avionics systems has just taken a giant leap forward with the introduction of the world's first ANET3910 Ethernet-based test and simulation solution from AIM.

Using Ethernet-based test solutions offers an open, modular and flexible architecture, reducing the user's dependence on specific host-computer platforms and operating systems.

The new ANET3910 includes one dual redundant STANAG3910 high-speed and STANAG3838 low-speed bus interface and a standard 10/100/1,000Mbit/sec Ethernet interface. The box is designed using AIM's latest 'digital core' technology based on a powerful SoC (system on a chip) FPGA. A general-purpose USB interface supports devices such as wi-fi sticks (such as for encrypted wireless ANET operation), mass-storage devices, serial interfaces and many others. Additional interfaces include general-purpose discrete I/O and triggers. An IRIG-B time code generator/decoder is provided for time synchronization.

The standard API interface (common across AIM's family of STANAG3910 interface cards) can be used to easily migrate existing applications or create new ones via the API. The onboard application support processor runs a real-time Linux OS, so customers can take full advantage to run directly 'in the box' Python scripts or dedicated C/C++ applications that require optional ADK (application development kit). Even AIM's optional PBA.pro test and analysis software can run in the box using the PBA.pro Engine option.

The ANET3910 is delivered with a complete suite of software, including the 'net detection tool' to configure the ANET on the network. This new concept provides the market with unprecedented performance and flexibility in avionics bus testing wherever Ethernet-based systems are to be deployed.



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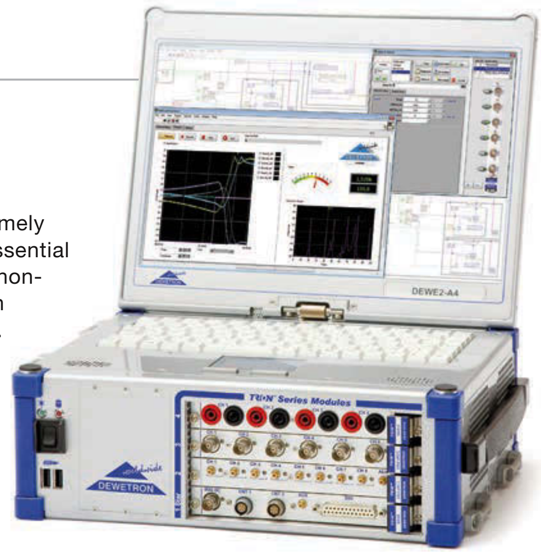

OPEN MINDED WITH OPEN SYSTEMS

In order to deliver best-in-class test and measurement solutions in the instrument market, Dewetron has now unveiled a new business model: Dewetron Open Systems.

These are instruments or components without ready-to-use measurement software, but with the support of a wide range of software development tools, drivers and libraries, example codes and documentation. This will enable engineers, system integrators, developers and OEMs to carry out any measurement task with Dewetron hardware solutions.

Seamless merging with any third-party hardware is possible with the implementation of specific real-time analysis, without the need to share or disclose potentially classified application knowledge. The source code remains the full intellectual property of the user; this avoids a problematic dependency from the instrument manufacturer.

As well as complete instruments, Dewetron now also offers core measurement components, such as multifunction IO cards with analog inputs, digital I/Os, high-speed CAN ports and an RS485 interface on a PCI bus (ORION series boards), or TRION modules with a PXI interface (with onboard signal conditioning for direct connection of almost any sensor) as well as the proven analog signal amplifier modules with full galvanic isolation (DAQP series modules for up to 300kHz bandwidth or HSI modules with up to 2MHz bandwidth).

These analog signal amplifier modules will work on an analog basis, without any CPU or software involved which could 'hang.' This makes these modules extremely failsafe. This is an essential requirement for any non-repeatable test (such as destructive tests). The direct analog signal conditioning will generate the output signal without any latency time, which is essential for any kind of closed-loop controlling.

Furthermore, the conditioned signal outputs are also available in redundant configuration, which allows for redundant data acquisition along with independent instruments. Even in the event of an electric shortcut at one of the output channels, the sibling channel on the second bank would not be affected at all. Dewetron Open System instruments and components are available with drivers and programming libraries for National Instruments LabVIEW and DASYLab, as well as text-based programming languages such as C#, C++, Visual Basic, Java, Delphi, Phyton and others. Besides Windows 32bit and Windows 64bit, hardware drivers for Linux distributions are also available.

