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

SEPTEMBER 2009

# AEROSPACE TESTING INTERNATIONAL

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An exclusive visit on board the largest aircraft carrier in the world: USS Nimitz

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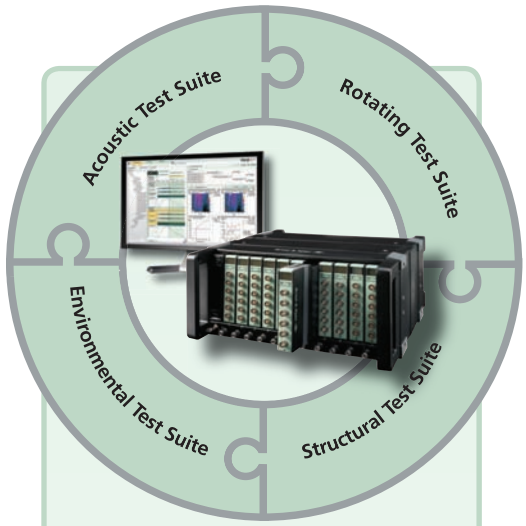


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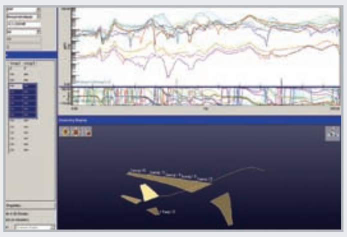

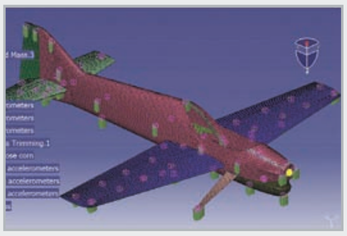

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The UK's armed forces are in a state of disarray. They have been fighting in Afghanistan for eight years (having all but vacated Iraq) and although they do not have the magnitude of scale to match the USA, their smaller professional force in Afghanistan is currently being hit hard – very hard. Subsequently, the UK government is now under fire. However, unlike the many other NATO countries involved, whose electorate may criticize involvement in the conflict solely due to ethical reasons, in the UK most criticism stems from the current government's lack of support and commitment to the in situ fighting force. This extends to lack of and dysfunctional equipment, poor supplies, bad facilities… the list is long. Combined with a lack of direction and interest, this is not the greatest morale booster.

Nothing epitomizes this more than the ongoing helicopter debacle. Back in July 2009, it became apparent that the 9,000 troops from the British Army were supported by a total of just 12 serviceable Chinooks – and one of these has recently been destroyed. At a maintenance service level of 82%, that means a maximum of nine usable helicopters (just eight, six months ago). This is in a vast operational area. When I heard there was a shortage of helicopters I was stunned to hear how few were actually operational. Already the defense procurement budget is apparently £35 billion (US$58 billion) over budget and five years behind schedule.

However, I'll focus on the bit that is of interest to the readers of *Aerospace Testing International*, which is the deal made with Boeing way back in 1995. It has just been reported in *The Times* (UK) that the Ministry of Defence signed a deal with Boeing to buy eight Chinook Mk3 helicopters. The then-Conservative government had no pressing military need for combat helicopters and, according to the report, the MoD told Boeing it did not want the software codes for the expensive avionics systems. This was aimed at saving £40 million (US$66 million) from the original £300 million (US$496 million) deal. The military was under pressure to save money, and an 'improvisation' scheme was bolted together. The MoD would devise its own codes.

When the Chinooks were finally delivered in 2001 at a cost of £259 million (US$428 million), they could not be certified as airworthy because of the lack of software. Apparently, they could be flown but pilots were barred from flying in cloudy conditions or at low altitude. The MoD codes did not work.

The Chinooks were mothballed. It was only in 2004 that officials returned to Boeing with a request. By now, these eight workhorses needed to do the job they were made for – the UK had wars to fight – but the improvisation was not going to work. Could Boeing fix the problem? Costs began to spiral, and are now huge. The government backed away from rectifying a peacetime deal. The problem still stands… in a hangar on Boscombe Down in southern England, with an in-service date of 2011 and upgrade costs of well over £200 million (US$331 million).

Until 1994, I was a soldier in the British Army and was heavily involved in the first Gulf War and a couple of smaller conflicts. Equipment was always a bone of contention when troops were mobilized onto an operational footing. But once committed, full government support and correct procurement always came through… in the end. It is essential for winning the battle – and the minds of the forces.

I recently got in touch with a senior Army friend who had just returned from duty in Afghanistan and, playing devil's advocate, put to him another argument: maybe the modern warrior was expecting too much, especially in terms of utility helicopter support? He choked, recovered, choked again, then nearly hit me. I spent more than eight years in the Army, and yet was shocked by his unique and breathtakingly colorful arrangement of expletives thrown in my direction. Obviously my suggestion was misguided.

This depth of feeling has been played out by the most senior members of the UK's armed forces. In unprecedented moments of candor the most senior generals have openly complained about the state of support. Even the Queen has reportedly complained to the government about the treatment of her forces (servicemen pledge allegiance to the Queen, not the government).

Canada, for example, has a smaller force than the UK (about one-third of the size) and has six Chinooks, yet it has opened its wallet and leased six civilian Mi-8 as support, and also has another eight CH-146 utility helicopters to add to the fleet.

Aggressive nations aside, governments tend to enter conflicts without being on a proper 'war footing'. However, when war is entered and commitments are made, support should be unequivocal, end of story. Mistakes in equipment procurement never come cheap.

**Christopher Hounsfield, editor**





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**COVER IMAGE:** A Boatswain's mate moves an FA-18C forward onto the catapult system onboard USS Nimitz (picture courtesy US Navy)

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# On an even keel

IT HAS A CREW OF 5,000 AND WEIGHS MORE THAN 100,000 TONS. *AEROSPACE TESTING INTERNATIONAL* GAINED AN EXCLUSIVE INSIGHT INTO AIRCRAFT MAINTENANCE ON THE LARGEST WARSHIP IN THE WORLD, THE USS NIMITZ

BY CDR RUSSELL DICKISON

There are 11 active aircraft carriers in the US Navy. The aircraft on board are not permanently attached to the carrier; each is assigned to a regional base and fly aboard as the ship begins her training and certification cycle prior to deployment. When the ship is configured for overseas deployment, the carrier is composed of multiple sea and air assets that offer support either logistically or on a tactical level, and they are led by a Carrier Strike Group (CSG) commander.

The CSG is comprised of four core commands. The first is the carrier, which has its own commanding officer. There is the Destroyer Squadron, which is generally comprised of two destroyers, a cruiser, and a frigate with its own commander or commodore. The third component is the embarked air wing and it has overall responsibility for the implementation and maintenance of more than 60 aircraft. Finally, there is the CSG, which devises the strategy with which to implement these assets and it is under the charge of an Admiral. The elements of the CSG that require constant interaction and facilitation and are essential for safe and successful aviation operations are the Carrier and the Carrier Air Wing (CVW).

The CVW is composed of multiple types of aircraft that bring full capability to the CSG. Currently, a typical CVW is composed of eight squadrons totaling approximately 65 aircraft. The squadrons each have a maintenance crew, led by a maintenance officer. The Carrier Air Group (CAG) commander staff has one central maintenance officer who serves as the CAG maintenance officer (CAGMO). Each individual squadron brings its own maintenance crew aboard that provides specific on-aircraft maintenance expertise for that aircraft type.

## Chain of command

On board the carrier itself is a commanding officer, executive officer, and 18 different departments. There are another four departments that deal heavily with the air wing: aircraft intermediate maintenance department (AIMD), supply department, air department, and weapons department.

Although the primary source of repair parts comes from the supply department, AIMD has a tremendous capability, increasing the readiness of the CSG as it receives and repairs broken components from the air wing. AIMD and squadron maintenance organizations work closely to ensure aircraft

Members of the flight crew have different colors for different jobs. Green is catapult crew and maintenance. Yellow is plane directors, among others

**"There is approximately three acres of space on the flight deck and even less in the hangar"**

are mission-ready at all times. Air department controls the movement and placement of aircraft on the flight deck and in hangar areas.

Despite aircraft carriers' great size (the Nimitz-Class Carrier's flight deck is just over 1,115ft long), there is a constant hawking of space and aircraft placement. The hangar decks below can accommodate only about one-third of the aircraft. The air department is always cycling aircraft from the flight deck to the hangar bays, and they are very skilled at moving them into and out of tight spaces.

The weapons department provides, of course, the armament for the aircraft – like all other departments, this is an essential component of the CSG puzzle. If there were no ordnance, what would the aircraft go and do? If there were no carrier, how would the planes get there? Other departments interact with the squadrons, providing necessary services to keep the crew and day-to-day operations, such as the medical, dental, telephone, and water, running smoothly. It is with great pride and direct interaction that the aviation maintenance officer can say he or she is the reason those planes can safely take-off, perform their mission, and come back home. This rewarding incentive is not without highly complex maintenance considerations.

There is approximately three acres of space on the flight deck and even less in the hangar bay of a carrier. It is quite a challenge to maneuver aircraft in such tight spaces; there is absolutely no room for error. For this reason, it can be difficult to get an aircraft positioned to conduct maintenance. The EA-6B Prowler is probably the best example. The Prowler has an electronic bay located in the tail of the aircraft, but the tails of aircraft are usually extended out over the water to conserve the precious deck space. When a squadron needs to perform maintenance on the electronic bay, they must request permission from the deck crew to pull the jet forward to give the technicians access to the bay. There are many other instances just like this for each of the aircraft and for many of the maintenance evolutions.

Aboard a warship, there are many requirements to maintain readiness that are mutually exclusive with flight operations and mainte-

# LT Ashley Bower

Lieutenant Ashley Bower has been a Strike Fighter Squadron 97 pilot for two years. He completed one deployment tour to Japan in 2008 and is now taking part in his first deployment on board a US Navy aircraft carrier, the Nimitz.

He hails from Pittsburgh, Pennsylvania, USA, and graduated from the US Naval Academy in 2004.

**What training did you undertake to become a US Navy pilot? Was there any special training needed to serve on board the USS Nimitz? And is it a semi-permanent posting?**

Training involved three different steps. It started with six weeks of initial academic and survival training. I then moved on to my first real flying – a T-37 – as part of an exchange tour with the US Air Force at Vance Air Force Base, Oklahoma. At that point the pupils registered preferences for future aircraft and we all went in separate directions from there. I moved on to fly T-45 Goshawks [a variant of the British Hawk] at the Naval Air Station Meridian in Mississippi. At the end of the training, we learned to land and take off from an aircraft carrier. Upon the completion of this 'advanced' training we earned our Navy wings. This process took me almost two years. I then went on to learn in my specific aircraft, the F/A-18 Hornet, for almost a year at Naval Air Station Lemoore in California. At the end of this I received my carrier qualification by practicing carrier landings again, which included night-time landing and take-offs for the first time.

On completion I moved to our fleet squadrons, just across the street to Strike Fighter Squadron 97, the Warhawks. Our service with our fleet squadron is for three years, and I am about two years into it. The squadron is part of an air wing, which deploys on a particular aircraft carrier. The Warhawks are part of Carrier Air Group Eleven, which deploys (as we currently are) on board the USS Nimitz.

**Can you describe a typical day?**

A typical day involves more on-the-ground work than people may realize. In addition to my job as a pilot, I am also in charge of all the 'plane captains' in the squadron. These are the folks that help prep the jet, help you start it and shut it down, and service it in between launches. I spend a chunk of the day working with them, making sure their qualifications and paperwork are in order, and just talking to them. Then I will spend a couple hours or so preparing for a flight, then another hour or so briefing a flight. A typical flight is about an hour-and-a-half. We then debrief maintenance on the jet and then debrief the flight. So a typical hour-and-a-half mission takes seven hours of work, or maybe a lot more if it is a complex flight.

**What is the worst element of what you do?**

The worst element would probably include all the commitment. This is not unexpected, nor unusual for the military, but involves more than many may assume. It involves living where they tell you to live, and the bigger commitment of deploying to a ship for six months or more – during that period, you are working for a very large portion of your time. It can be wearing on a person when trying to make plans or commitments outside of work. This said, it is an understandable by-product of the job.

**What unique problems does a sea-based environment create from your perspective?**

A sea-based environment makes air operations a completely different animal. Instead of taking off and landing being a relatively routine and, at least for fighter jets, safe part of the flight, it becomes the most dynamic and potentially dangerous.

**How does the maintenance department team work from your perspective?**

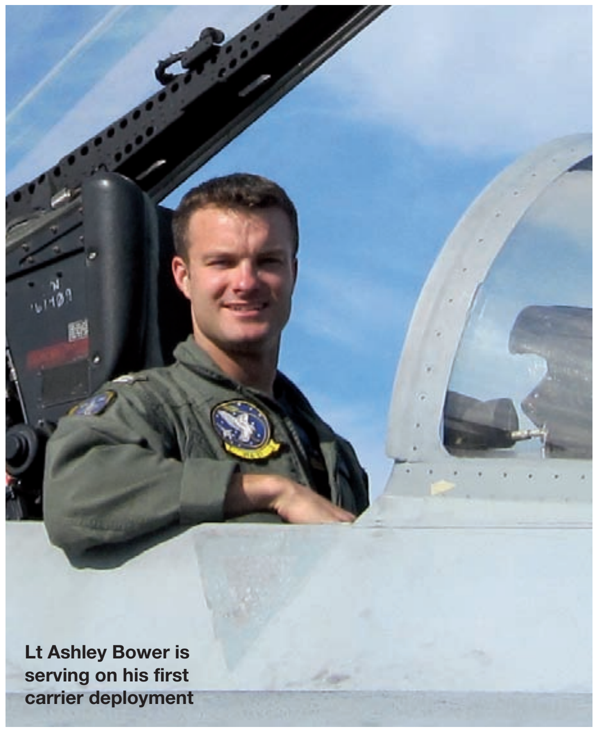
It is the backbone of the squadron. It makes up the majority of the squadron, and for good reason – they fix and keep up these complex machines. Without good maintenance, there would be no jets and no flying – or at least, no safe flying.

**What are the biggest challenges you face?**

Staying focused and applying effort where needed when there are many different things to work on. You can be talking to someone about problems at home and then need to review your procedures in the cockpit for a mission five minutes later.

**From a purely technical/equipment point of view, what are the biggest challenges you face as a carrier-based Navy pilot?**

Strike fighter airplanes are very complex. There are many times I feel more like a glorified computer and systems operator who just happens to be thousands of feet in the air than a fighter pilot. I'd say 95% of our job is spent studying and concentrating on the systems.



Lt Ashley Bower is serving on his first carrier deployment

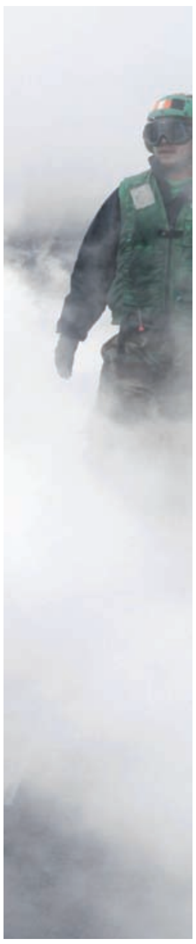
**What is the difference serving on the huge USS Nimitz rather than being land-based or on a smaller ship?**

Being on board a carrier has a lot of advantages over being on a smaller ship such as a cruiser or destroyer. For me, I like having a more stable ship to walk around on, and work out on treadmills, etc. A better supply of water and energy also helps. However, I have heard from friends that sometimes many people like the smaller number of people on board the smaller ships.

**What makes Navy pilots among the best?**

The evolution of landing and taking off from a carrier. It keeps any flight from being a simple or usual one.

This probably takes some training away from other aspects of flying – but it still probably improves the overall ability of Navy pilots, who have to adapt to many different and more dynamic situations than operating off land. Landing on a ship, where a lot could go wrong pretty quickly – it's dark, and you're far from any other way of landing – tends to improve your ability to concentrate.



nance, including a knowledgeable staff working together to prioritize and effect trade-offs. An example of such a conflict is with the ship's lighting posture and aircraft maintenance during the night hours. Much of the aircraft maintenance occurs immediately following the flight schedules, which normally extends late into the night. The carrier does not fully illuminate the flight deck, but rather technicians are required to work by flashlight. The ship also has a doctrine that enables it to change its lighting configuration to deceive enemies. When the ship is in a deceptive lighting configuration, no lights are allowed on deck, hence no maintenance can occur topside – yet another lost maintenance hour.

> "There are more than 5,000 people who need to sleep, eat and work"

## Give me some room

Though a carrier such as the USS Nimitz looks like it has a lot of acreage, there are more than 5,000 people on board who require room to sleep, eat, and work. As on the flight deck,



space is a premium asset. As such, the AIMD is structured to maximize capability per square foot. The result is that each of the shops has wall-to-wall equipment. The typical avionic shop is about 1,000ft$^2$ and has between eight and 12 large test benches. Each bench has hundreds of connection cables and interface devices stored in the workspace. The number of technicians assigned to work in the shops range from seven to 25 to create seamless 24-hour, seven-days-a-week supporting flight operations.

Everything on a carrier is designed to be on a warship, and is anchored down in the event of high seas or severe weather. The majority of items must be secured for sea (loose items tied down with straps bolted to the bulkhead) or shock-proofed. The term 'portable' is used very sparingly. Because of the small size of the spaces, sailors sometimes must get themselves into very tight areas to make repairs to the test equipment itself. For example, when a 1,200 lb engine fails, the efforts required to get the old motor out and the new one in to the tight space can be quite challenging, requiring outside expertise.

There are innovations on the ship that require the specific placement of equipment, and come with restrictions. The jet engine test cell is one such item. Test cells are positioned on the fantail of the carrier (at the very back of the ship). Engines are placed on a moveable fixture, rolled out to an open area at the back of the ship, and positioned so that their exhaust will vent to the open water. Restricting test cell use even more is a multitude of other evolutions that are required to occur in the same location that the engines are run. One of the biggest constraints is flight operations. As the exhaust of an engine on the cell is positioned aft, it could disrupt the airflow of aircraft landing on the flight deck just above. Therefore, for many reasons, the test cells are operated only at night, after flight operations have finished for the day.

## The list gets longer

The intermediate maintenance department is responsible for maintenance and repair not only of each aircraft, but also of all the support equipment (SE) used in aviation maintenance.


## Floating facts

- Nimitz reaches more than 18 stories high from the keel to the top of the mast.
- The Hangar Bay extends for most of the ship's length. It is used for major repair and shelters the aircraft not needed for that day's flight schedule.
- Four distilling units enable Nimitz engineers to make over 400,000 gallons of fresh water a day, for use by the propulsion plants, catapults, and crew.
- Nimitz's Food Services Department provides 18,000-20,000 meals a day.
- Nimitz can stock at least 70 days of refrigerated and dry storage goods.
- Nimitz's one barber shop trims over 1,500 heads each week.
- The ship's post office processes more than 1,000,000 lb of mail each year.
- The ship has a fully equipped dental facility, staffed by five dentists.
- The medical department is manned by six doctors, including a general surgeon, who provide care from surgery to hydrotherapy. The ship also features a 53-bed hospital ward, a three-bed ICU, and acts as the hospital ship for the entire Nimitz battle group.
- Nimitz's three chaplains conduct daily religious services in an interdenominational chapel.
- Nuclear power enables the ship to store 50% more ammunition and almost twice as much aviation fuel as the largest conventional carrier.

Hundreds of maintenance-intensive support items from forklifts to auxiliary power units are kept and maintained in the forward portion of the hangar bay until needed. SE division owns a 'garage' where maintenance can be conducted; the space used to house all the support equipment, and is slightly bigger than a two-car garage.

The SE division is heralded for its ability to be ready when called. With approximately 50 SE technicians in the garage, it is easy to see why little maintenance actually occurs in that area. Instead, much of the routine maintenance occurs in the hangar bay. Technicians have to climb over multiple items of equipment to access the gear, and gaining access to use the equipment is very much like an involved game of 'Tetris' – but in reverse. Although the hangar bay is covered and therefore gets no rain, there are no environmental controls. The air temperature is the same as the ambient air temperature of the region in which the carrier is operating. Off the coast of Alaska, extreme cold weather measures are necessary to keep equipment up and running; in the Gulf in September, it's the opposite.

### Is there anybody out there?

For industrial work facilities at sea, one of the hardest things to contend with is communications with the outside world. Whether it is with other US Navy repair facilities or civilian engineers, communications are often cut short.

Although communication at sea has greatly improved over recent years, gaining access to the communications lines available can be a challenge in itself. Because the Nimitz is a warship, first and foremost, operational security is always a consideration. The information being communicated aside, even the emissions of electronic signals from the ship can jeopardize the mission or strategy at hand. The ship does not carry a high-speed LAN line that stretches back to the USA, so those on board are at the mercy of the strength of the satellite signal from a ship whose position is constantly changing.

An E-2C Hawkeye assigned to the Wallbangers of Early Warning Attack Squadron (VAW)

> "Off the coast of Alaska, extreme cold weather measures are necessary"

Email is readily available to nearly all hands, but sometimes just gaining access to an available computer can be the challenge. This is realized or felt more heavily by the technicians in the shops where numerous sailors may need to take turns of the well-used terminal space.

Phone lines on and off the ship are limited, so access is carefully controlled, and on a need-only basis. Due to bandwidth restrictions, internet access is typically placed on a tier system. When open for the majority of the crew, there is much activity and hence slow connection. All these factors require the carrier technician to be heavily self-reliant, and aware that speaking to a technical representative is not an easy matter.

### I'd give my right arm for a…

One of the main constraints on a ship like the USS Nimitz is the supply chain. There is limited storage available for repair parts and supplies. As a result, the ship relies heavily on off-ship support.

The primary delivery method is the carrier onboard delivery (COD) aircraft. The COD typically detaches to a shore site near the carrier operating area. The CODs make almost daily flights to the ship, bringing passengers as well as much-needed parts. Weight considerations and of course space are concerns for the aircrew flying in the parts. Also available is the replenishment at sea (RAS) option, when a USNS supply ship pulls up alongside and passes stores to the carrier. This method is typically used for bulkier items and fuel. ∎

*Cdr Russell Dickison is from the USS Nimitz (CVN 68) and is the ship's aircraft intermediate maintenance officer*

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# Typhoon cuts threaten UK industry

On July 31, 2009 the UK government announced that it was cutting its order for Eurofighter Typhoon fighter jets by 72 aircraft. Amid a great deal of media spin, the vast majority designed to cover up the fact that in May 2009 Prime Minister Gordon Brown had given the impression that the UK was to order its full quota of 88 aircraft under the Tranche 3 phase of the four nation Eurofighter program, the UK MoD revealed that the Royal Air Force would now receive only 16 new aircraft under the Tranche 3 contract.

Quentin Davies, defence minister, said the UK had 'no foreseeable plans' to buy more Typhoon jets. He told the *Financial Times* that the UK was within its rights to drop its final aircraft from Tranche 3, arguing that, "We have no obligation to our partners to buy any more, and we have no current intention or expectation to purchase more at the present time."

The partner companies – BAE Systems, EADS, and Finmeccanica – made the best of the situation, issuing upbeat press releases, but the smiles were undoubtedly a bit thin.

For the UK industry partners, the premature termination of Typhoon assembly has serious implications, particularly the engineering design and product development teams at BAE Systems' Warton site in Lancashire, northwest England. Details of the new shape, size, and duration of the UK's Typhoon are still very unclear and the MoD gave away few details about technology insertion and upgrade plans for the RAF's 'rump fleet' of 160 Typhoons. It seems that the remaining Tranche 3 aircraft to be built by 2013 will not have active electronically scanned array (AESA) radars or any of the other advanced features beyond a new computer and 'wiring and plumbing', to allow upgrades at an unspecified later date.


Added to this issue is the growing paralysis in UK defense procurement planning as the next general election nears, as well as the looming defense review that will come in its wake.

BAE Systems had been banking on increasing work on unmanned aerial vehicles (UAVs) to take up the slack caused by the downturn in Typhoon and keep its designers and technology experts in work, but this now seems also to be in doubt. The MoD has decided to defer the decision on launching new UAVs until 2012 at the earliest. This is a particularly hard blow for BAE following its efforts to persuade the MoD to fund the purchase of its Mantis operational-level UAV to supplement and replace its current fleet of General Atomics MQ-9 Reapers. The company had hoped to get a decision this year and immediately begin work on the second Mantis air vehicle.

The longer-term future is also uncertain, beyond the demo flight of the Taranis unmanned combat aircraft early next year. In partnership with the MoD, under the four-year £124 million (US$201 million) contract signed in December 2008 BAE Systems, together with Rolls-Royce, GE Aviation, and QinetiQ, are aiming to prove the technologies for a system that would eventually replace, or augment, the RAF's fleet of Tornado GR4 strategic strike jets in the 2030s.

The post-election defense review is now certain to delay any firm decisions about the RAF's long-term procurement plans. The 2005 Defence Industrial Strategy (DIS) identified the maintenance of air systems' design and manufacturing capability on shore as a key capability for the UK, but Gordon Brown's government has not been keen to follow through with it, pushing a DIS update far into the future.

The future of the UK military aircraft industry now looks very uncertain unless the defense review firmly anchors the retention of air systems in the UK industrial base. The clock is ticking…

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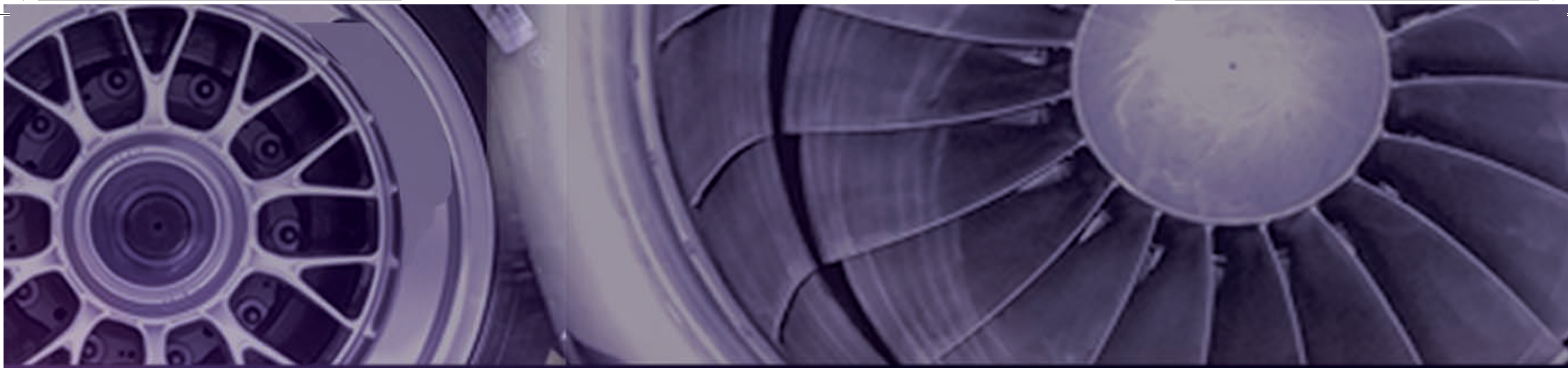


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# UAVs – the future of the war on terror

When news emerged at the beginning of August 2009 that a missile fired from a US Predator drone, or UAV, had killed Pakistani Taliban leader Baitullah Mehsud, it made headlines around the world. This was the culmination of several years of strikes aimed at 'decapitating' the leadership of Islamic insurgents hiding in the mountainous Afghan-Pakistan border region.

Combat operations from Kosovo to Afghanistan over the past decade have convinced the US military and many allied armed forces that the era of weaponized UAVs is here to stay.

Speaking at the Shephard Unmanned Vehicles Europe event in July 2009, Ryan Hartman, director of unmanned systems for US missile maker Raytheon, said the trend to weaponize UAVs was across "all tiers" of systems, because of their "ability to compress the kill chain". He said weaponized UAV potential has not been fully realized.

Lockheed Martin Missiles and Fire Control's business development director for tactical missiles and maneuver systems, John Morris, said at the same event at the Celtic Manor resort in Wales, "UAV missiles are the global war on terror weapon. Range, surprise, and accuracy are worth their weight in operational effect."

Both executives predicted that there would be considerable growth in the market for weapons specially developed for employment from UAV, beyond the current generations of ordnance. These existing weapons are all adopted for systems used on fixed-wing aircraft and are not ideal for use from UAS air vehicles. All the benefits of UAV – removing human crews and their life-support systems to free up weight for extra fuel and to reduce the physical size of the air vehicle – can be lost if heavy and bulky weaponry intended for manned aircraft has to be carried.

UAVs are also not usually built to the same robust standard as many manned aircraft so they cannot take stresses of firing large and powerful missiles from under their relatively flimsy wings or fuselages, as this would lead to catastrophic structural failure. This has meant that a limited number of weapons could be carried on the current generation of UAVs – only small 500 lb bombs and anti-tank missiles. The latter weapons had obvious limitations because they were usually armed with shaped charge warheads, which had limited utility against personnel in the open, inside buildings, and in soft-skinned vehicles.

Hartman identified four gaps in the marketplace, including weapons in the ranges of 10-15 lb and 50-80 lb, as well as 250 lb and 1,000 lb. Raytheon is developing a future portfolio of UAS weapons, with three main products known as the Small Tactical Missile, the Tactical Missile, and the Monson Concept weapon.

Lockheed Martin is in the process of fielding a specialized UAV variant of the Hellfire II missile, extending the capabilities of the AGM-114P currently used on USAF Predator and Reaper UAVs, to include off-axis engagement capabilities. Morris said that Lockheed Martin was also developing new weapons for the UAS, including two 70mm guided rockets, dubbed the 10 lb Shadow Hawk and the 25 lb Joint-Air-to-Ground Missile (JAGM). The JAGM is expected to be the company's first offering in the future large UAS weapon class.

## Iran trials homegrown drone

Iran has successfully tested its homemade drone, according to the IRNA news agency. Iran's Air Force commander Brigadier General Hassan Shahsafi is reported to have said, "The research sample of the military drone that has been made by the Air Force was tested... and mass production of the drone will begin soon." In June 2009, Shahsafi announced that Iran had successfully tested a homemade radar-evading unmanned aerial vehicle (UAV) with bombing capabilities.

"This airplane is a model drone built on a one-seventh scale for the Defense Ministry," the semi-official Fars news agency quoted him as saying. Iran has reiterated that its military capability enhancements have defensive and peaceful purposes.

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# A400M in a delivery dilemma

The trials and tribulations of the A400M program have been covered by *Aerospace Testing International* extensively over the past five years. In July 2009, the European airlifter was given another lease of life by the partner nations. The European industry consortium building the aircraft led by Airbus now has until the end of the year to come up with a way out of the current mess.

The Airbus team now has to crack the development of the TP400 engine and the software of its fully authorized digital engine control systems. The C-130 Hercules testbed aircraft made its first flight in December 2008 from Marshall Aerospace's site in Cambridge, UK, but attention has switched to when the A400M will first take to the skies. Airbus has consistently missed its self-imposed deadlines for the first flight, and aerospace insiders now believe it will not happen this year (although Airbus begs to differ – see below).

The partner nations, it seems, are not setting this as a precondition for the signing of a new contract at the end of the year, which is hoped will inject billions of extra Euros to kick-start the stalled A400M program. Airbus, however, has been told it has to come up with a convincing new plan to solve the aircraft's technical problems and set a realistic delivery schedule. Whether this latest effort is successful has yet to be seen, but no doubt *Aerospace Testing International* will be returning to subject again in the near future.

According to an Airbus Military spokeswoman, the troubled A400M military transport plane should still make its first flight around the end of 2009.

The first A400M (MSN1) left the Final Assembly Line (FAL) on September 2, to be moved to the next ground test station which now is outdoors. Trials to be performed on the first outdoor station (station 30) include fuel tests, pressurisation tests, as well as navigation and communication checks, and will last approximately two weeks. Subsequently, the aircraft will receive its engines.

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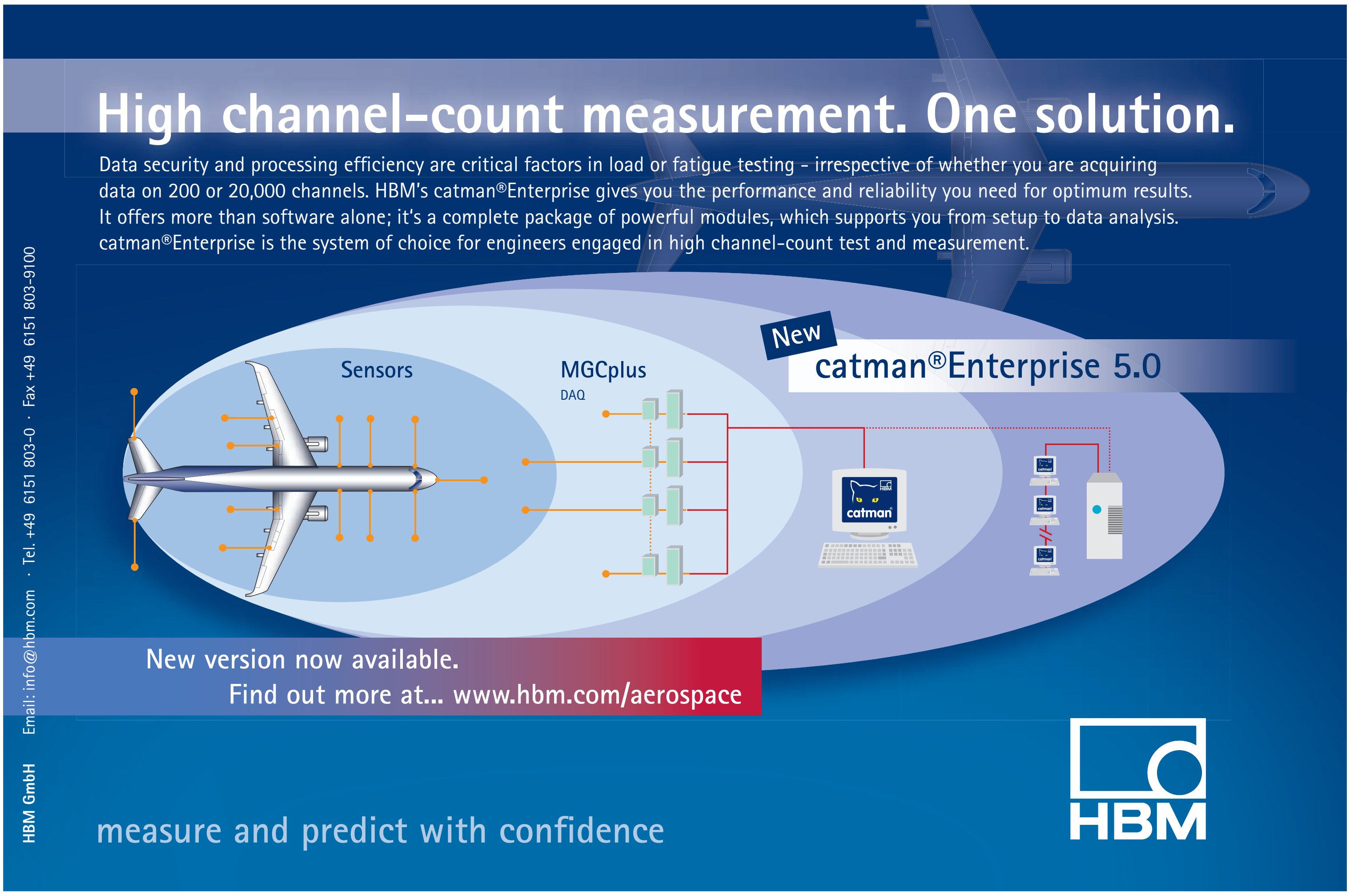
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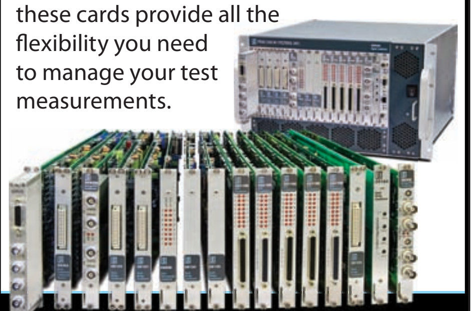

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# Telescopic view for Galileo

At the Paris Air Show in June, the European Space Agency and Arianespace signed a contract for the launch of the first four operational Galileo satellites. The satellites will launch on two Soyuz launch vehicles from Europe's Spaceport in French Guiana. The agreement was made on behalf of the European Commission's Satellite Navigation Programme.

The contracts are proof at last that the European Union is serious about going through with its ambitions to create a space-based navigation system to rival the US GPS and Russian GLONASS systems. The project has been dogged by technical, financial, and political problems since it was first mooted more than a decade ago. Two years ago it seemed almost dead until the European Union took the project in-house from an industrial consortium. Now the project looks like it is back on the rails: a 2013 target has been set for it to be up and running.

The Galileo In-Orbit Validation (IOV) Launch Services Contract covers the launch of the first four operational Galileo satellites using two Soyuz rockets. The launch vehicle chosen is the Soyuz ST-B with a Fregat MT upper stage, which has been adapted for the deployment needs of the Galileo program.

The European Space Agency is now in the process of rolling out a series of contracts for the construction of the Galileo satellite systems. EADS Astrium and Germany-based OHB have both received contracts this year for long-lead items for the first of some 28 satellites that will eventually comprise the Galileo constellation. It seems that the first batch of 16 satellites will be equally divided between the two companies and a further competition will be run for the next batch of 12.

A battle has begun between the two companies, with Astrium claiming that a single source procurement would be cheaper in the long run because it would enable economies of scale to be achieved in the manufacturing phase, potentially saving 40% of the cost.

The first test flight of a trial satellite will be made early next year, and if all goes to plan, the first operational satellite will be launched in late 2011 if all goes to plan. It is still unclear if the constellation will be in orbit on schedule because of delays in producing enough launch vehicles with multiple satellite carrying capacities. Soyuz has limited means and is unlikely to be able to ramp up production of its launchers in time to meet the Galileo schedule. Arianespace is also suffering problems getting a satellite dispenser systems into production for its Ariane 5 rocket, which can carry six or eight Galileo spacecraft instead of the current four.

If these problems cannot be resolved, then the launch window might have to be extended and more launchers will needed. This will delay the program and add to its €3.4 billion price tag. So far European nations have stuck with the program. Its potential to stimulate economic growth and protect European jobs is considered high.

## The only way is up

Following the successful launch of the GIOVE-A and GIOVE-B satellites, the signing of the IOV Launch Services Contract is an important milestone for the Galileo program as it progresses toward the operational deployment of the satellites of the Galileo satellite navigation system. The four IOV satellites will be placed in a circular orbit at an altitude of 23,600km by the end of 2010. The launch vehicle chosen to carry the four Galileo IOV satellites into orbit is the Soyuz ST-B with a Fregat MT upper stage, which has been adapted for the deployment needs of the Galileo program.

When in operation, it will have two ground operations centers, one near Munich, Germany, and another in Fucino, 130km east of Rome, Italy.

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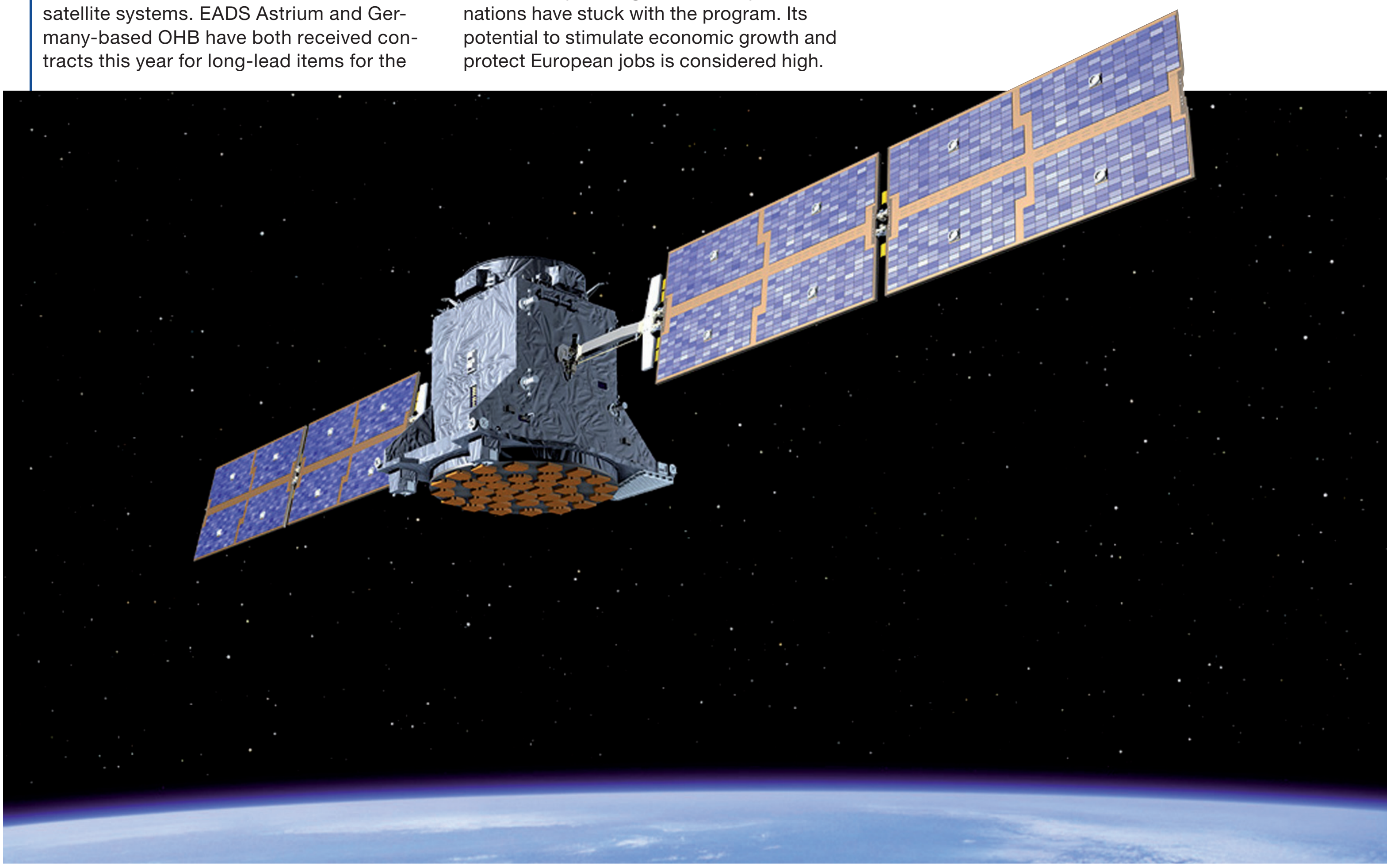

Operations 'Iraqi Freedom' and 'Enduring Freedom' provide the ultimate test environments for new and modified helicopters. The latest Chinooks have joined the fight and offer digital cockpits, new airframes, and advanced flight controls. Frank Colucci describes the role of a test pilot at war in the CH-47F

# Test pilot at war

> The US Army Aviation Technical Test Center (ATTC) currently at Fort Rucker, Alabama (and moving to Redstone Arsenal, Alabama, by 2011), is the airworthiness qualification and systems flight test authority for all US Army aircraft. ATTC experimental test pilots (XPs) routinely deploy to Iraq and Afghanistan to lend their engineering expertise to operational units and to relate their engineering observations to combat missions. Their feedback refines current aircraft and systems and helps to build relevant test plans for future army aviation systems.