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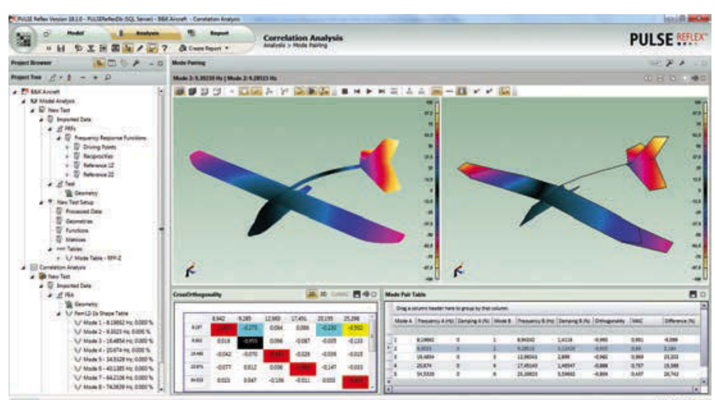
ENGINEERS, ANALYSTS AND SHARING COMMON TOOLS

Increasingly, the integration of physical testing and finite element analysis (FEA) is vital for modern structural dynamics. Integration helps to improve the development of more accurate virtual finite element (FE) models, and to optimize the strategies for testing physical models. As a result, fewer physical prototypes are required and development costs are reduced.

Brüel & Kjær's structural dynamics platform, PULSE Reflex, brings physical testing and FEA tightly together throughout the development process. From early optimization of test setups using baseline FE models, to the final test-based refinements of FE models, this practice ensures accurate tests and reliable predictions.

In PULSE Reflex, engineers can work with FE models from leading FEA programs, such as NASTRAN (MSC, NX and NEi), ANSYS and ABAQUS, or as UFF files. Large FE models can be quickly decimated to smaller test models, on which accurate excitation and response locations can be found for the physical tests. Close cooperation with leading CAE companies has secured a strong link between PULSE Reflex and simulation data and platforms.



Integrating test and FEA in a shared environment requires a powerful geometry tool. PULSE Reflex Geometry is designed with industry standards and methods in mind, in order to satisfy both test engineers and analysts. In addition to basic wireframe test models, advanced models can be created by meshing CAD-based models into nodes, lines and elements. An extensive range of animation types and layouts means the results can be presented in any number of ways.

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CANBUS DATALOGGER FOR FLIGHT TEST DATA

Vector has developed the GL1020FTE datalogger for analyzing CANbus communications in aircraft. On February 26, 2014, the CANbus datalogger passed its first test trial aboard an A350 XWB MSN2 Airbus test aircraft. The device fulfills stringent requirements for equipment use on aircraft and was designed according to the RTCA DO-160E standard.

The logger synchronously records up to 32GB of data from two CAN channels and four analog measurement channels. It operates on Layer 2 of the CAN protocol and is also able to acquire error frames, bus load and bus timing. Both long-term and event-triggered loggings are possible. To reduce data volume, the test engineer can define extensive filters and trigger conditions with a Windows-based logger configurator. The configurator software can be used to quickly upload the logged data via USB 2.0 and to convert the data to various formats for evaluation. Vector also offers high-performance software tools for offline data analysis, such as CANoe, CANalyzer, CANape and CANgraph.

The hardware can withstand high accelerations up to 6g and the vibrations that occur during operation; it can also handle temperatures between -40°C and +85°C and flight altitudes up to 36,000ft. It offers protection against the indirect effects of lightning strikes as well. The rugged orange-colored housing offers protection against dust and moisture, and has compact dimensions of 208 x 120 x 37mm. The logger is supplied with 28V DC from the electrical system, and it can withstand peak voltages of up to 33V; it can buffer voltage interruptions of up to 200 milliseconds.

It can be used in aircraft with CAN networks such as galley, water and waste, environmental control, doors or de-icing systems.

INDEX TO ADVERTISERS

Sun rising

Is this the most revolutionary aircraft of modern times? Is it the dawn of a new aviation horizon? After the successful test flight of Solar Impulse 2, it certainly seems that way

BY CHRISTOPHER HOUNSFIELD

Solar Impulse 2, the revolutionary single-seater solar-powered aircraft, successfully completed its maiden flight on June 2, 2014, from its base in Switzerland.