ATTC has about 50 XPs, most trained in repeatable data collection and other testing disciplines at the US Naval Test Pilot School. The army test pilots started going to war with new software drops for the AH-64D Apache Longbow and helped to debug the Common Missile Warning System (CMWS) rushed to the combat theaters. They went to Iraq with the VUIT-2 system that shows imagery from unmanned aircraft systems (UAS) in Apache cockpits. ATTC commanding officer Colonel Christopher Sullivan explains, "We've been deploying our test pilots with Combat Aviation Brigades for four-and-a-half years. Their missions are: to assist the brigade commander with whatever he wants done, to assess equipment being fielded and report that back through the test and evaluation community, and to bring back the way the aircraft are flown – the mission relation-piece."

XPs deployed with the first CH-47F Chinooks in Iraq and the first UH-60M Black Hawks in Afghanistan. According to ATTC XP Chief Warrant Officer Sean Magonigal, "Each deployment gives that Combat Aviation Brigade commander a Swiss Army knife – an operational pilot, a technical writer, a translator of sorts to communicate pilot likes and dislikes back to the engineers who write the software, and a good staff officer."

Magonigal joined the Combat Aviation Brigade of the 4th Infantry Division from June to December 2008 for the first deployment of the CH-47F. Before leaving for Iraq, he was rated in 23 different aircraft and had about 100 hours in Chinooks including 70 hours in the digitized CH-47F. The XP ultimately flew 230 hours in the new cargo helicopter in theater while doubling as a Black Hawk pilot for the brigade as needed. Magonigal says, "Most of what I did was just operational flying for the unit… But as things came up in the course of operational missions, I would give a more detailed look with a more engineering-type analysis."

When the first CH-47Fs in Iraq suffered occasional digital map failures, ATTC engineers and testers suspected overheating in the map servers of the Rockwell Collins Common Avionics Architecture System (CAAS). Magonigal developed a test plan using the ATTC test planning process and won approval and an Airworthiness Release to install a simple test instrument he received from Fort Rucker. "It was a small, battery-operated thermal logger with eight thermocouples," he explains. "We just took some temperature measurements of the air and surface measurements on avionics components." Data from Iraq went to CAAS engineers in Cedar Rapids, Iowa, to help diagnose the problem.

To help his brigade commander navigate the Army acquisition system, the embedded test pilot wrote mission need statements for an improved internal cargo handling system, better gun mounts, and other Chinook refinements suggested by the flight crews of the 4th Infantry Division (ID), Combat Aviation Brigade. Magonigal observes, "They needed something for that guy in the back who mans the gun on the ramp. A six-hour mission, and he didn't have anywhere to sit."

The test pilot also recorded the likes and dislikes of other Chinook pilots. "I think I flew with just about every other CH-47 pilot in the unit. I would keep notes, ask questions." First-hand reports and collected observations emailed weekly from Camp Taji, Iraq, to ATTC ultimately went into a wrap-up of CH-47F operational user findings.

## Smarter, stronger Chinooks

The US Army now expects 513 new, 'renewed', and remanufactured Chinooks to be in service by 2022. Operational lessons learned will refine the

**Right: Fat Cow missions loaded a CH-47F with additional tankage and fuel hoses to refuel other helicopters at forward refueling points (4th ID Combat Aviation Brigade)**

**"I think I flew with just about every other CH-47 pilot in the unit. I would keep notes, ask questions"**


The CH-47F is distinguished from the earlier CH-47D by its digital cockpit, stiffened airframe, Digital Automatic Flight Control System, and multi-theater 'sage' paint scheme

CAAS cockpit and other pieces of the modernized cargo and special operations helicopters. Army requirements for an improved cargo helicopter with digital connectivity and lower operating and support costs emerged soon after Operation Desert Storm in 1991. In June 2001, the first CH-47F Engineering and Manufacturing Development aircraft flew with a modest 'glass' cockpit that supplemented analog 'steam gauges' with digital multifunction displays.

Early CH-47F production plans remanufactured CH-47Ds with new cockpit sections, partially integrated avionics, stiffened airframes, and reclaimed dynamics and systems. Special operations MH-47Ds and MH-47Es would be replaced by MH-47Gs with the fully integrated CAAS. The CAAS cockpit presents primary flight symbology, digital maps, engine and systems information, and digital communications on five color displays.

Starting in September 2001, the global war on terror accelerated the need for special operations aircraft and killed the Comanche armed reconnaissance helicopter. CH-47Fs were delayed while MH-47Gs led the remanufacturing line, but Comanche money paid to give the cargo helicopters the CAAS cockpit and all-new airframes. Monolithic aerostructures machined from solid aluminum could 'de-tune' the Chinook to reduce vibration and replace cracked and corroded parts at lower cost than patchwork repairs. A new BAE Digital Automatic Flight Control System (DAFCS), meanwhile, promised to enhance safety and reduce pilot workload without costly fly-by-wire controls.


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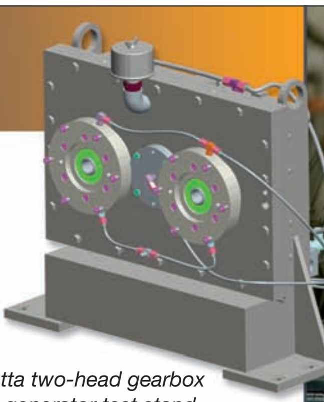

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The First Unit Equipped with the CH-47F, the 7th Battalion of the 101st Airborne Division (Air Assault), completed operational testing at Fort Campbell, Kentucky, in 2007 before the DAFCS could be certified with coupled flight director functions. However, 'brownout' mishaps in dense, recirculating sand or dust had taken a heavy toll in helicopters in Operation Enduring Freedom (OEF) and Operation Iraqi Freedom (OIF), and a coupled flight director afforded pilots low-speed cues to prevent lateral drift and catastrophic rollover in zero-visibility landings.

A combined test team including ATTC, the cargo helicopter program manager, Aviation Engineering Directorate, Boeing Rotorcraft, and Rockwell Collins completed DAFCS testing and cleared the coupled functions before the 4th Infantry Division – the second unit to receive the CH-47F – deployed from Fort Hood, Texas, to Iraq. Pilots of the 2nd Battalion, 4th ID, finished their CH-47F transition training in March 2008. A new DAFCS software drop arrived in April, and the helicopters embarked by sealift in May.

## Flight control system

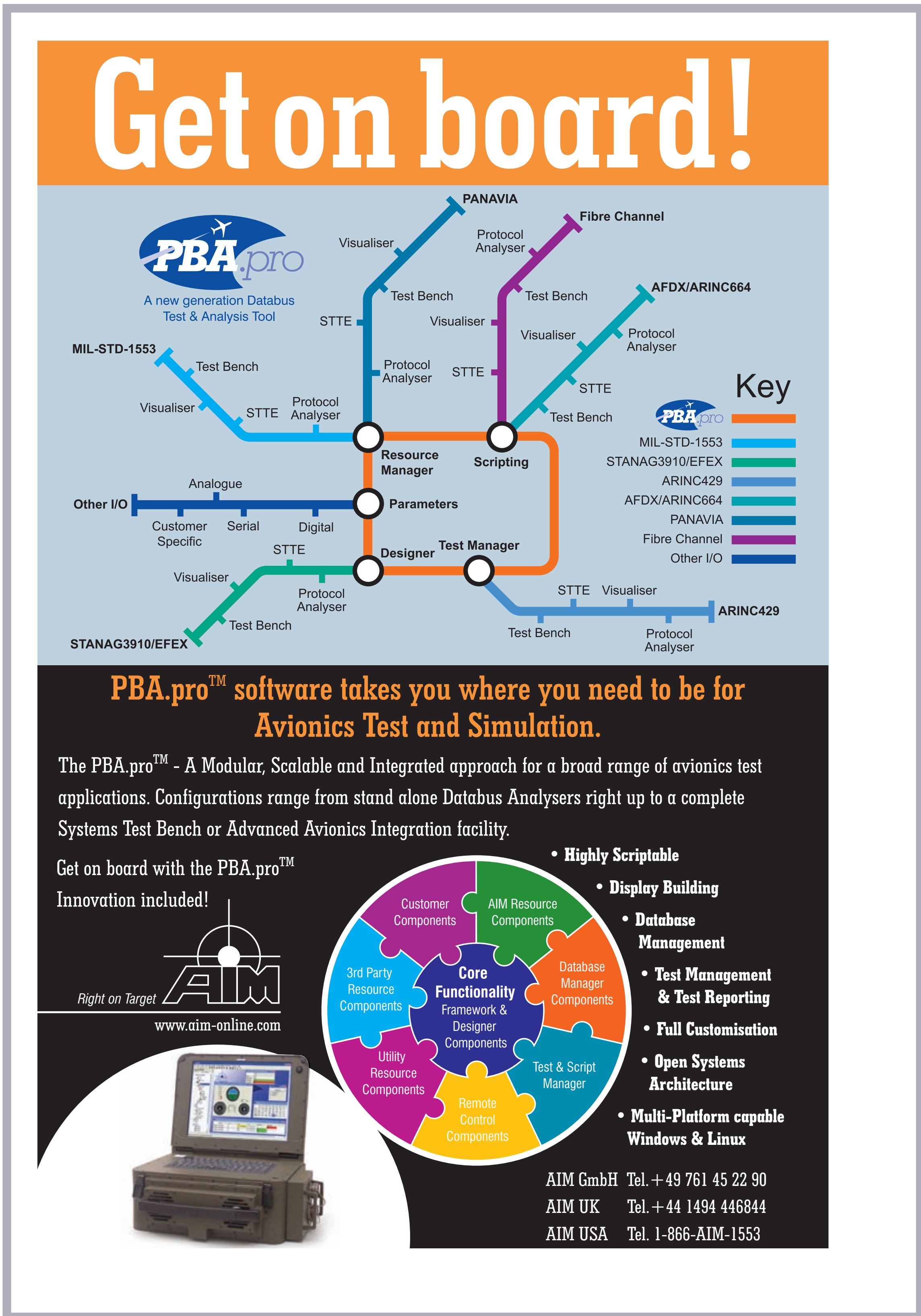
CH-47F pilots of the 4th Infantry Division flew more training hours in Kuwait, and about three weeks in Iraq made them proficient with the CAAS cockpit in operational theater. Every CH-47F pilot practiced brownout landings in the Camp Taji training area, starting at 100ft and flying to dust-blind landings. ATTC test pilot Sean Magonigal admits, "The first time I did it, I was climbing out of my seat. I did not want to trust that DAFCS system. My proprioceptive cues were certainly not lining up with what the aircraft was doing."

Ultimately, the enhanced flight controls were engaged and ready to take over every landing in good or bad conditions. "When you did encounter a brownout situation, having that DAFCS in the low-speed environment was just great for your confidence," says Magonigal. The DAFCS enabled pilots to fly a coupled approach to a 50ft hover in brownout and 'beep' the aircraft to the ground with a collective switch.

DAFCS also offered a three-axis autopilot in cruising flight and other assisted modes to pilots flying over featureless desert at night. In his first week in theater, CW4 Magonigal grew spatially disoriented in a turn while following a CH-47D to Fallujah, and quickly used the DAFCS to recover. Other CH-47F pilots came to use the coupled flight director at least one way on all missions.

Like most Chinook pilots in Iraq, Magonigal flew mostly at night. Missions typically launched between 20:00 and midnight, and returned between 02:00 and 05:00 in the morning. "I was flying six nights a week for the first month or so," recalls Magonigal. "After the first six weeks, my pace slowed down to three or four nights a week."

"I was flying six nights a week for the first month or so"

Most Chinook missions mixed passengers and cargo, and most cargo in central Iraq traveled in internal pallets rather than external slings. CH-47F maximum gross weight is 50,000 lb, unchanged from the CH-47D. Typical operating gross weight during Magonigal's tour was about 45,000 lb, but occasionally reached the full 50,000 lb. Mission profiles varied from two long legs of 250 nautical miles each with a fuel stop midway, to six or eight legs of 20 nautical miles flown around Baghdad.

The CAAS cockpit became extremely popular with CH-47F pilots and was envied by visiting CH-47D crews. "It's the situational awareness that comes from digital maps that did it," says Magonigal. "Knowing where you were in relation to borders was a big deal, especially in limited visibility. If you were going within 5km of the border, you had to have something that indicated where you were visually."

'Fat Cow' missions loaded a CH-47F with three internal auxiliary fuel tanks to refuel Chinooks, Black Hawks, or Apaches at forward locations. Mixed aircraft missions paired a CH-47F with a UH-60 for air assaults or high-priority passenger or cargo loads. Magonigal recalls, "As a developmental tester and one of only two aviators in the brigade rated in both the UH-60 and the CH-47F, I was able to help develop the mixed multi-ship mission checklist and briefing." The covert exterior lighting on the CH-47F made the new Chinook the first choice to lead mixed formations moving troops. TACAN helped CH-47F pilots hold formation at night in bad weather.

User notes on how CH-47F pilots used secure FM, satcom, non-secure UHF and VHF radios, and Blue Force Tracker text messaging will be used for future workload assessments. (The CH-47F upgrade in the works will have two integrated AN/ARC 231 multiband radios, a separate back-up non-integrated AN/ARC 231, and two AN/ARC 201D FM/VHF radios.)

### Configured cockpit

Blue Force Tracker (BFT) showed the positions of friendly ground and air units on the CAAS digital map. The icons on the pilot displays helped define 'hot' sectors closed to air traffic but not always identified by radio. In the CH-47F, Magonigal typically turned the ground vehicle icons off to declutter his display, but left artillery icons up to define busy zones around Baghdad. His opinions on cockpit management subsequently helped engineering and cockpit user working groups to shape changes in the CAAS cockpit user interface and software functionality. The Chinook test pilot is also working with the UH-60M Upgrade test team to keep CH-47F CAAS discrepancies out of Black Hawk operational software.

Future CH-47F upgrades will enable IFR operations without ground-based navigation aids and give the army cargo helicopter an integrated RNAV that will meet FAA requirements. Test pilot Magonigal says, "Based on how we did operations in Iraq, I have suggested that tactical profiles be incorporated into the testing of these features."

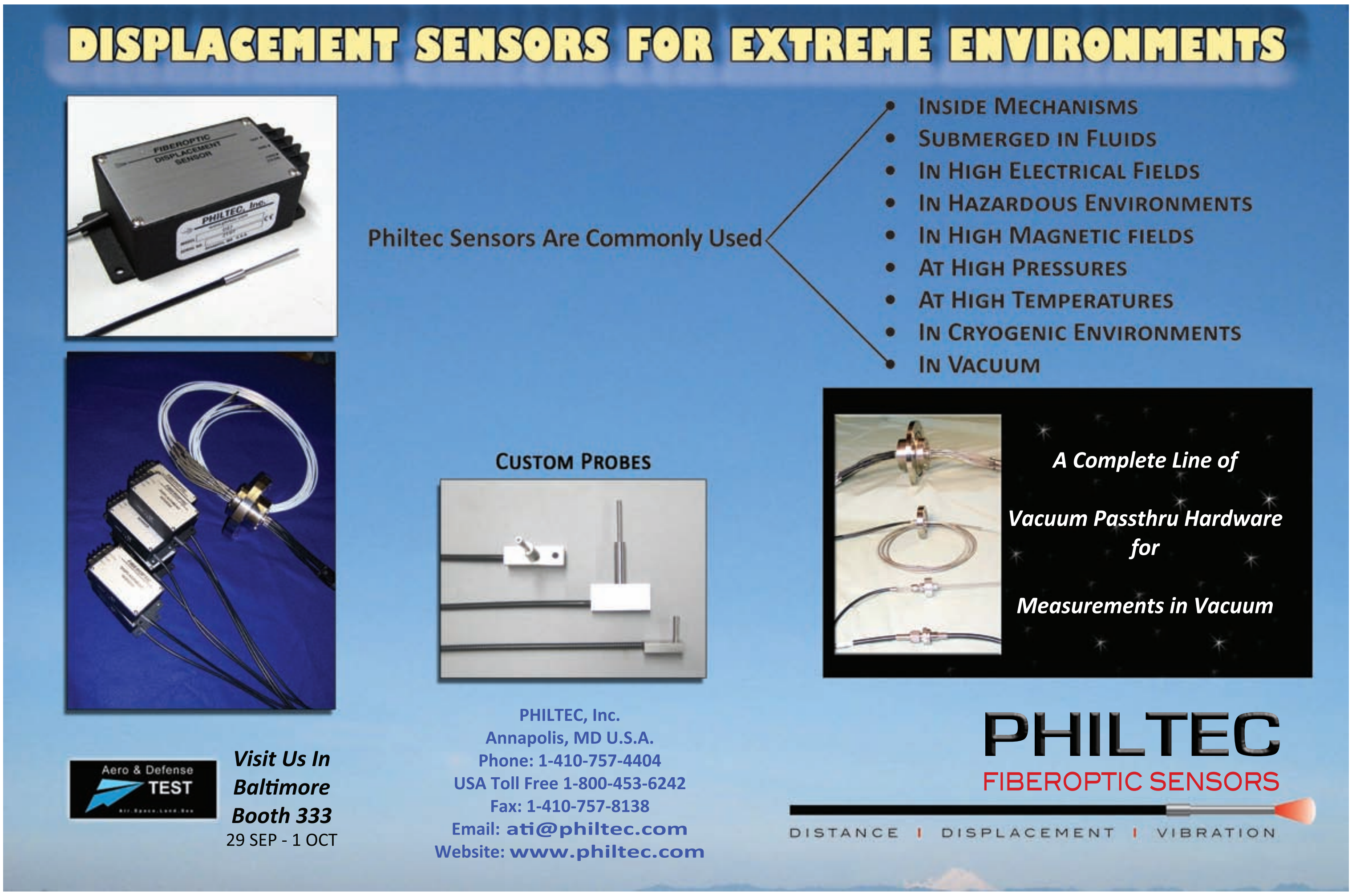
Back in Alabama, the ATTC test pilot flew infrared engine suppressor tests on both the CH-47D and CH-47F. He explains, "I have also been able to provide utilization information to PM Cargo as they analyze the types of profiles in which the CH-47 infrared exhaust suppressor will be used and what, if any, operational restrictions should be imposed."

**Soldiers from the Combat Aviation Brigade, 4th Infantry Division, Multi-national Division – Baghdad, sling load a 10,500 lb up-armored Humvee under a CH-47F during a training exercise at Camp Taji (4th ID CAB)**

During the ATTC pilot's deployment, the 13 CH-47Fs assigned to the 2nd Battalion, 4th Aviation Regiment, flew about 600 hours per month with better than 80% mission availability. The unit routinely launched six CH-47Fs a night and never canceled a mission for lack of available aircraft.

The Army Chinook fleet still awaits a Health and Usage Monitoring System, and the first CH-47Fs deployed had no special maintenance data collection system. The army cargo program manager (PM) nevertheless reported in spring 2009 that the two CH-47F units so far sent to OIF had maintained mission-capable rates of 82.4%. With 68 aircraft delivered by the summer, two units in Iraq, and one in Afghanistan, Boeing reports overall fleet Operational Readiness Rates of around 91% for the year.