For 2 hours and 17 minutes, test pilot Markus Scherdel was the first to test the aircraft's performance. The initial test results have not been released, but the team has said that all results are in line with its calculations and simulations. There will now be several other flights taking place in the coming months in order for the experimental machine to attain certification before its 35,000km circumnavigation of the globe. To produce an aircraft that will take off and fly autonomously day and night, propelled only by solar energy, was an amazing challenge. It required the optimization of new kinds of technology and a drastic reduction in energy consumption. Solar Impulse's 80 engineers and technicians, under the leadership of Solar Impulse co-founder, CEO and pilot André Borschberg, have had to apply highly innovative technological solutions.

While Solar Impulse is not the first solar aircraft project, it's by far the most ambitious. With its successful 26-hour night flight last year, Solar Impulse 1 became the first aircraft ever to come close to perpetual flight.

It has taken a total of 12 years of calculations, simulations, construction and testing to arrive at the launch of Solar Impulse 2, the second aircraft, and the one set to fly around the world.

"Solar Impulse 2 incorporates a vast amount of new technology to render it more efficient, reliable and in particular better adapted to long flights. It is the first aircraft to have almost unlimited endurance," highlights Borschberg.

The engineers led by Borschberg reduced the weight of the entire structure proportionately. Every gram added had to be deducted somewhere else, to make room for enough batteries and to provide a cockpit in which a pilot can live for a week. A monitoring system constantly checks the functioning of the autopilot and detects any anomaly or transgression of safe limits. A man-machine interface provides the pilot with a sensory alert if the bank angle goes beyond 5°.

TECHNICAL INNOVATION

- 17,248 monocrystalline silicon cells, each 135µm thick, mounted on the wings, fuselage and horizontal tailplane, providing the best compromise between lightness, flexibility and efficiency (23%)
- Airframe made of composite materials (carbon fiber and honeycomb sandwich)
- Upper wing surface covered by a skin consisting of encapsulated solar cells, and the lower surface by a high-strength, flexible skin
- 140 carbon fiber ribs spaced at 50cm intervals give the wing its aerodynamic cross-section and also maintain its rigidity
- Stimulating innovation in the field of sheets of carbon, which now weigh 25g/m^2 – just one-third the weight of a sheet of printer paper

FLIGHT

Pilot:
Markus Scherdel

Flight duration:
2 hours 17 minutes

Highest altitude reached:
1,670m (5,500ft)

Average ground speed:
55.6km/h (30kts)

Solar Impulse 2 is set to accomplish what no other aircraft has ever achieved: flying without fuel with only one pilot for five consecutive days and nights over oceans from one continent to another. This is the challenge for which the aircraft has been built. To do this, it has four brushless, sensorless motors, each generating 17.4hp (13.5kw), mounted below the wings, and fitted with a reduction gear limiting the rotation speed of a 4m diameter, two-bladed propeller to 525rev/min. The entire system is a record-breaking 94% energy-efficient.

The single-seater solar aircraft is made of lightweight carbon fiber, and has a huge wingspan of 72m (236ft) for its total weight of just 2,300kg (5,000 lb), producing what the team proudly describes as an aerodynamic performance and energy efficiency greater than anything to date. There is a 3.8m^3 cockpit, every detail of which has been designed for a pilot to live in for a week. However, for the sake of maximum energy efficiency, the cabin is not pressurized or heated, a further endurance challenge for the pilot, who is to fly around the world drawing power only from the sun. ∎

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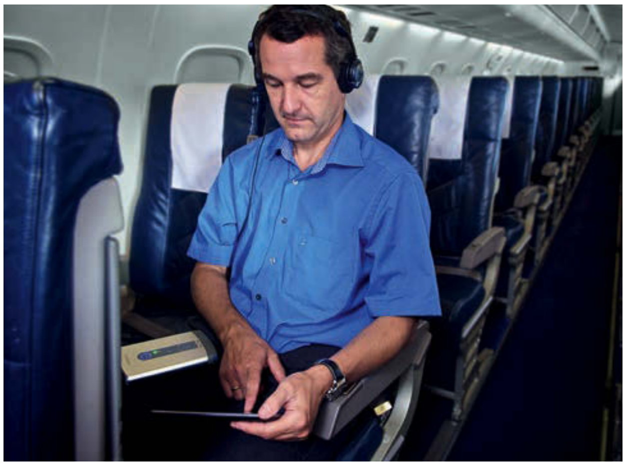

Used as a standalone recorder, with a tablet over Wi-Fi, or connected directly to a PC through USB, the LMS SCADAS XS truly is the first personal testing front end on the market.

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