Pilots returning with the 4th Infantry Division will eventually contribute to an after-action report that may help Boeing and the Army to refine the newest Chinook. User feedback from the first deployment CH-47F was very positive. According to test pilot Magonigal, "There were a lot of little things the guys wanted, but in the end they wouldn't trade it." ∎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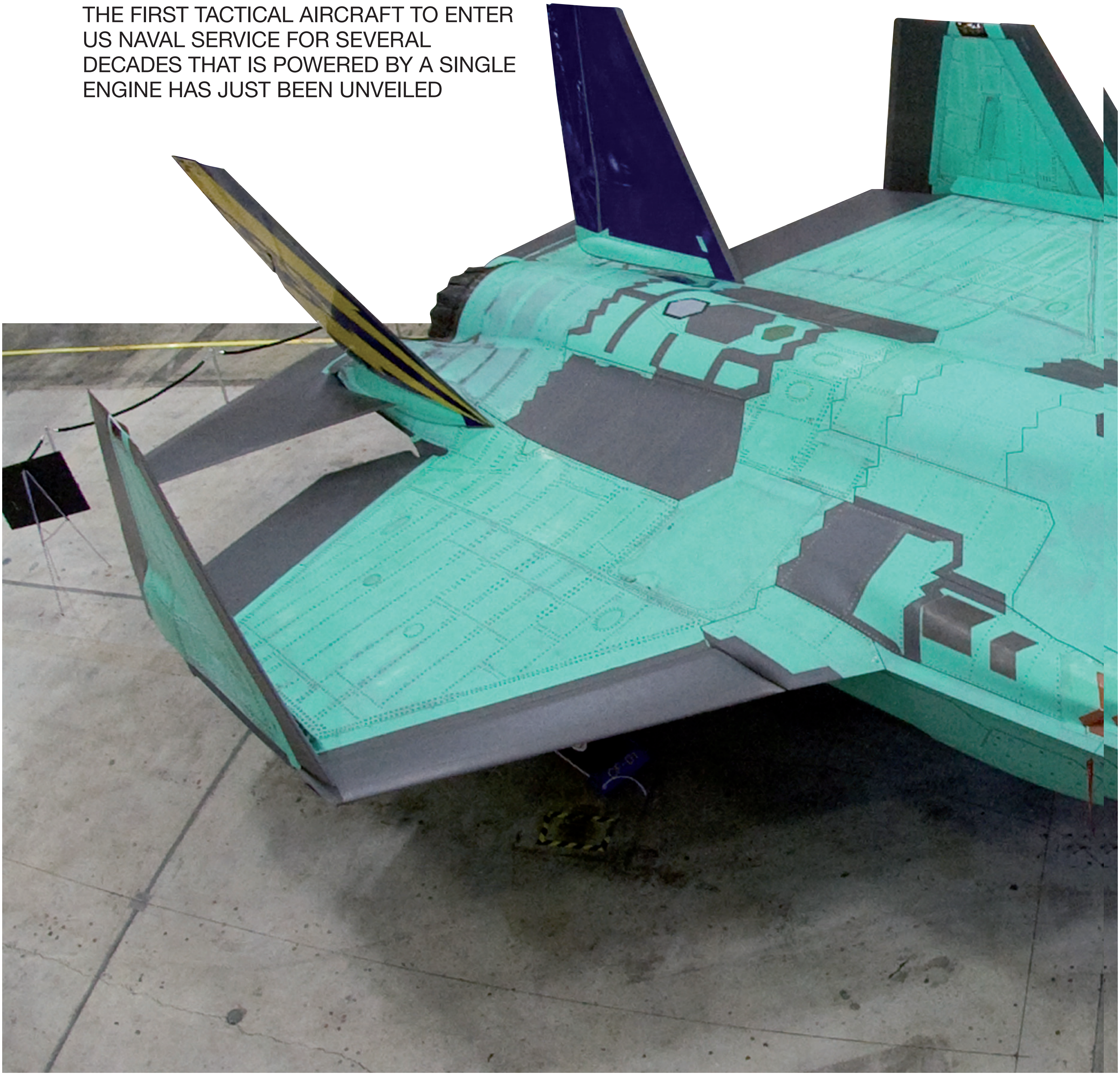
THE FIRST TACTICAL AIRCRAFT TO ENTER US NAVAL SERVICE FOR SEVERAL DECADES THAT IS POWERED BY A SINGLE ENGINE HAS JUST BEEN UNVEILED



BY STEVE WEATHERSPOON

On July 28, 2009, the US Navy rolled out its first-ever stealth strike fighter, at Lockheed Martin's mile-long production facility in Fort Worth, Texas. Top US Navy leadership, along with reserve and retired navy personnel who work at Lockheed Martin, were on hand to celebrate the unveiling of the F-35C Lightning II (also known as the Joint Strike Fighter).

"The JSF will show the world that our sailors will never be in a fair fight because this airplane will top anything that comes its way. It will give our sailors and pilots the tactical and technical advantage in the skies, and it will relieve our existing aircraft as they age out," said Admiral Gary Roughead, the US Navy's chief of naval operations, as he welcomed the new aircraft.

The F-35C represents the next stage of tactical aircraft modernization for the US Navy following the F/A-18E/F Super Hornet. Versions of the F-35 will also update the tactical air forces of the US Air Force, US Marine Corps, and the military services of the program's partner countries, including the UK.

The US Department of the Navy currently plans to buy 680 F-35s, to be split between US Marine Corps' F-35B short take-off/vertical landing variant (also to be used by the Royal Air Force and Royal Navy) and US Navy F-35C carrier variant. For the US Navy, the F-35C will replace F/A-18Cs and will operate with F/A-18E/Fs currently being procured, to provide the future TACAIR striking power from US carrier flight decks. The F-35C is scheduled to make its first flight in late 2009 and will reach initial operational capability in 2015.

Tom Burbage, a former navy test pilot and the vice president and general manager of F-35 program integration for Lockheed Martin, has recognized the US Navy leadership for being fully engaged in the F-35's development, and "actively working to define joint and coalition tactics that will exploit this platform in ways we've never envisioned".

## The first one

The first F-35C will undergo a wide-ranging series of ground tests before its first flight. The aircraft, designated CF-1, is the ninth F-35 test aircraft to be rolled out, and joins a fleet of F-35A (conventional take-off and landing) and F-35B (short take-off/vertical landing) variants that have logged more than 100 flights.

The July roll-out of the F-35 carrier variant was the culmination of years of conceptual and strategic thinking, along with the actual development of the aircraft and its associated systems. Even at the outset, F-35 design challenges were impressive. The first was to design a weapon system that will be good over a 40-year service life. The system had to be dominant in a worldwide spectrum of threats and levels of conflict, and serve the needs of three US services and numerous international partners. All this had to be done without compromise or penalty for each individual service, at an unprecedented low cost of approximately US$49-60 million per unit. The terminated TACAIR programs of the late 1980s and 1990s (A-12, AX, AFX, Multirole Fighter) showed that a new aircraft, no matter how capable, would never exist if it was too expensive or too high risk. These cancellations also made the need to field a replacement all the more urgent.

The Joint Strike Fighter Program Office ran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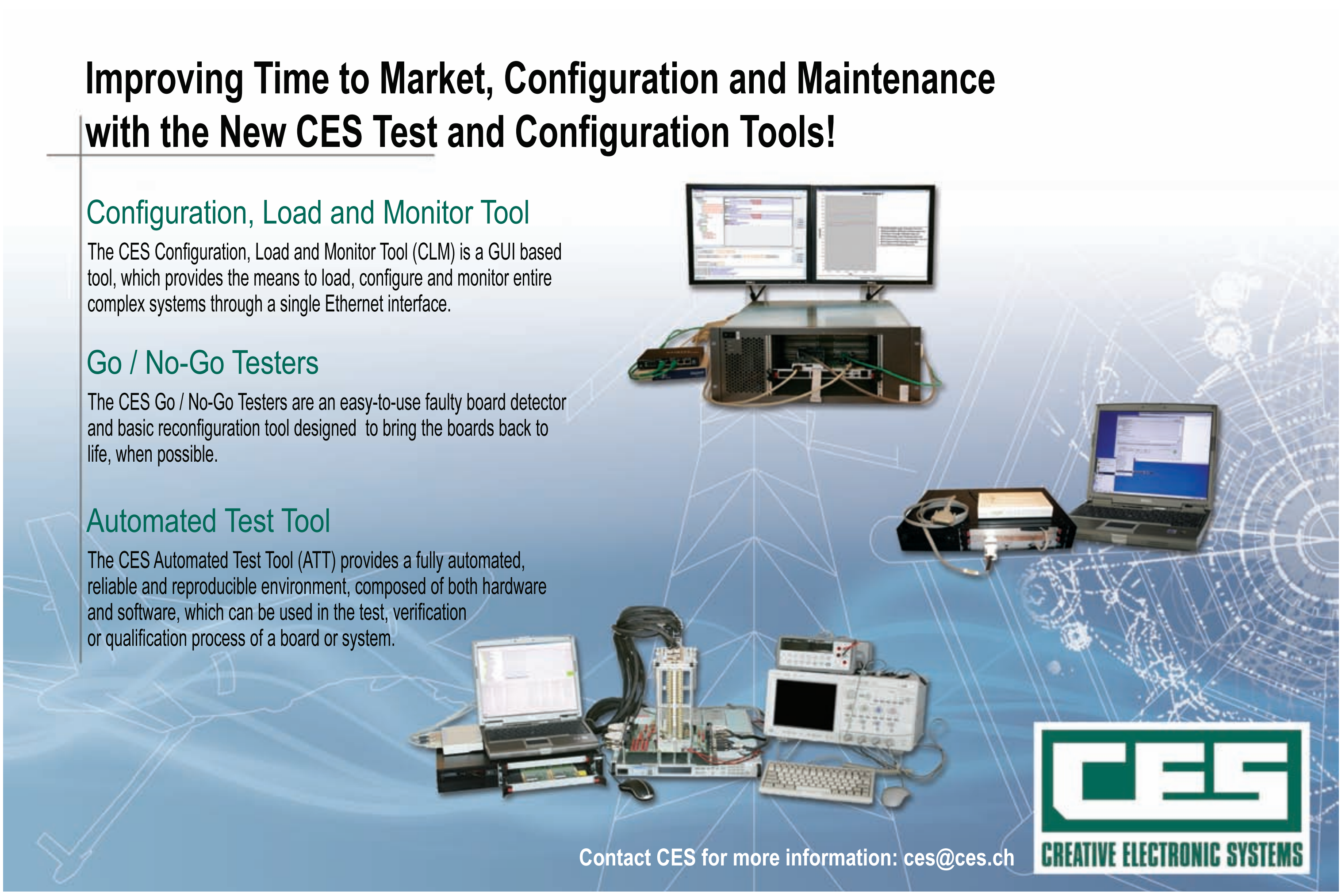
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the requirements process, and over several years, US Navy, US Marine Corps, US Air Force, Royal Air Force, and Royal Navy operators sat down together and hammered out what the airplane should do and at what cost. Rather than specifying a system, they specified what they wanted to do, and it basically boiled down to a single operational requirements document (ORD) that defined common war fighting capabilities and unique basing requirements for each of the services. This, of course, included very specific carrier suitability requirements for its naval role. The ORD was approved by the Joint Requirements Oversight Council in October 2001 and a final contractor team, led by Lockheed Martin, was selected to develop the F-35 the same month.

Lockheed Martin was teamed with Northrop Grumman, BAE Systems, Pratt & Whitney, and Rolls-Royce to meet the design challenge. This team brought vast experience and technology base encompassing all the critical elements of the F-35 Program – low cost, stealth, advanced sensors, and carrier suitability.

The three F-35 variants are highly similar for affordability and interoperable war fighting effectiveness, and all services get the affordability benefit of a 3,000-unit production base and learning curve. The F135 powerplant, provided by Pratt & Whitney, is common in the USAF and USN versions, producing about 25,000 lb thrust in military and is in the 40,000 lb thrust class in afterburner. The same core powerplant runs a shaft-driven lift fan in the STOVL version for short take-off and vertical landing operations. An F136 powerplant, under development by a General Electric/Rolls-Royce consortium, will be interchangeable with the F135 system.

> **"The major visible difference is the larger wing area and larger control surfaces"**

## Naval differences

The fuselage and weapon system of the carrier version are almost identical to the other two variants. The major visible difference is the larger wing area and larger control surfaces for low carrier approach speed and outstanding low-speed flying qualities. The wingspan of 43ft is reduced to 35ft using a wingfold for compact spotting and handling aboard ship. What is not so visible is the extra strength of the structure, landing gear, and tailhook to accommodate high-rate-of-descent carrier landings and catapult-launch forces.

The carrier variant of F-35 is 5ft shorter in overall length than the F/A-18 C/D, and nine feet shorter than the F/A-18E/F. Its maximum density spot factor (a measure of the relative space it takes up aboard ship) is 1.16 (relative to an F/A-18C at 1.0 and an F/A-18E at 1.24). Overall carrier suitability requirements for height, deck clearance, elevator compatibility, and servicing spotted tail-over-water are easily accommodated in the relatively compact design.

In terms of performance, a critical key performance parameter (KPP) for the US Navy is to achieve a minimum combat radius of 600 nautical miles on a representative combat profile. With the larger wing and an internal fuel capacity of more than 20,000 lb, the Navy F-35 achieves that requirement. That extra internal fuel not only means more radius, but also means not having to take up weapon stations with external fuel tanks, less reliance on mission tanking, and it converts to longer persistence time supporting troops on the ground and other missions.

Up and away combat maneuverability and speed are in the F/A-18 and F-16 class. Low- and high-speed maneuverability are predicted to be excellent, and top speed is Mach 1.6 at altitude, even with a full internal weapons load of more than 5,000 lb.

As noted earlier, the major deviation from commonality in the whole F-35 family are design features for carrier suitability. The larger wing enables an approach speed of less than 145kts with 10,000 lb of bringback fuel and weapons. Just as importantly, the addition of ailerons, larger horizontal tails and rudders, and an innovative integrated direct lift control (IDLC) assure precise flying.

The designers recognized early on that a relatively slick (due to stealth) configuration combined with a powerful, high rotational mass engine could cause glide-slope control issues. By integrating direct lift control (using drooped ailerons) with the throttle, the pilot is able to make near-instantaneous glide slope corrections, using throttle only to precisely fly the carrier glide slope. Full auto-throttle and Mode I capabilities are also available with the variant.

Outstanding results were demonstrated in more than 250 field carrier landing practice (FCLP) landings with contractor and Navy pilots in the X-35C Navy F-35 test aircraft back in the winter of 2001. Precise controllability and landing structural strength will be key features of the upcoming F-35C flight- and ground-test program.


**The aircraft was modified under contract by BAE Systems at its facility at the Mojave Spaceport**

## CATbird – testbed in the sky

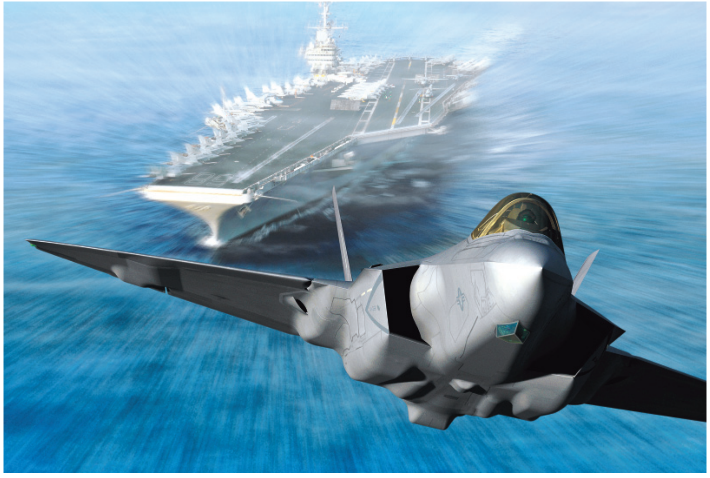
**The Joint Strike Fighter Cooperative Avionics Testbed (CATBird) aircraft completed a two-week deployment to Edwards Air Force Base in April 2009, where it demonstrated the robust qualities of avionics systems being developed for the F-35 Lightning II.**

**The deployment included successful airborne testing of the F-35 Lightning II radar, electronic warfare and communications/navigation/identification systems and more than 2.8 million lines of mission systems flight software. The testing reduces hardware and software risks that cannot be carried out in ground laboratories and individual sensor testbeds before the testing of the first mission systems-equipped F-35 aircraft later in 2009.**

**CATBird, a highly modified 737 airliner equipped with the integrated F-35 mission systems suite, conducted 10 mission systems test flights, successfully evaluating the radar, CNI, and EW infrastructure and sensor function.**

**"Performance of the aircraft infrastructure and onboard sensors exceeded my expectations and gives the test team added confidence that we are on track to fly the first mission-systems F-35 aircraft this summer," says Doug Pearson, Lockheed Martin vice president of the F-35 integrated test force. "The deployment was superbly supported by the Air Force Flight Test Center."**

**Airborne avionics testing onboard the CATBird and other flying testbeds is underway concurrently, with ongoing validation in ground-based laboratories that have already amassed tens of thousands of hours of testing time.**



The US Navy will be the sole user for the carrier variant

> "Once the target is designated, the F-35C will be capable of delivering a wide array of weapons"

## Sensor and weapon package

Lethality is the area where the requirements writers expected the greatest breakthrough capabilities. With more than 80% of the F-35 targets expected to be moveable or moving, the F-35 must have a very strong, autonomous sensor suite. The Lightning II employs the most powerful and comprehensive sensor package ever incorporated into a fighter. As well as the onboard sensors, F-35 will have a full digital, reprogrammable communications, navigation, and inertial (CNI) suite, including UHF, VHF, full Link-16, and a new, low probability of intercept multifunction advanced data link (MADL) with high bandwidth for rapid transmission of imagery and tactical information among F-35s.

Testing of all F-35 sensors is currently being conducted in ground-based and airborne laboratories, including the Cooperative Avionics Testbed (CATbird), a highly modified Boeing 737 incorporating the entire F-35 integrated avionics suite, and an F-35 cockpit. Later this year, the first avionics-equipped F-35 aircraft will begin flight tests.

Among the top capabilities required in the F-35 is all-weather autonomous target detection, ID, targeting, and attack. An advanced electronically scanned array radar from Northrop Grumman is the heart of the system. It enables simultaneous air-to-ground and air-to-air operation, with sufficient range and resolution to leverage modern stand-off weapons. Ground moving target, inverse synthetic aperture radar, and passive modes are also available.

An electro-optical targeting system (EOTS) located internally will provide long-range high-resolution targeting infrared imagery, laser target designation, and battle damage indication capability. The technology is low-risk medium-wave IR imagery that is based on the USAF Sniper pod. Since the EOTS is mounted internally, it does not take up a weapon station or greatly add to the drag or signature of the aircraft.

The F-35 will be a true multimode sensor platform, seamlessly transitioning between sensors to provide long-range targeting and ID for the pilot.

Once the target is designated, the F-35C will be capable of delivering a wide array of weapons from four internal and six external weapon stations. Each of the two internal bays is designed to carry a 2,000 lb class-size weapon (JDAM, JSOW, MK-84) plus an AMRAAM for self-protection. External stations provide weapons flexibility, both air-to-air and air-to-ground.

## Maintenance

The maintainer was not left behind in technology applied to F-35. Half of all the F-35 KPPs are focused on reducing operating and support costs by demanding high sortie generation, high reliability, and minimal maintenance footprint. Mission reliability must exceed 95% and overall reliability and maintainability must enable manpower reductions with higher availability. F-35's reliability over legacy platforms must double or triple to meet minimum requirements. Some example features that improve reliability are inlets with no moving parts slots or boundary layer diverters, simple forward-retracting landing gear, simple leading and trailing edge flaps (no slots or boundary layer control), reduced fasteners, and an electronically scanned array radar with no moving parts to wear out or repair over the service life of the aircraft.

Hand-in-hand with increased reliability, improved maintainability on the flight deck will generate more combat sorties. General routine maintenance will be accessed from the flight deck without using stands or ladders. Onboard prognostics and health management (PHM) information is downlinked and information is sped through the entire support system to assure high sortie-generation rates.

Some of the most important technology on F-35 is improved low observable (LO) materials and integration. The best way to reduce LO maintenance aboard ship is to eliminate the requirement, so the vast majority of routine maintenance occurs behind naturally opening doors or access doors that require no LO restoration. New durable LO materials will also greatly contribute to reduced maintenance.

By leveraging commonality with a large production base to drive down unit cost, the US Navy is getting a state-of-the-art stealth strike fighter with breakthrough capabilities in adverse-weather target detection and attack, and first-day-of-the-war survivability. This long-range, carrier-suitable, stealth strike fighter will continue to influence world events for decades to come. ∎

*Steve Weatherspoon is deputy director of F-35 test and verification for Lockheed Martin*

## Survival of the most complex

Survivability is the area that sets apart fifth-generation strike fighters such as the F-35C. Stealth is a fundamental element of F-35 survivability, but certainly only one of many cards for the pilot to play to survive in the 21st century advanced SAM environment.

First is a beyond-the-horizon situation awareness (SA) available through Link-16 and other off-board sources. Then long-range, accurate emitter location capabilities fix threat locations, and enable rapid onboard route adjustments or countermeasures as necessary.

In-close, airborne, and ground-launched non-emitting threats are detected by infrared (IR) detectors that provide full spherical coverage around the aircraft and allow adequate warning for maneuvers or countermeasures. F-35s complete the tool kit for survivability with a suite of onboard countermeasures, outstanding maneuverability, and vulnerability hardening features.

Technology improvements are also seen in the pilot's displays and information. The F-35 cockpit centers on information displayed on an 8 x 20in glass display panel that is reconfigurable from one to dozens of color displays. A helmet-mounted display provides the pilot off-axis cueing, a 'virtual' head-up display that is projected onto the helmet visor, and, integrated with the distributed aperture system, a night-vision capability that eliminates the need for separate night-vision devices. The innovative F-35 helmet-mounted display is already being employed in early F-35 test flights.

Active noise reduction, directional audio warning, voice actuation, digital video, and data and audio recording round out the technologies incorporated to reduce pilot workload and enhance training.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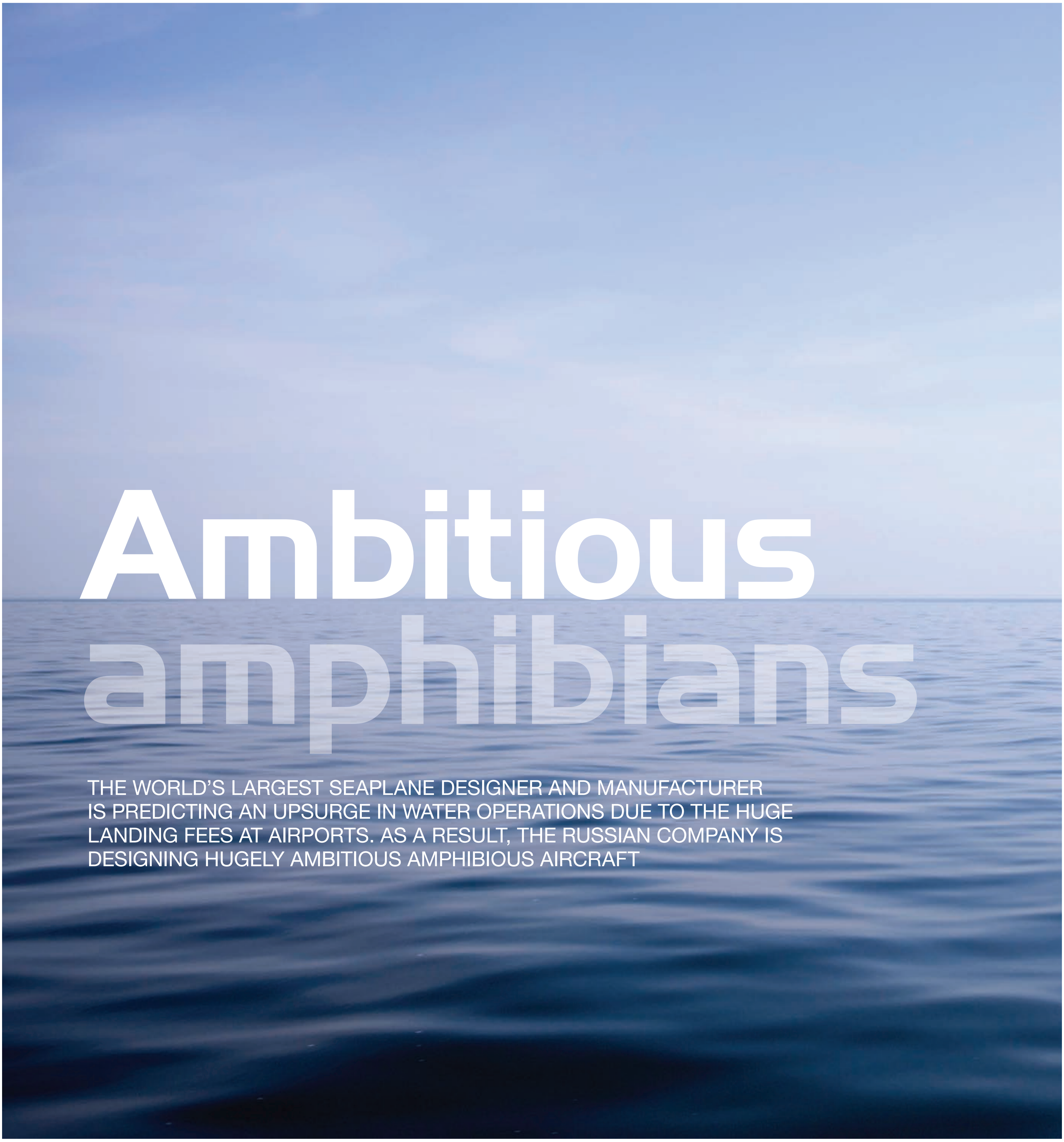

# Ambitious amphibians

THE WORLD'S LARGEST SEAPLANE DESIGNER AND MANUFACTURER IS PREDICTING AN UPSURGE IN WATER OPERATIONS DUE TO THE HUGE LANDING FEES AT AIRPORTS. AS A RESULT, THE RUSSIAN COMPANY IS DESIGNING HUGELY AMBITIOUS AMPHIBIOUS AIRCRAFT


BY VICTOR A. KOBZEV

The 1930s and the beginning of the 1940s were the golden age of hydro-aviation. The development of jet aircraft then took center stage, and interest in hydro-aviation declined so much that it was almost forgotten. But the Beriev Aircraft Company, based in Taganrog, Russia, continued to design and operate seaplanes and amphibious aircraft and gain manufacturing and operational experience.

Amphibious aircraft are a reliable form of transport used throughout island and coastal areas, as well as in regions with lots of lakes, rivers, or reservoirs. They do not need expensive runways, and seaplane port support and equipment costs are much less than the huge costs associated with the construction of airports on land with their paved runways and facilities. Special equipment has already been designed and tested so that seaplane ports can also be used during the night.

Today problems relating to environmental pollution and safety are becoming increasingly important. Amphibious aircraft can provide an efficient marine-based transportation system that does not add to pollution and respects the natural ecology of a region. Many of these sensitive areas possess important mineral resources, as well as marine resources that are being commercially exploited, and in this context, marine search and rescue capability is a high priority for those working in these environments.

Beriev has a large design office. It produces all classes of amphibious aircraft from the lightweight craft with a take-off weight of less than two tons up to super-heavy aircraft with a take-off weight of more than 100 tons.

## Radical program

Today, Beriev is implementing a radical program to develop advanced amphibious aircraft that meet 21st-century requirements. In particular the company has developed the Be-200 multipurpose amphibious aircraft and the Be-103 light multipurpose amphibious aircraft. The Be-101 light amphibious aircraft is being designed and constructed at the moment, and the Be-112 commuter amphibious aircraft configuration is being prepared.

The Be-200 amphibious aircraft has good market prospects. In its basic modification it is intended for fighting forest fires using airborne water or retardants. The aircraft can also be used for cargo-passenger transportation, search and rescue missions, environmental monitoring, and patrolling maritime borders and trade zones. The Be-200 has been certified to be in compliance with the Russian AP-25 airworthiness regulations.

Based on the Be-200 aircraft, the Be-200ES modification was specially designed for the Russian Ministry for Emergency Situations. It is fitted with equipment designed to deal with a variety of tasks, including the locating of emergencies and conducting search and rescue missions on the water and in coastal zones, as well as firefighting and cargo transportation. The Be-200ES amphibious aircraft was certified in 2003, and has been employed by the Russian Ministry for Emergency Situations since then.

The multirole Be-200 can be configured as an amphibious water drop firefighting aircraft, a freighter, or as a passenger aircraft



**Above: If it enters service, the Be-2500 will become the largest aircraft in the world**

**Left: The Be-101 amphibian will be equipped with a piston engine IO-550-N from Teledyne Continental Motors, USA**

Based on the Be-200ES amphibious aircraft, Beriev has already worked out the technical data required for the Be-210 passenger aircraft. Cargo and patrol modifications are also in the process of development. In close cooperation with EADS, work is going on to achieve European aircraft standards certification.

The Be-200 has been demonstrated in France, Germany, Italy, Greece, Malaysia, and China. It has taken part in fighting forest fires in Russia, Italy, Greece, Indonesia, and Portugal. It was flown by French, US, and Italian pilots, and all approved its performance and capabilities. In 2008 the aircraft was supplied to its first foreign customer, the Azerbaijan Ministry for Emergency Situations.

## Light amphibians

The latest generation Be-103 light amphibious aircraft is intended to be used in coastal and island zones and in regions with many rivers, lakes and water reservoirs. It can be used as a multitask craft for patrols over forest areas, borders, and water basins, and can also be employed for environmental status monitoring, follow-up and interception of poachers' boats and motor boats, as well as maritime search and rescue operations.

The Be-103, currently being operated by Beriev, was certified to Russian AP-23 and US FAR-23 airworthiness regulations as well as complying with those of Brazil, China, and Europe. Produced at the KNAAPO company in Komsomolsk-on-Amur, the craft has an unusual aero-hydrodynamic layout with a low water-displacing planing wing. This avoids the need for high-lift wing devices and wingtip floats.

The Be-101 light amphibious aircraft is being intensively developed at the moment. It is intended for commercial operations, and can also be operated as a private aircraft for general-purpose aviation. It can take off from airports and airfields on land, as well as from small lakes or reservoirs with a simple, unsophisticated ramp. The Be-101 is partly constructed of composites and is being used to test how the composites survive exposure to salt water over a long period of time.

## Heavy seaplanes

The Be-112 is a promising multipurpose amphibious aircraft, and is designed to be used primarily by regional and local airlines in regions with poor transportation infrastructure. It can be operated from airfields and on water, where ramps are required to enable fuelling and maintenance to be carried out on the shore. The aero-hydrodynamic design of the hull incorporates a broad aft portion and a cargo ramp that expands the aircraft's transportation capabilities and simplifies mooring.

Beriev is now considering projects for a giant amphibious aircraft with a take-off weight of more than 1,000 tons (the largest fixed wing aircraft in the world, the An-225, has a maximum take-off weight of 600 tons). In future, these metal monsters of the air will be able to compete equally with standard aircraft and sea-going cargo vessels, using available sea port infrastructure. Its development will require radically new aero-hydrodynamic designs, some of which, designed by Beriev, are already being used in the Be-103. The Be-2500 transport seaplane is an ongoing project that will show the advantages of super-heavy flying vehicle concepts.

Beriev has a separate division that operates civil amphibious aircraft, and it provides technical and post-sales support of aircraft at customer facilities and in its own Be-200 and Be-103 maintenance facility.

The company's strategy is to develop a multi-industry 'closed-loop enterprise', employing extensive cooperation, to cover design, production, testing, maintenance, repair, retrofitting, and utilization of aircraft. ∎

*Victor A. Kobzev is the director general and general designer of Beriev Aircraft Company, Russia*

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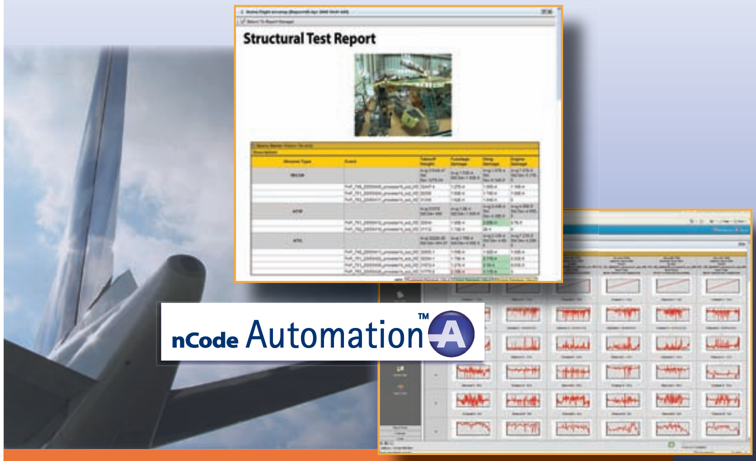


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# The Poseidon adventure

EARLY DEVELOPMENT OF THE LATEST ANTI-SUBMARINE AIRCRAFT WAS NOT EASY, BUT THE METAMORPHOSIS OF A BOEING 737 INTO THE P-8 POSEIDON IS NOW A SUCCESS


BY CHRISTINE VELARDE

The Boeing P-8 Poseidon is the latest military aircraft developed to conduct anti-submarine warfare and engage in electronic intelligence – and is built from a commercial aircraft. Using the body of the Boeing 737-800 and the wings of the 737-900, Boeing is leading the team building the new aircraft for the US Navy.

"The 737 is probably the most successful commercial aircraft of that size and type ever made," explains Bob Feldmann, Boeing vice president and P-8 program manager. "It's the workhorse of many of the world's airlines. For the (bid) competition in June 2004, Boeing offered a leveraging of the 737 with a large commercial base and a very mature airframe and airplane-engine combination to the US Navy. They saw the value in that, and so when you look at the P8, it's a very stable, very mature, very capable aircraft with design modifications to it."

In order to turn a commercial airplane into a military aircraft, Boeing had to make modifications to add to its capability. The design team did not make downstream modifications, but planned into the design the changes needed to give the P-8 teeth. "The changes 'beef it up' in certain areas, and we put a bomb bay or a weapons bay in it," explains Feldmann. "Basically, we modified at the design level all the drawings, so that when the airplane comes off the production line, instead of a 737-800, it's a P-8, fully built and assembled with all the weapons and structural capabilities built into it.

"We took that very proven 737-800 fuselage and put on it the 737-900 wings. A 900 wing is not substantially different from the 800 wing, but it provides extra range and capability. Then we take the basic systems and propulsion from the 737 and built around that with design modifications, so that when you go down the production line, what comes off the other side is an airplane that is fully capable structurally for a Navy mission," says Feldmann.

Changing major components from one aircraft to another is fairly common and "a relatively straightforward process", says Feldmann. Even switching the type of wings on an aircraft to another model is not considered very risky, as the components have been thoroughly tested and used in real world situations for years. The Boeing Business Jet is one recent example – the BBJ1 is based on a 737-700 airframe, with elements from

# Poseidon heads to the subcontinent

January 1, 2009, the Indian government signed a contract with Boeing for eight P-8I aircraft – a derivative of the Poseidon – built to Indian Navy specifications. India is the first international customer to place an order, although the Royal Australian Air Force has also made inquiries.

"When you look at the nations that have a significant coastline, and maritime needs, there is a need for the P-8," Feldmann says.

The P-81s are replacing the Indian Navy's Tupolev Tu-142M maritime surveillance turboprops at a cost of US$2.1 billion. Boeing will deliver the first P-8I within 48 months of the contract signing, and the remaining seven by 2015.

The P-8I will be equipped with torpedoes, depth bombs, and Harpoon missiles. Reports suggest the P-8I aircraft will also boast magnetic anomaly detection (MAD) equipment. "The Indian Navy had a competition, which we won, to provide eight aircraft for their long-range maritime anti-submarine marine-warfare programme, LRMASW," says Feldmann. "They are very similar to the US Navy systems, but there are a few changes that the Indian Navy asked us to incorporate, such as an aft-facing radar that we'll install in the belly of the aircraft, and some specific Indian Navy-developed equipment.

"The interesting thing in this is that we have never done business with the Indian military before. Two or three years ago, policy changed and now US companies can potentially be involved in the defense needs of India. It's a new customer to us and we need to understand that customer, make sure that we know what they expect; and provide them that," explains Feldmann.

Spirit delivered the first fuselage to Boeing in late March 2008 and final assembly of the aircraft began the same day in Renton, Washington

the 737-800 included, while the BBJ2 and BBJ3 are based on the 737-800 and 737-900ER series, respectively. "It takes a considerable amount of work because this airplane flies in a different environment than a standard 737," explains Feldmann. "The aircraft spends much more time at lower altitudes and in sustained and more aggressive maneuvering because of its mission. So the planners analyze those environments, analyze the aerodynamics and the loads on the structure, and then decided what structural changes are needed to ensure that the airplane will work within those environments. It is a considerable thing to take this 737 design and then change it so that in-line you're building P-8s right off the line."

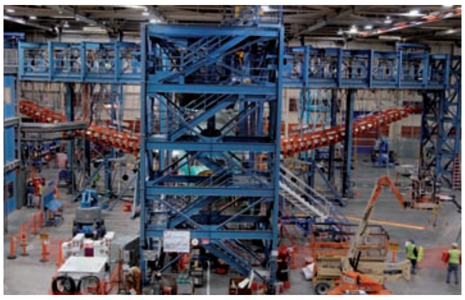
## Design changes

The design changes were made to accommodate the many military needs of the P-8, as the aircraft has been designed to handle a variety of military missions. "The P8 is a maritime patrol aircraft," says Feldmann. "The role of the P-8 is to provide anti-submarine capability and anti-surface war front capability and surveillance and reconnaissance. So there are three major missions that the P-8 will have, over the oceans or over land as a surveillance asset." Boeing worked with the US Navy to ensure that the aircraft would be fully equipped with all necessary equipment to handle any of its many mission types.

"The biggest structural change was that we put a weapons bay in the aft fuselage of the aircraft, which can carry up to five torpedoes and two weapons stores. There are bi-fold weapons bay doors that have been included. We have also added pressure boxes fore and aft for electro-optical infrared sensors, and a turret that deploys in and out of the aircraft with an electro-optical infrared camera system," says Feldmann.

"There are structural modifications from nose to tail at various places where the green structure of the 737 needed to be beefed up in order to exist in the different environments that the Navy flies in. We've also added auxiliary tanks in what used to be the baggage compartment of the airplane to carry fuel for the extra range that's needed.

"A number of antennas and other systems installations transform the interior into a P-8. The interior of a P-8 will have 10 operator stations, with racks of equipment such as radar, electronic warfare systems, and buoy launcher systems, and a very small crew area – much different to the



commercial interior. So with those changes also come wiring and air-conditioning modifications to cool the equipment that you're carrying. This is a military aircraft with a full system of mission-systems avionics in it," explains Feldmann.

## System integration

The P-8 has also been designed to operate in conjunction with the Broad Area Maritime Surveillance UAV. The aircraft is interoperable with UAVs and with many other US Navy systems and systems from other military organizations.

"The P8 has the ability to control UAVs, so the aircraft can give a UAV directions and



The P-8 can carry up to five torpedoes and two weapons stores

commands," says Feldmann. "Basically it works through the data links that are in the P8 that tie the systems together."

Boeing has been contracted to develop and design five test aircraft for the US Navy, two of which are static test aircraft, and three are flying test aircraft. "We went under contract on June 14, 2004 and we will finish development tests early in 2012," asserts Feldmann. "We are just on the verge of entering the flight test portion of development tests and then there will be an initial operational test and evaluation (IOT&E) in 2012, all aimed at releasing to the fleet initial operational capabilities of one squadron of deployable P8 aircraft in 2013.

"We will go through a standard test program – the US Navy standard test program of the system. The first aircraft about to go into flight test will be in flight test for slightly over two years, doing all the aero, all the loads, all the testing that validates the design. This aircraft will be in the US Navy's inventory 25-plus years so they do a very thorough test program to ensure the airplane meets all their requirements.

"We are about to enter our flight test program and will start with our first aircraft T1, which is an air and 'loads' aircraft – this aircraft has a single purpose in life: it has to clear the aerodynamic and loads envelope for the craft. That aeroplane is about to enter flight testing to check-out all the systems. The T1 aircraft has actually flown once already – when it was finished in assembly, it was flown from Renton Field in Seattle where the airplane was built, to Boeing Field, which is only about five miles away, to finish the instrumentation installation. So that aircraft has already gone through a full check-out of what it takes to clear it for flight, and then a full check-out of all the systems and instrumentation on it; they're finishing that right now," explains Feldmann.

"At the same time, the other two flying airplanes, T2 and T3, are full mission systems aircraft, so they will have the radar and the EO/IR, all of the sensors and mission systems, all the operator stations, everything, and they'll look just like fleet airplanes. Those two aircraft will both enter the flight test program in the spring of 2010. In order to be ready in the spring of 2010, the biggest thing we do is check-out that mission system. So as well as talking about the weapons systems integration lab, or WSIL ('whistle', as we call it), all that equipment is undergoing all kinds of detailed checks of all the software systems inside every one of these subsystems to ensure that when we activate any anti-submarine warfare (ASW) mission, or surface warfare, or Intelligence, Surveillance or Reconnaissance (ISR), that all the systems and electronics work together.

**"A 25,000-hour lifetime is demonstrated in one year"**

"In addition, inside the weapons bay are five launcher systems that will be checked out on T2 and T3. It is a major undertaking in and of itself, and that is ongoing and will culminate in the entry of these two aircraft, T2 and T3, into the flight test program in the spring of 2010.

"In addition, there are two static and fatigue test aircraft. One is called S1, which will never fly and is inside of a huge test tube in the factory right now. It is undergoing tests where we apply loads to ensure that the structure can exist in the expected flight environments. So we bend the wings, twist the fuselage to the structure to ensure that the structure is capable of meeting the loads that it's going to see in flight. We also will test the weapons bay doors, to ensure that the doors open and close and seal the way they should. There will be structural loads applied to the structural backup of those doors, to ensure that as the doors swing open into the air stream, the loads that are applied by the air stream are effectively dealt with and the structure is sound. The test S1 started in May 2009 and it will be ongoing through a significant part of next year.

"We will clear the whole envelope on the ground before it ever encounters it in the air in T1. Those two test airplanes are tied together pretty tightly. The fatigue test aircraft, S1, won't be finished in assembly until the end of this year, and then it will go on to start a two-year fatigue test, where the aircraft is put through a whole lifetime in a year. So a 25,000-hour lifetime is demonstrated in one year; in under two years, it will see two lifetimes. That testing will start the middle of next year as well," says Feldmann.

## Propulsion system

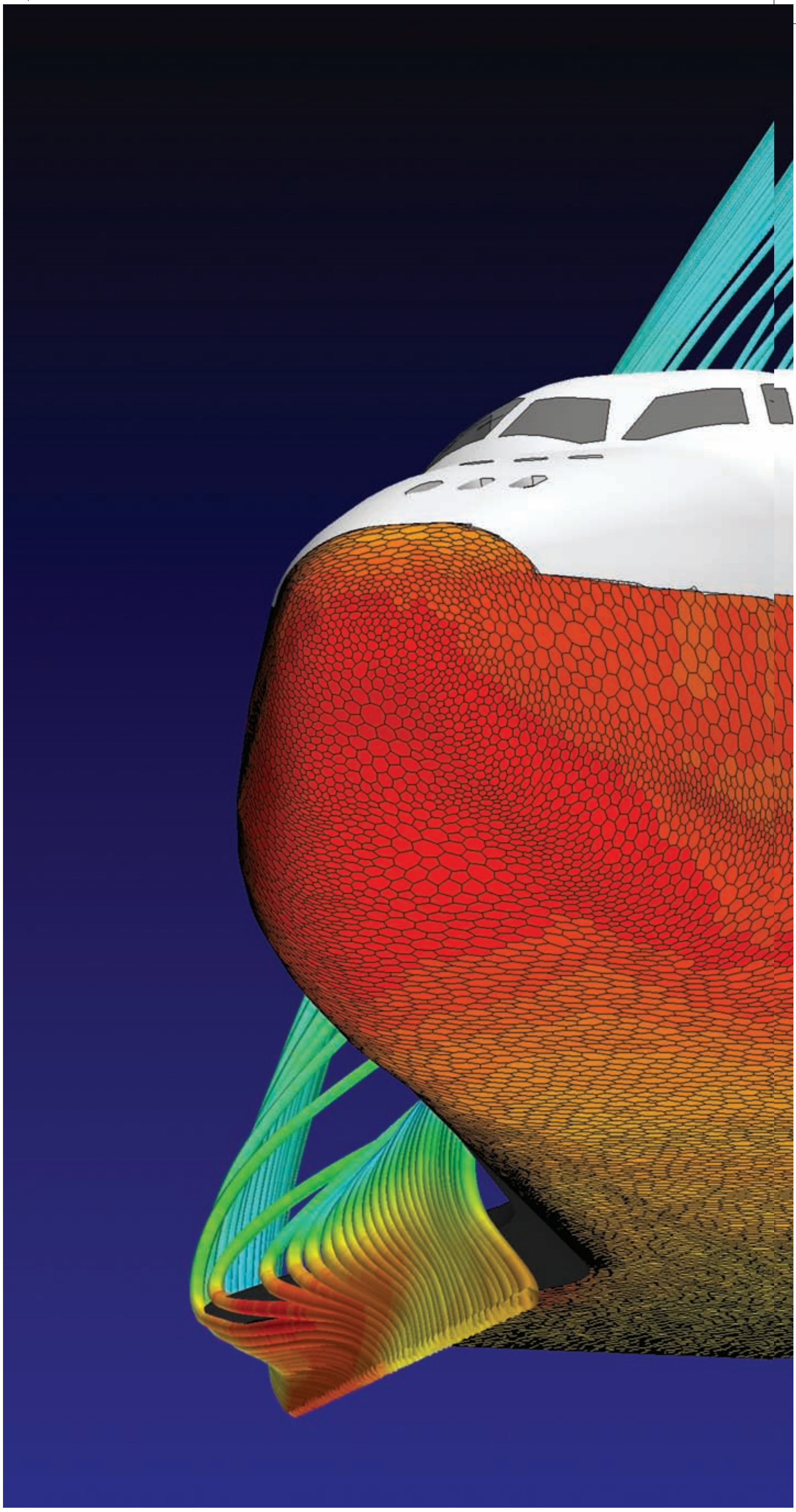
Using an already tried-and-tested 737 body has also taken some of the time out of the testing program, says Feldmann. "We have taken advantage of the 737 database and a proven design wherever possible. When you look for instance at the propulsion system of this airplane, we have a standard CFM56 engine with a higher capacity generator that was developed for our AEW&C (Boeing's Airborne Early Warning and Control aircraft) program. But, comparing the amount of testing that would normally go on a new aircraft for the propulsion system, we have just a small fraction of what would normally be done, because we are taking basically a commercial engine that's already been integrated onto this airframe, therefore we don't have to do significant testing on the propulsion system. There are a number of other systems that come to us 'green' – relatively unmodified or unmodified for the 737 – which generally do not take any or much testing in order to be able to clear it. Boeing and the Navy are taking advantage of the 737 in every possible way we can, where the commercial basis is still there for what's on the P8."

T1's first flight in April was 3.5 hours, completing a full check-out of all the systems, including lowering and raising the gear, engine off and all kinds of maneuvering. The two test flights already completed for T1 and T2 in April and June, were unexpectedly clean.

"We had virtually no squawks, and it really validated to us that the in-line process has built a very sound aircraft," concludes Feldman. "When we put the mission system with it, this will be a workhorse for the US Navy." ∎

# Go with the flow

ALTHOUGH THE FOUNDATIONS OF COMPUTATIONAL FLUID DYNAMICS HAVE BEEN AROUND FOR WELL OVER 100 YEARS, OVER THE LAST FEW DECADES THERE HAS BEEN AN EXPLOSION OF CFD APPLICATIONS FOR AEROSPACE VEHICLE DEVELOPMENT



CFD models were used to simulate the Space Shuttle re-entry. It shows the high angle of attack

BY THOMAS N. RAMSAY

It is no coincidence that the use and, frankly, usefulness of computational fluid dynamics (CFD) has followed the advances in computer technology, and has been a direct function of processor speed. However, although CFD is steeped in the tradition of computational mathematics, most modern users of CFD for aerodynamic simulations consider themselves aerodynamicists who just happen to sit in front of a computer rather than work in a wind tunnel.

In recent years, CFD has been applied widely in many non-aerospace industries, from water treatment to chemical processing, from fuel sloshing to heating, ventilation, and air-conditioning systems, and from bicycles to race cars, and CFD has even been applied to biomedical applications, such as blood flow simulations and rhino surgery research.

CFD is just another tool in the modern engineer's toolbox with inherent strengths and weaknesses that are different from wind tunnel and flight testing. CFD is best used to complement and enhance experimental investigations, not replace them. And of course, maximizing the advantages and minimizing the disadvantages is the key to implementing a successful CFD program.

## What exactly is CFD?

It is numerical flow modeling by solving a set of coupled non-linear, time-dependent, partial differential equations, called the Navier-Stokes equations, named after Claude-Louis Navier and George Gabriel Stokes, two 19th century physicists. CFD enables the solution of real-world problems by the discretization and solving of the Navier-Stokes equations by various numerical methods. This means that the surface geometry must be

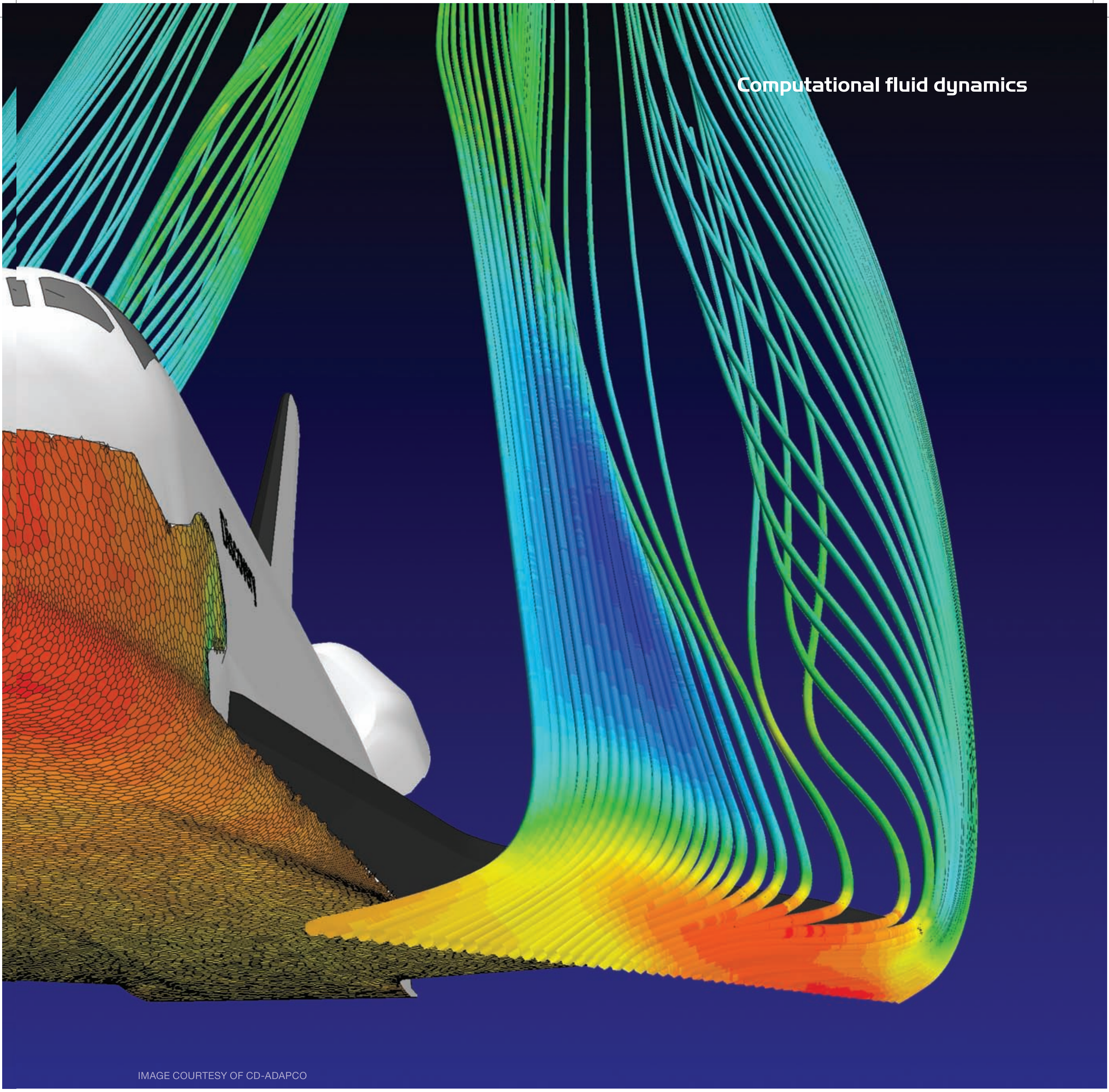


IMAGE COURTESY OF CD-ADAPCO

divided up into small patches, more commonly called a grid or mesh, which typically contains triangular elements. Think of dividing up the surface of an entire airplane into triangles of varying size based upon the local curvature. Thus, smaller triangles are created on the leading edges and larger triangles along the fuselage.

Not only must the surfaces be meshed, but also the fluid – typically (but not exclusively) air – must also be meshed or discretized, which is ultimately the area of interest. Current CFD codes enable these volume cells to be any number of shapes, such as tetrahedrons, prisms, and pyramids. By discretizing the problem, though, errors are introduced, which must be managed in order to find an accurate solution. Suffice it to say that there is a lot of mathematics and code development behind these methods. This form of CFD is called direct numerical simulation (DNS) and is capable of finding a solution to almost any conceivable flow field – you could even combine and discretize Maxwell's equations to solve magneto-hydrodynamics problems if you were so inclined.

However, that means if you are looking to capture a particular aspect of a flow field, the grid and time step must be small enough to calculate that flow property, and at this point it's important to realize most flows of interest involve turbulent flows. Therefore, for most of the really interesting flow problems in DNS, the entire range of turbulence spatial and temporal scales must be resolved. In other words, the grid size and time step must be small enough to capture the turbulent flow. From a practical standpoint, this means an average CFD model, such as an airplane, would contain billions of grid cells and it would take many months if not years to solve a single model. That is way too long for modern development schedules.

In order to reduce the cell count, and subsequently reduce the solution time, turbulence

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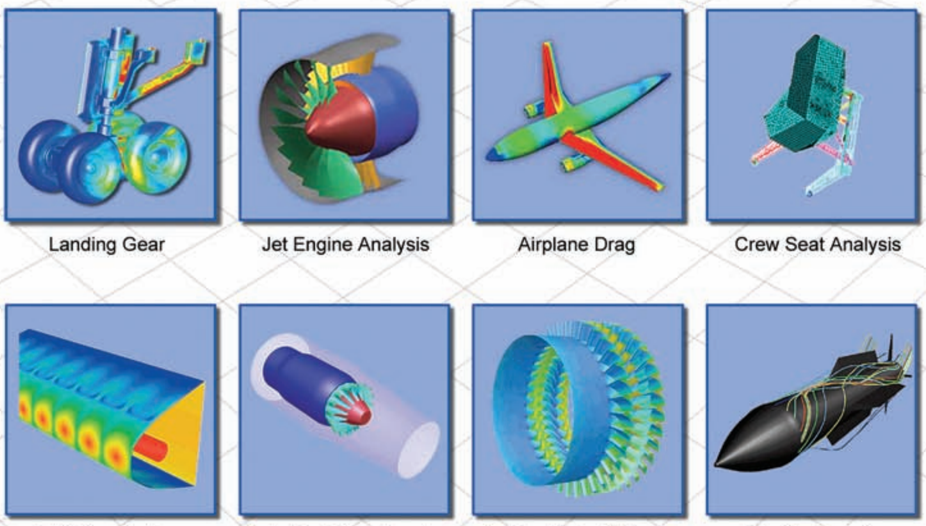

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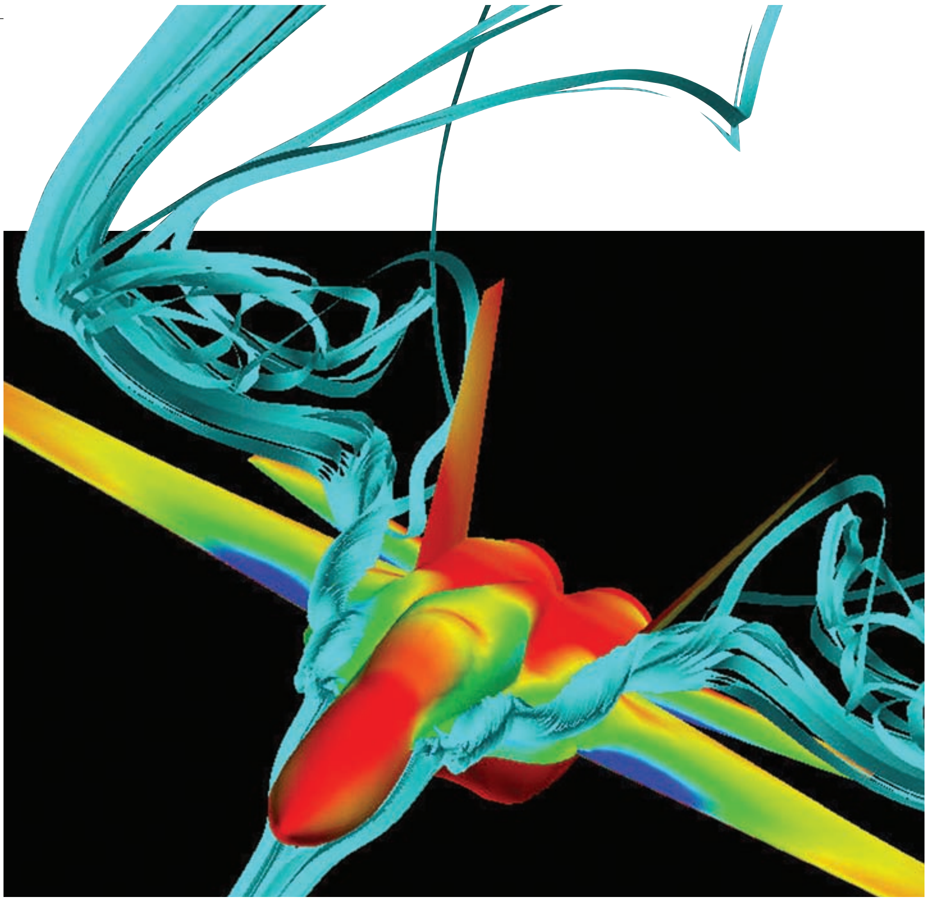


# The place for analysis

Engineers rely on computer modeling and simulation methods as vital components of the product development process. As these methods develop at an ever-increasing pace, the need for an independent, international authority on the use of this technology has never been more apparent. NAFEMS, the International Association for the Engineering Analysis Community, is the only worldwide independent association dedicated to this technology.

Companies from numerous industries and every part of the globe have invested heavily in engineering technologies such as FEA and CFD. But how do they ensure they get the best return from their investment? How do they develop and enhance their capabilities? And how do they use the technology in the most effective way? NAFEMS is uniquely placed to help answer these questions.

NAFEMS is an association of more than 900 companies from around the world. Members range from major corporations such as Boeing, NASA, and Ferrari through to mid-sized organizations, academic institutions, and small engineering consultancies.

The NAFEMS CFD working group was founded in 1995 with the objective of promoting the safe and reliable use of CFD and providing guidance and information for CFD users of all levels.

*www.nafems.org. How to Understand Computational Fluid Dynamics Jargon (http://www.nafems.org/resources/CFDJargon/)*

modeling was introduced to CFD modeling. Instead of calculating the turbulence properties directly, they are modeled according to various methods, each of which involves its own underlying theory and subsequent complexity. The most common version of CFD used today employs the Reynolds-Averaged Navier-Stokes (RANS) equations, which, in addition to using a turbulence model, further simplifies the solution by also neglecting the fluctuating component of the flow variables. In recent years, the advance of RANS codes has stalled somewhat, and large eddy simulation (LES), which is a transient turbulence modeling technique, has been investigated and implemented. LES works by separating the large and small eddies, which are theorized to be geometry-dependent and universally self-similar, respectively, allowing only the small eddies to be modeled. There are other specialized turbulence models, but they tend to be applied to niche problems.

Transient CFD, including LES simulations, is particularly challenging from a computer resources point of view, because the flow field must be solved for a series of time steps. The common practice for transient CFD is to de-feature the grid to reduce the overall solution time. Typical aerodynamics RANS models contain tens of millions of cells and take tens of hours to solve, giving average flow properties, whereas LES models take days to weeks to solve, but yield instantaneous results. In any event, what's important to know is the physics of the problem you are trying to model.

## CFD applications

The ultimate question is, what can CFD do? And more importantly, how does it fit best within an overall product development schedule? As computers have become faster, CFD has been applied to more and more problems, covering almost every conceivable flow regime, from simple, laminar flow over an airfoil to chemically reacting turbulent flow of hypersonic flight.

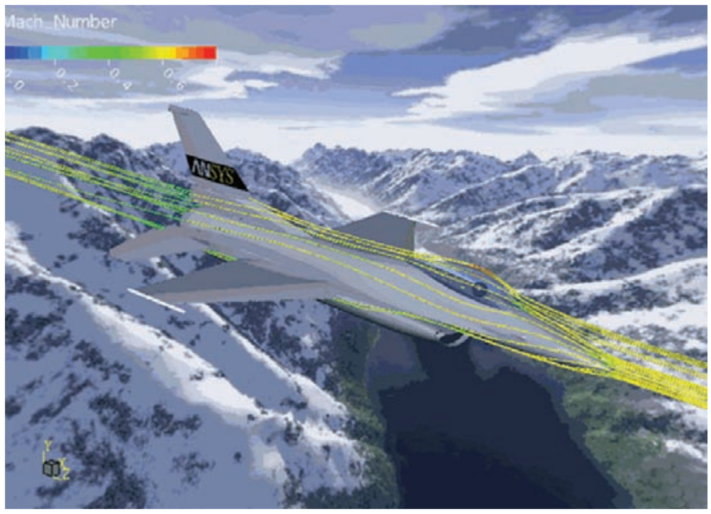
Current aerospace aerodynamics applications range from general aviation aircraft to space shuttle re-entry, from rocket flight dynamics to landing a probe on Mars, and everything in-between. Where CFD really succeeds in all these cases is in the visualization of the flow field itself, especially in the early design process before any hardware has been built. How the air flows over the aircraft and to be able to compare two similar configurations side-by-side is enlightening to a trained aerodynamicist, allowing them to gain more insight into the flow field before making design or development decisions. Then being able to show the same thing to someone else who is perhaps not even an engineer is invaluable. Therefore, including CFD before or after experimental tests currently seems to be optimal. Running CFD models alongside wind tunnel tests is a recipe for failure: once you have an experimental model, reams of data can be (relatively) easily and quickly generated, whereas CFD models take time to solve and are quickly outpaced in terms of generating results.

**"Where CFD really succeeds in all these cases is in the visualization of the flow field"**

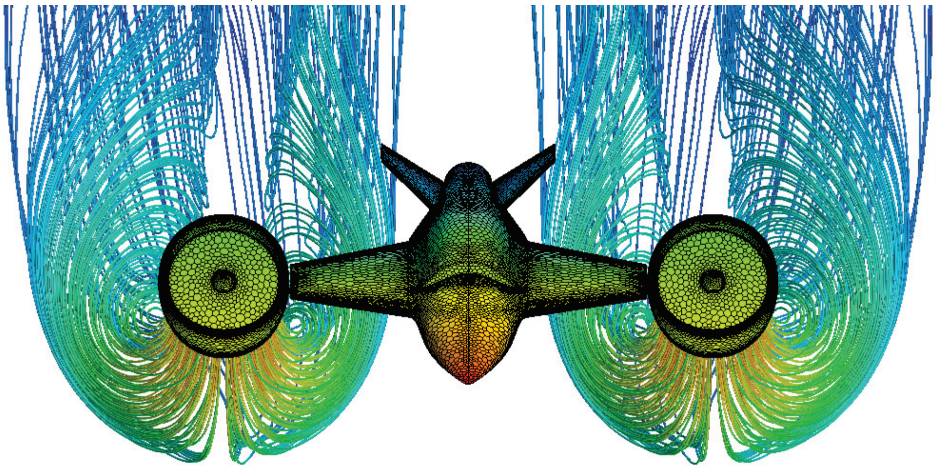
However, if comparative – or even competitive – designs can be modeled in CFD before any hardware is made, this makes experimental testing better by addressing only those designs that have a reasonable chance of success, or even starting the testing with a prioritized list of research items. Additionally, after a series of experimental tests are completed, CFD enables unexpected results to be further investigated.

## Case studies

The two images in this article show some of the power of CFD. For the US Space Shuttle image, not only is the heating to the vehicle depicted via the temperature of the lower surface (red is hotter), but also the flow field over the wings at




**CFD is being used to support the design and evaluation of passive concepts which have the potential to reduce noise from an F/A-18**



CFD is finding a role in producing data that design teams need to support flight vehicle development

this high angle of attack. By using CFD, the best re-entry attitude could be determined, balancing vehicle speed, thermal load, and flight characteristics, which is pretty much impossible without actually performing this maneuver repeatedly.

Clearly, NASA engineers came up with a perfectly acceptable re-entry profile, but this is likely to have been slightly different if CFD had been available in the 1960s.

The image of the F-16 Falcon (*see previous page*) is notable not due to the streamlines themselves, which really do not have much engineering use, but because of the inclusion of the image background. The mountain range behind the F-16 is not actually included in the CFD model. However, this is important because, as CFD has realized more and more mainstream applications, it is the post-processing – from both a qualitative and quantitative perspective – that has seen a dramatic advance in recent years. In addition, new and novel comparative calculations for flow field parameters, stunning images, and animations are also possible, and their use in explaining CFD results is an important, if undervalued, aspect of CFD.

## An engineering tool

As previously mentioned, CFD has become another engineering tool. As with most computational tools, however, CFD also follows the axiom 'garbage in equals garbage out'. Many CFD codes, whether commercial, research, or public domain, have similar solver options and turbulence models, and although selecting appropriate boundary conditions can sometimes be a challenge – especially for new simulations – setting the relevant values for boundary conditions is relatively straightforward. Generating a good-quality grid is currently the single most important user-controlled aspect of CFD, and is the most difficult aspect of CFD modeling. For very complex geometry, it can take days to weeks (or even months) to create a quality grid.

On the other hand, it is possible to take CFD too far and create marketing-only results that get used for engineering decisions; after all, back in the 1970s, CFD actually meant 'colorful fluid dynamics'. Certainly, there is much more to CFD than has been outlined here – the sheer amount of research into CFD, from numerical schemes to turbulence modeling to transient applications, is staggering.

CFD is an extremely powerful tool that enables the flow field to be visualized in ways not possible with other methods – applying CFD where and when it is appropriate is the key. More and more, that 'appropriateness' has meant applying CFD to non-traditional aerospace problems, involving more that just aerodynamics, and including multiphase flows, cavitation, mixing, combustion, and even fluid structure interaction. ∎

*Thomas N. Ramsay has more than 10 years' experience working with CFD and is a member of the CFD subcommittee of the Fluid Dynamics Technical Committee at the American Institute of Aeronautics and Astronautics*


# Speeding up the system

**In the current climate of economic uncertainty and growing demand, it is important for businesses to be able to go to production with a model that they are certain delivers. In past decades, wind tunnel testing was the primary method for isolating design defects and optimizing aerodynamic performance. In recent times however, with the onset of faster computers and larger memory chips, virtual testing and prototyping have begun to take center stage.**

Over the past 10 years, IDAC Ltd has seen an increasing demand for CFD within the aerospace industry. Using CAD models as the starting point, the general CFD approach involves generating a mesh over which the solution is solved and boundary conditions set up. While in the early days, CFD was used only for external aerodynamics, today's advanced turbulence models are used for flame propagation, chemical reactions and thermally induced flows.

The advantage of CFD over wind tunnel testing is the ability to change the operating conditions quickly and run multiple scenarios in parallel. "Once we have an established method and comparable output to acceptable wind tunnel results, recreating different velocities or geometries becomes very easy," says K. C. Tang, a CFD engineer at IDAC. "Where the first benchmark could take a few days to set up, consequent runs can be duplicated in an afternoon or less."

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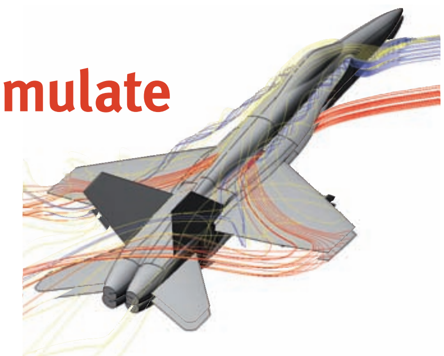
# Simulate to stimulate



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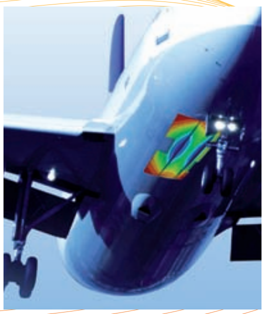


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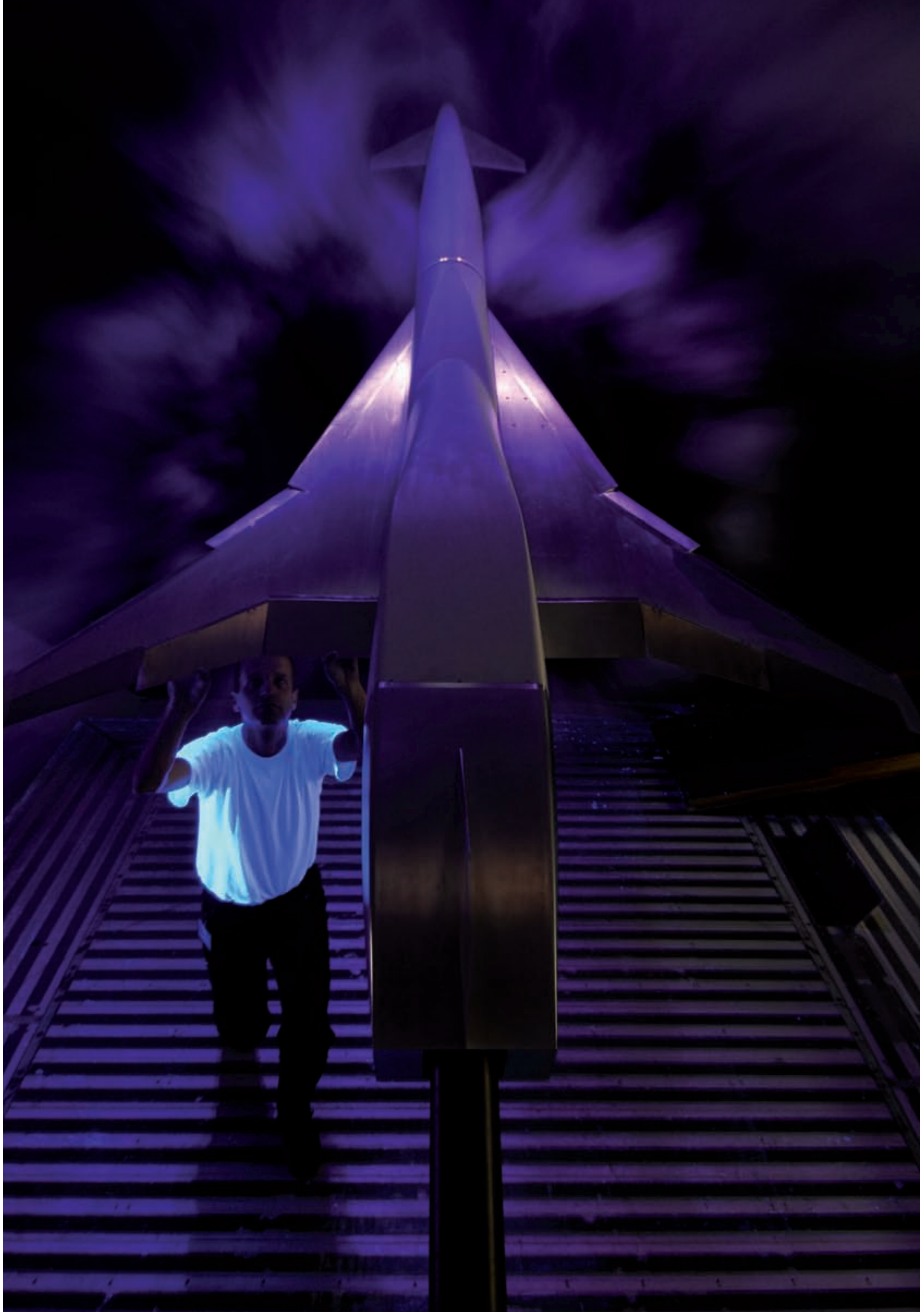
# Wind break?

AS HEAD OF AERODYNAMICS AT RUAG, MICHEL GUILLAUME HAS BEEN PART OF THE A400M, THE F/A-18, AND THE HISAC PROJECTS. HIS ULTIMATE VISION IS USING CFD FOR VIRTUAL FLIGHT TESTING



BY CHRISTOPHER HOUNSFIELD

Computational fluid dynamics (CFD) is now used as a basic design tool in the aircraft development process. But CFD still has to be validated using wind tunnel tests. In particular, for high-lift devices, the uncertainty in CFD results is substantial due to the uncertainties in turbulence and transition modeling, in addition to errors introduced due to complex grids.

The RUAG Aerospace Aerodynamics Center has been at the forefront of integrating wind tunnel practical methods and the science of CFD. Michel Guillaume has been the general manager of aerodynamics and head of the center for the past five years. He has also been central to the A400M tests.

Recently the company, based in Switzerland, has been working on low-speed tests for the A400M. According to RUAG, the most challenging part of the project was the powered low-speed tests. The slipstream effect and the engine integration under the wing were complex tasks for the design. As a result, powered tests with correct aerodynamic conditions have been essential.

To achieve the thrust values with the right advance ratio, a special hydraulic engine was developed to meet the size of the model scale of 1:15. Also, to provide good, measured results, a balance crossing system in the center section was integrated. Two test campaigns were completed. Important moments were cross wind conditions with reduced engine power and runs with reversed thrust. However, even with state-of-the-art CFD, it was not possible to complete such simulations in a short time.

Guillaume believes that currently CFD studies can only complement hard tests in the wind tunnel. "The main focus of the computational fluid dynamics study in an early phase of the development was to determine the effect of the presence of the ground on the aerodynamics of the airplane (ground effect).

"In a first step, the numerical method was validated using test cases from the literature and previous wind tunnel measurements on a different airplane. The results were found to be satisfactory and in a second step the actual geometry was modeled. The simulation matrix included various angles of attack and sideslip, and altitudes over the ground.

"Due to the complex aerodynamics, a good understanding of the effects is of prime importance in order to assure a safe take-off and landing. For this reason, it was decided to confirm and complement the theoretical results with wind tunnel tests.

"For the establishment of an aero database, the productivity of our Large Wind Tunnel Emmen (LWTE) is still the best solution, as it provides very fast and accurate data. Still today simulations cannot compete with a productive wind tunnel." The LWTE has a test section 7 x 5m across and 12m long and the maximum speed is just under 70m/s. For 60-70% of the time it is used for aerospace work, but the company also carries out specific automotive industry projects. RUAG also operates two low-speed facilities.

## High-speed aircraft

The RUAG Aerodynamics Center has been involved in two work packages for the aerodynamic development of the European HISAC (high-speed aircraft) research project. The involvement was primarily wind tunnel testing, and numerical-flow simulations. The main focus of activities in the LWTE was an investigation of aerodynamics at low speeds with a 1:10 scale model.

"Together with CFS Engineering in Lausanne, which is our subsidiary specializing in CFD calculations, one of the HISAC configurations was analyzed in the high-speed range," explains Guillaume.

"The second work package we were involved in was the wind tunnel testing for the high-lift phases of the flight (take-off and landing). Next to force and pressure measurements, many flow measurements were performed to help with the validation of CFD results."

Numerical calculations have been carried out in the supersonic range at a speed of Mach 1.6. This enabled the positioning of the engines to be analyzed. Integration of the engines has played an important role in the project, as the intention is to reduce noise emissions. The project aim is for the new supersonic business jet to fly at supersonic speeds over land, in contrast to Concorde, and for its noise emissions upon take-off and landing to be lower than those produced by current commercial aircraft.

**Above: The HISAC low-speed wind tunnel test at 68m/s**

**Left: For 10 years Michel Guillaume was head of structural testing for the Swiss version F/A-18**

"The HISAC project is close to finishing," says Guillaume. "Many questions could be answered but we are still a long way from having an economical, environmentally acceptable, low-boom, high-speed business jet ready for the market. There is certainly a need for further research in the area, but whether there will be a follow-on research project will mainly depend on the OEMs."

## CFD's virtual encroachment

Across the board, CFD virtual studies and tests have been encroaching more and more into the territory of practical, old-school wind tunnel trial and error. Guillaume considers that the wind tunnels can do the donkey work, and CFD can be exploited to refine development – one method validates the other.

"First design approaches are normally done using low-fidelity CFD calculations to come up with an initial configuration that meets the design goals in terms of performance, control, and stability. Then wind tunnel tests are conducted to validate this initial design. During low-speed tests, the high-lift devices are optimized and improved to find the best solution. High-fidelity Navier Stokes CFD simulations are used to refine the design. Usually, several wind tunnel campaigns are needed before the design is frozen.

"At the end, the final aerodynamic database will be generated using wind tunnel tests, to accurately predict the performance of the aircraft, and its stability and controllability. In this phase, the high productivity of our wind tunnel plays an important role, and CFD still cannot compete in this field. CFD is used to complement the wind tunnel tests to account for missing or incomplete data.

"The ultimate vision is to perform virtual flight testing using CFD, but in my opinion we are still many years away from rendering the wind tunnels obsolete," says Guillaume.

In the future, greater emphasis will be placed on the simulation of fluid structure interaction, which will deliver more real information for aircraft design. More efficient algorithms will be important to speed up the design process and find the optimum shape of a wing.

"The development of reduced-order modeling methods is important to reduce the number of CFD simulations for design, while keeping the necessary precision," says Guillaume. "Also, unsteady simulations will play a more important role. Recently we were able to simulate the buffeting at the F/A-18 vertical tail using unsteady fluid structure coupling with modal integration.

"This procedure will help us to develop an efficient way to test loads for a fatigue investigation and to assess the structural integrity of a buffeting environment under Swiss usage." ∎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# Wingman

## COLONEL WILLIAM THORNTON, COMMANDER OF 412TH TEST WING AT CALIFORNIA'S EDWARDS AIR FORCE BASE, TALKS ABOUT LIFE AT THE LARGEST MILITARY FLIGHT TEST CENTER IN THE WORLD

BY JOHN CHALLEN

Set in an area larger than the city of Los Angeles, and home to a fleet of aircraft that perform more than 7,400 missions a year, Edwards Air Force Base is steeped in history, having played host to numerous milestones in flight in the 50+ years that it has been in operation. Today, as it prepares for the arrival of its first allocation of F-35s for testing, the base's 412th Test Wing aims to keep making history by offering a comprehensive array of test services for the USA's military fleet. The core evaluation work is carried out in the Test Wing, supported by the site's Air Force Flight Test Center, which exercises control over the test programs.

The man responsible for the smooth running of the 412th Test Wing is Colonel William Thornton, a 25-year veteran of the Air Force who was previously commander of the operations group at Eglin AFB in Florida. The working population of the Test Wing, encompassing military and government officials, civilians, and contractors, numbers more than 5,000 people, close to half the total employees at Edwards AFB. Although the base is set in more than 308,000 acres, land area is not the all-important attribute, says Thornton. "The space above us is what we consider a national resource, as it is restricted from surface to infinity. There is a low population density that enables us to conduct all types of high-risk testing on very remote and isolated areas, greatly minimizing any danger to civilians."

As commander of the whole test wing, Thornton is kept very busy with the organization of a punishing schedule of aircraft undergoing strict development programs. "The Test Center has around 90 aircraft assigned to it at any one time," he explains. "We own around 70 of them, and the remainder are from the combat and military forces."

Thornton and his team have an extensive range of aircraft under evaluation at the moment: F-22, C-17, C-130, F-16, T-38, K-2135,


A vast array of different tactical aircraft have been put through their paces at Edwards Air Force Base including the B-2 and the T-38

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# The Raptor at Edwards

The F-22 Raptor is the highest visibility program currently at Edwards AFB. It was also one that provided new challenges for Colonel Thornton's Test Wing. "As an all-new fifth-generation aircraft, there was a lot of equipment that hadn't previously been used, and as a result, its development had its fair share of problems," he says. "But from the outset, it was to be the world's best fighter and I think that is undisputed now, in terms of performance, signature, and weapons capability."

But getting to the point where the F-22 is now was far from simple. "In its mission systems, F-22 was revolutionary, and certainly a steep curve in terms of evolution," recalls Thornton. "The onboard sensor integration was a tremendous challenge for flight testing, so we could really understand what was and wasn't working. We might have got the right answer, but as we dug into it, there were plenty of subsystems that weren't supplying their share of the right answers. Ultimately, it was a much advanced airframe that was still subject to the laws of aerodynamics, so propulsion, although revolutionary, still conforms to performance measures that we're able to capture in a more conventional sense." Despite the complexity of F-22, the project was actually much smaller than many. "There have been much larger teams than the F-22, in terms of the number of test vehicles and the tests that needed to be done," explains the commander. "F-15 had 20 dedicated aircraft, F-22 had eight, so obviously you don't need as many maintenance staff or pilots. Plus, nowadays we have a lot more automated software tools that help to analyze the data."

At the peak of the program there were eight aircraft, of which two were part of dedicated OT&E (operational testing & evaluation). "We don't get all the aircraft right away, maybe one for six months and two or three together. Some were specifically for flight sciences, aero work, or propulsion system performance, and those came with very little mission systems capabilities – we knew that these were due to be used for specific tests. Later we got some test aircraft, that looked more at the overall plane." Thornton reveals that there are still five F-22s on site, because "testing doesn't stop until you retire an aircraft".

**"Edwards isn't an easy base to get into if you're a national. It's also tough to land in"**

Right: Colonel William Thornton, Commander 412th Test Wing Edwards AFB

Below: Despite a fatal crash this year, the investigation found no problems with the design or airworthiness of the F-22

KC-135, CV-22, RQ-4, MQ-1, MQ-9, F-117 B1, B2, B-52, C-5, and very soon, the F-35. They currently have what Thornton describes as 'a small wing' of F-16s (there are 35 of them) that are split between support aircraft, those undergoing testing, and the test pilot school. Gliders are also available at the school for training. A number of the aircraft – such as the aforementioned C-130 – are currently being subjected to an upgrade program.

Precautions have to be taken and the security team has a big job in guarding the plethora of military metal: "Edwards isn't an easy base to get into if you're a national. It's also tough to land in – we can't just get permission at the local level for even a British aircraft to land here. On a test program level, every program has the information that it needs to be protected and this is identified to us. We have security experts that look at what needs to be protected and how we do it."

## Evaluation and schedules

In terms of equipment, tests are undertaken on the site's Benefield anechoic chamber. The chamber is used for electronic four-point shear testing, and is the largest of its kind in the world, capable of swallowing up a B1 bomber with ease. Elsewhere, the test engineers have access to flying-quality simulators for F-22s, F-35s and F-16s, SIL and HIL laboratories, and telemetry links to the test ranges.

With such a large number of aircraft at the facility at any one time, Thornton and his Test Wing staff have to carefully plan evaluations schedules. Fortunately, there is a tried-and-tested method that does most of the work on computer: "We are in an environment that is restrained by resources, whether it be aircraft, personnel, range, time, or frequency, and it all has to come together to come up with a realistic schedule," says the Colonel. "We use a concept called 'Theory of Constraints' in a program called Concerto. This program takes our scheduled resources, de-conflicts them from other requirements for resources, and comes up with a realistic schedule." Delays to programs are also accounted for with a buffer in the schedule, but manpower is still needed to keep a watchful eye on proceedings. "It still takes human involvement to make a rational, reasonable schedule. We try to build in the buffer because things don't normally work the first time we do them."

Thornton explains that all test programs begin with a requirements document – and from there the test team determines what they want the aircraft or weapons system under test to do to meet those requirements. "Then we develop a test plan, which is done primarily by

the program office, with influence from testers themselves. Information sheets are written to describe what the tests will do and what results will yield. A test program is then developed and we go from there to develop the flight test." Once the test plan is finalized, it's time to make a list of what is needed for the evaluations. "We also look at what the expectation requirements are, and that is probably the toughest and least appreciated part. We have to concentrate on getting the instrumentation we need to get the right data for analysis of the flight envelope or weapons system."

## Human resources

As well as the equipment, human resources is an area that requires attention. "As we go through this procedure, the number of people that we will need on the program becomes apparent. This is based on the program schedule, and that is driven by external factors such as key milestones and production factors, which determine the number of engineers." Thornton says that when the F-35s finally arrive at Edwards, close to 600 contractors and government people will be working on the airplane's very tough test schedule."

The ideal would be to have multiskilled staff, who could work across any project that came along, but in reality, it's not that simple: "We have RADAR people that have worked on projects from F-16 to F-35, but it is not something they can adapt to overnight. We can't just pull them off one program and then put them back on another the next day," says Thornton. "It takes them a while to learn the program, the instrumentation, and what the test program is like. We move them in a carefully planned manner to minimize disruption to all areas of the test program. When we were trying to make milestone decisions on the F-22 program and flight testing was really starting to get going, they needed engineers and we moved them over there.

**Above: A B-52 became the first US military aircraft to fly with 'clean fuel' from Edwards AFB in 2006**

**Right: On December 15, 2005, the F-22A entered military service**

Despite meticulous planning and preparation for incoming test planes, issues still have to be overcome: "In general, the biggest problem that we encounter is the maturity of the system when it comes to us for testing," says Thornton. "It is normally not as mature as has been advertised, and sometimes it can take weeks to get things up and running, even though the very same system works fine in the lab. Sometimes an airplane or system sails through the program, but this is a rare exception." Thornton cites the Airborne Laser (ABL) as a good and current example of coming up against problems: "The science and physics of the laser is well understood, but putting that on the aircraft and ensuring all the systems come together is a massive task. There are always a couple of things that we need to work through, but the program remains on track. It constantly needs a lot of work, because we are always discovering new things to fix."

After 50 years in operation, Edwards' original and main runway (there are 22 in total) was replaced – one example of the many upgrades that Thornton sanctions every year. "The main runway is 15,000ft long and 300ft wide and was just starting to deteriorate," he explains. "The new one, which is the main runway that we always use for take-off, will be good for 100 years." He says that investments and upgrades to physical and computer-aided equipment account for US$40 million a year just in the Test Wing. "There is continuous improvement in the chambers and simulators, and we do a constant stream of modernization. It is all about looking at our requirements, which may drive us to install very different control rooms or telemetry requirements. It is a constant process of upgrades."Despite the size of the base, not all of an aircraft's testing can be done at Edwards. Much of the weapons testing is done at other US facilities, and hot and cost simulations also require travel:

"The best climatic lab we have is at Eglin AFB, and we take the aircraft there to test in a controlled environment," says Thornton, who isn't willing to take the risks with the weather. "It's great to bring an aircraft out to mother nature – except when it doesn't snow when you're looking for snow, or you want 40°F and there's a heatwave going on."

## Working closely with NASA

Another key partner for the Test Wing is NASA, whose Dryden Flight Research Center is next door. "NASA-Dryden represents the aeronautics side of NASA, and they are doing advanced research that is very helpful to us," reveals Thornton. "There are a number of combined programs worked on by both parties, one of them being a ground collision avoidance system. They have a project involving an F16 that was given to NASA by the Air Force, and we are going to be flying it. The X-51 demonstrator from the DARPA program is also coming here soon, and although we are going to be running it, NASA will work with us with some of their engineers on the team."

Edwards AFB is not immune to the recession, and Thornton is acutely aware that tough times lie ahead: "We will face budget challenges, and programs may have to be revised," he admits. "We are looking very carefully at things and are working with our HQ now with the future year's defense budget. We are starting to take cuts and looking at potentially very strong cuts that impact our missions. Everyone has to tighten their belts, and we are no exception." ∎


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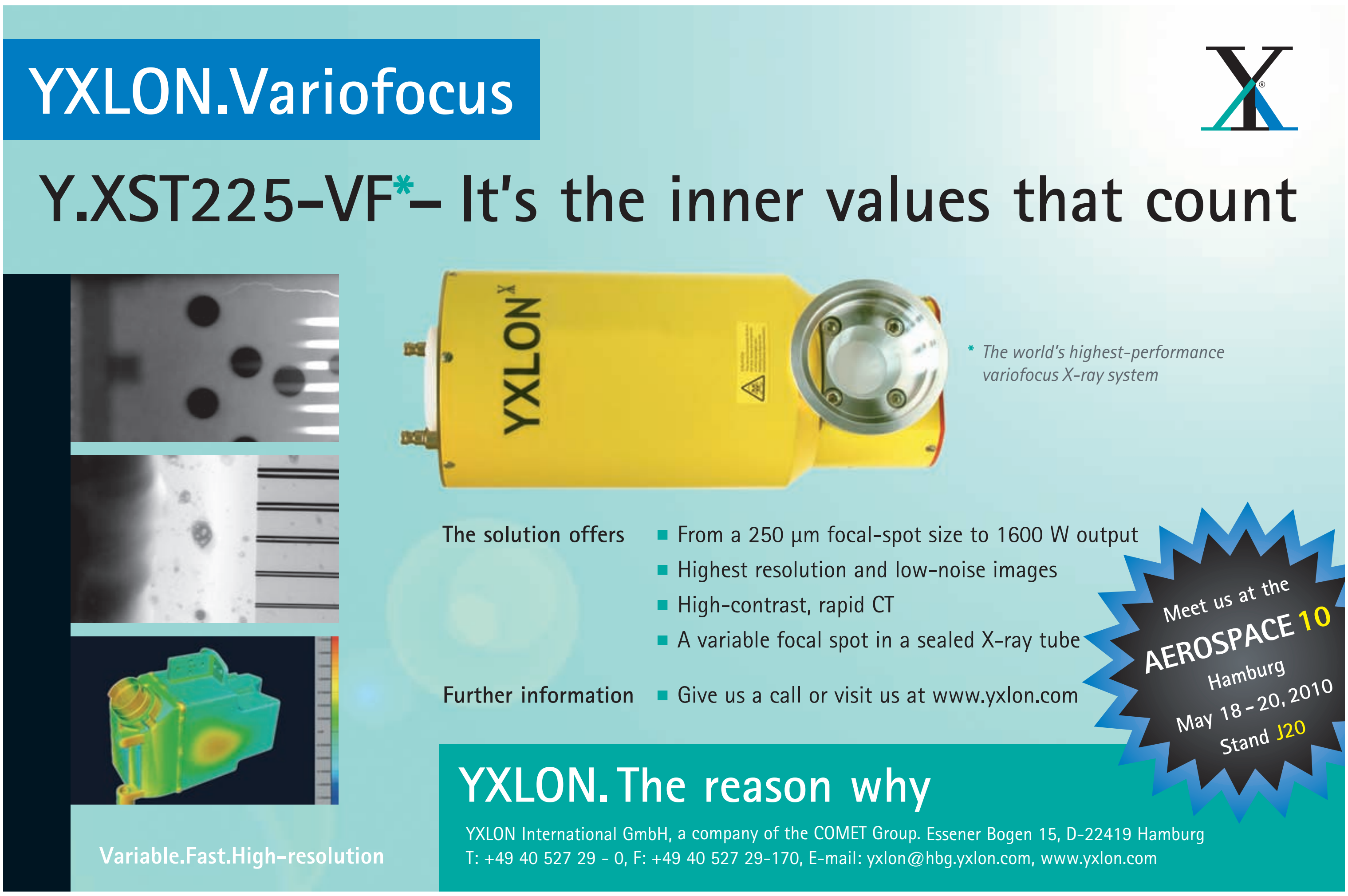
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“Within the next decade we will see a virtual aircraft, completely tested before the first metal is cut”

# Dieter Konnerth

Director, Research & Development, TechSAT GmbH

Dieter Konnerth, director of R&D at TechSAT GmbH, began his career in the aerospace industry in 1991 as part of the team developing test equipment for the Boeing 777 program. He was one of the main architects of TechSAT's flagship product, the ADS2 avionics development system, and has been involved in most major aerospace programs over the last 15 years, including the Airbus A340, Tiger, EFA, A380, A400M, and B787, and is currently working on the development of the A350.

## The last 12 months have been TechSAT's busiest ever. Why is that?

We have experienced a tremendous pressure on prices as a result of the economic squeeze passed from airlines, to airframe integrators, to Tier 1 suppliers, and finally to us as suppliers of development and test equipment. But this has forced us to come up with a whole set of new, more intelligent, and therefore more economical solutions.

## Can you give an example?

TechSAT's main business segments are system integration benches. In the past these were always monolithic single-purpose systems, built to customer specifications. The challenge was to come up with a flexible solution to test system modules, which could be combined in multiple ways for different test requirements. Therefore an aircraft integrator needs less specific test systems to achieve an even higher test coverage and more representative test scenarios at less cost.

## Sounds interesting. Can you explain in greater detail?

At one end of the process, the airframe integrator receives a large number of components from its suppliers which need to be tested for PTS compliance. At the other end the integrators need to test the completely integrated aircraft functions such as 'Iron Bird' or 'Cabin0'.

In between, a lot of intermediate steps are required where partially integrated functions are tested before integrating them into more complex functions. All these steps should ideally be performed on the same test equipment. The test system architecture must support easy reconfiguration for all these stages. Therefore test system modules (TSMs) can be combined into clusters, and the I/O configurations of the TSMs and the corresponding simulation models are adapted to the specific needs of each integration step. This complex task is performed by our new ADS2 Cluster Manager in combination with the underlying test system hardware architecture.

## Do you have other similar types of test systems?

Yes, another is a new family of I/O boards called FAST. These boards are specifically designed to support the flexible recombination of TSMs. They combine signal I/O, signal conditioning, error injection, signal routing, and signal breakout. The concept leads to a very efficient test system design, with a greatly reduced number of components and reduced cabling, which has direct impact on cost. Side effects are also improved reliability and lower MTTR.

This not only saves design, manufacturing, and material costs, but also improves reliability – which is of course an important factor in the overall lifetime cost.

## Has there been an industry trend that has changed your business considerably?

All aircraft designs have adopted or are currently adopting the concept of integrated modular avionics. These are general-purpose computing modules (CPIOM) for multiple applications with remote data concentrators (RDC) communicating through an AFDX network. This has had a great impact on the test infrastructure, which also moves away from test rigs for single specialized systems to generic systems for testing IMA modules at one end, and large integration test facilities for testing complex aircraft functions or complete aircraft on the other end. This is exactly where the TechSAT business focus has shifted.

## What trends can you predict for the near future?

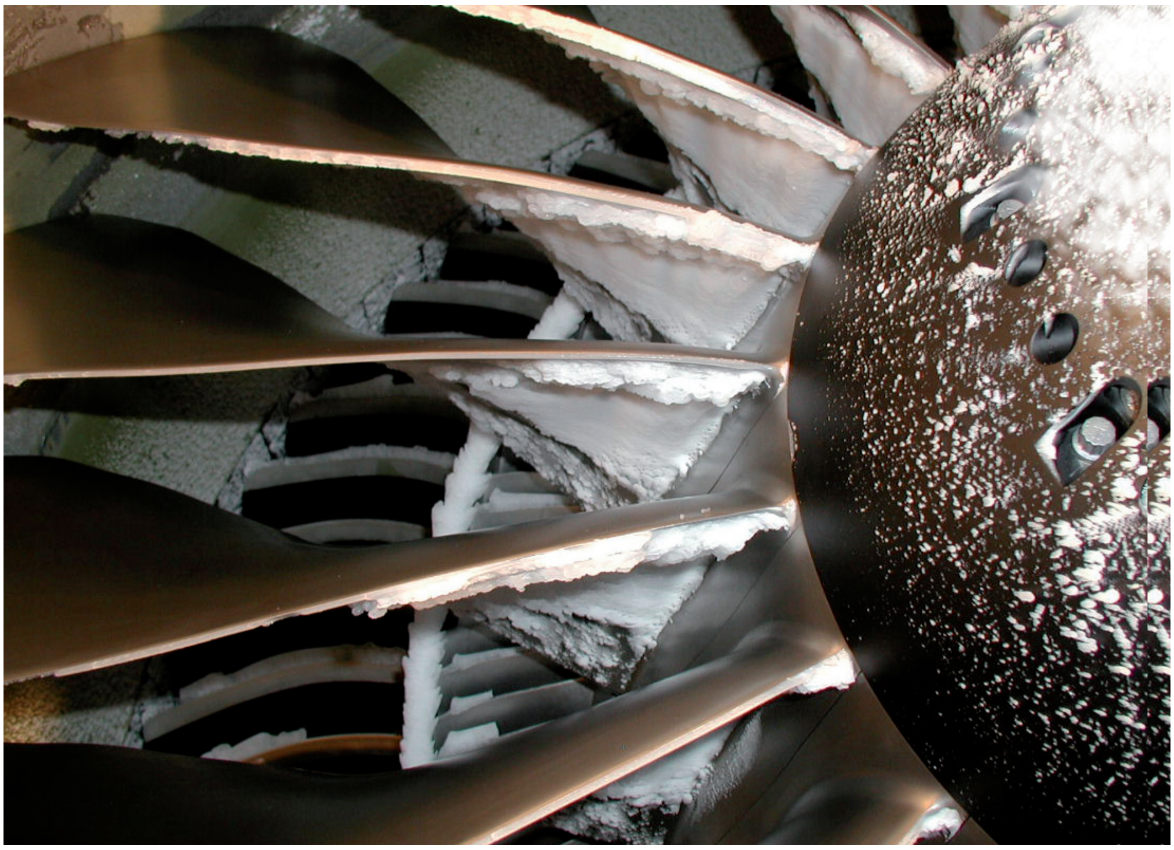
The magic words are 'process integration'. We see that specification, development, and testing are becoming a more and more integrated process. In software development, the trend is obvious. Test-driven development is state-of-the-art already. In the aerospace industry the complexity and high degree of formalization slows down changes in the development process, but nevertheless, changes will come. Within the next decade we will see a virtual aircraft, completely tested before the first metal is cut. Requirements and test procedures will be validated on the simulation model, greatly reducing the testing of the actual aircraft, and resulting in an even shorter time to market.

## How has your company's position in the aerospace industry changed?

As we grow, our test systems grow. TechSAT is now one of the few companies worldwide that has the products and experience needed to build an integrated test facility for a complete aircraft, or a considerable part of it. The number of customers for such systems is limited, so we are continuously expanding our geographic reach. We are now operating worldwide, working with most major aerospace companies. This is globalization at its best.

# Ice house

## THE AVIATION INDUSTRY WILL SOON BENEFIT FROM THE UNVEILING OF A NEW GLOBAL AEROSPACE CENTER FOR ICING AND ENVIRONMENTAL RESEARCH IN CANADA



BY JOE HAJJAR

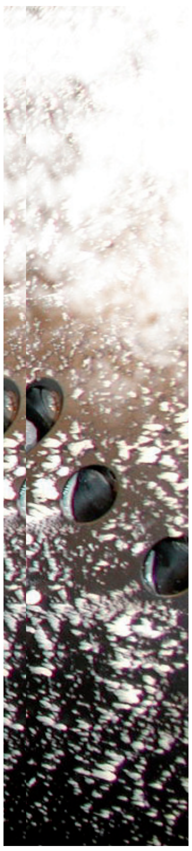
Modern aviation gas turbine engines are designed and certified to operate in inclement weather, including icing conditions. As regulations governing the icing certification of modern engines become more and more stringent, traditional facilities used in the past are no longer able to fulfill those changing requirements. For this reason a number of private and public organizations have joined forces and will build upon the clear world leadership of the National Research Council of Canada (NRC) in icing simulation and testing.

GLACIER, a joint venture between Rolls-Royce and Pratt & Whitney, has joined forces with research- and education-focused organization EnviroTREC and the NRC to create a one-of-a-kind cold weather engine test facility. This unique outdoor test center will become the principle outlet for icing certification and cold weather testing of civil aerospace gas turbine engines for the two companies.

Michel Toutant, president and chief operating officer at Rolls-Royce Canada Limited, says, "Ice testing and research are important for the aviation industry and we are delighted to be working with Pratt & Whitney to take the lead in this important area. The new state-of-the-art facility has been planned for a number of years and will be at the cutting edge of new technology, which will deliver benefits to the wider aviation industry."

Left: Turbofan engines undergoing icing certification tests

Below: The test stand. Temperatures as low as -48°C have been recorded during the winter months



**"The new state-of-the-art facility has been planned for years"**

Canada's natural resources at the 55th parallel, combined with extensive experience of the NRC, provide a logical and efficient solution. Dr Pierre Coulombe, president of the NRC, explains, "Icing is one of the most difficult operating threats for the gas turbine engines used in aviation. We are pleased that our expertise will play such an important role in establishing GLACIER and improving safety for the traveling public."

The NRC will own and operate the icing spray systems at GLACIER, expanding capability and skill as new regulations emerge. The GLACIER facility itself and all other engine test equipment are being designed and supplied by Ottawa-based MDS Aero Support Corporation. MDS will also manage, operate, and maintain the center over the long term. EnviroTREC is a network organization that through partnerships with colleges and universities stimulates and supports a variety of aerospace research programs.

Walter Di Bartolomeo, vice president of engineering at Pratt & Whitney Canada, comments, "This initiative will benefit the entire northern Manitoba community and will provide valuable opportunities in high-tech aviation for young people in the region. It will also help the aerospace industry to develop innovative solutions in the area of icing."

The facility will be built in Thompson, Manitoba, Canada. Located approximately 460 miles north of Winnipeg International Airport, Thompson is recognized as the 'hub of the north'. GLACIER will establish a baseline for aircraft icing certification, and will be the first and only facility capable of certifying new growth engines under current and future regulatory requirements.

## Facility overview

Cold weather conditions permit outdoor icing tests, low temperature endurance testing, cold soak, hail, snow, and other adverse weather testing of flight vehicles and their propulsion systems. During the off-season, the remote location provides ideal conditions for other performance, endurance, and operability testing. The test facility will accommodate the largest aircraft engine in existence today, and will support the future growth of gas turbine engines of up to 150,000 lbf thrust and 32,000 lbf reverse thrust with fan diameters of up to 140in.

The four-post test stand oriented in the direction of the prevailing winds will house a high-accuracy thrust measurement system, and an integral engine docking system for quick engine installation and removal.

Testing will be conducted from the warm comfort of a control complex, fitted out with a state-of-the-art proDAS data acquisition system. The system will have the capability to measure all key engine parameters and perform high-speed data logging and post-processing analysis.

## Icing technology

Integral to the center's performance, the test stand will be equipped with an MDS and NRC icing system. The system consists of a direct connect icing tunnel and multiple spray bars to control water concentration and droplet diameters.

The system will support liquid water contents (LWC) of 0.2-4g/m$^3$ (0.0002-0.04oz/ft$^3$), a FAR Appendix C standard Median Volume Diameter (MVD) of 13-45mµ (0.51-1.77 mils), and a mass airflow range of 110-3,500 lb/sec. The cloud uniformity will be 15% or better, with an MVD accuracy of ±2 microns (0.08mils) low spread, and an LWC accuracy of +10%/-0%.

Test equipment detailed design is in full gear, and the center's inaugural icing certification program is scheduled for the fourth quarter of 2010. The Canadian center of excellence in the north will go to market and open its doors for global business in 2011. The center's equipment and services will give global access to the world's most current icing and environmental testing and certification programs.

The extreme cold weather conditions of northern Canada will provide the conditions required by leading gas turbine engine manufacturers. This facility will create the much wanted platform to standardize icing certification testing worldwide, and will be the stepping stone for growth and future development of the next generation of aircraft engines. ∎

*Joe Hajjar is marketing manager with MDS*

# Compare notes

**BERNER & MATTNER'S POWERDIFF SYSTEM PROVIDES EADS DEFENCE & SECURITY WITH AN AUTOMATED CHANGE MANAGEMENT PROGRAM FOR STATEMATE MODELS**

BY DR MICHAEL STURM

The Eurofighter from EADS Division Defence & Security (DS) is one of the most effective tactical aircraft in the world. From its conception plan drawn from pilot surveys in the 1970s, its rapid technological progress has posed constant challenges regarding requirements and specifications for the development teams using complex embedded systems.

The graphical design tool IBM Rational Statemate has facilitated the development of the Attack computer. In order to solve typical change management tasks, the department in charge at DS, Military Air Systems (MAS), works closely with Berner & Mattner Systemtechnik GmbH. The configuration management tool PowerDiff, which was jointly developed by both organizations, reliably identifies, visualizes and documents any changes made in Statemate charts.

More than three dozen highly complex computer systems ensure the Eurofighter's systems are fully capable. The Attack computer and the Attack & Identification Subsystem execute elementary identification, friend or foe (IFF) within a split second. The long-term partnership of MAS and Berner & Mattner ensures the functional capability of these embedded systems work. To verify the constantly improving technologies with the aircraft's weapons systems, the EADS department, Avionics and Mission Systems introduced the graphic design tool Statemate (now distributed by IBM) at an early stage.

"In doing so, we kept reaching the limits of Statemate, which at first could hardly manage our complex and extensive models," recalls Dr Michael Randolph from EADS, who took a lead role in the system development process of the Eurofighter. The system is being developed by MAS and its partners, with teams of engineers spread throughout Europe.

"In cooperation with the manufacturer," continues Randolph, "we have therefore systematically enhanced Statemate in order to efficiently apply the tool in our development process."

## Fresh challenges

Trying to master the complex Statemate models revealed another obstacle. This was the ability to compare Statemate charts in order to retrace, document, and specify changes according to each client. For example, changes can be triggered by a Eurofighter customer requesting a new weapons system to be integrated into the tactical aircraft.

This puts into operation a complex process chain, as the corresponding requirements have to be implemented in the model and possible effects on the complete system have to be considered. By the time of system delivery, any changes have to be specified exactly by means of very detailed simulations and model process reviews.

This process does require the comparison between individual charts. "With no such function or tool being available for Statemate, the employees used to print the corresponding documentation before and after any change so they could manually highlight the differences," Randolph explains.

"At first this meant just a couple of prints, but in the course of the Eurofighter's development progress, it eventually added up to thousands of pages."

Due to the enormous effort involved, MAS entrusted Berner & Mattner (then Statemate systems partner for Germany) with the development of an appropriate comparison tool. This tool would be able to automatically detect any changes between two model versions as well as to visualize and document them in detail.

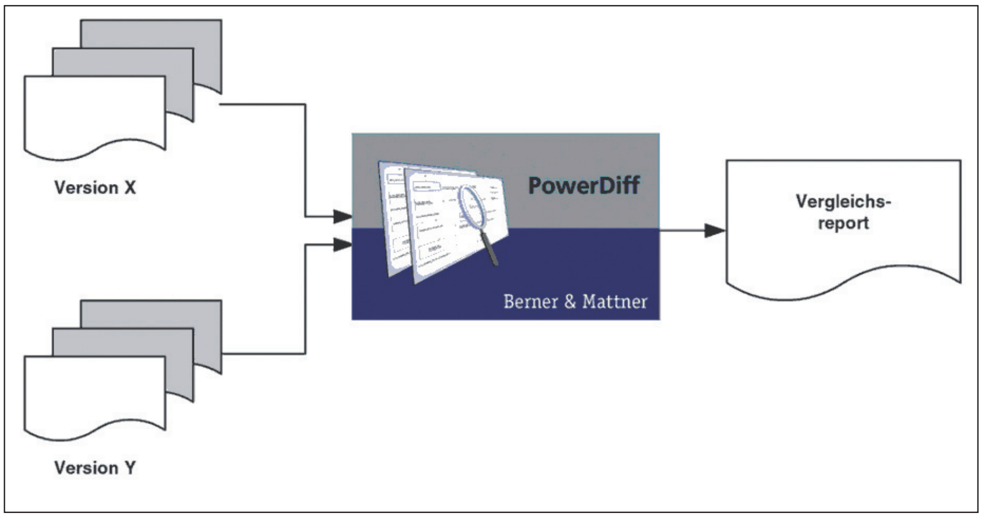
The Eurofighter has been in service at Deutsche Luftwaffe since April 2004

## Comparison-to-configuration

The prototype of PowerDiff meant that two Statemate charts could be directly compared so changes could be visualized and it would be easier for employees to retrace previous work. Due to the embedded systems' complexity, the number of comparisons quickly rose to a triple-digit number of objects.

"Once the supplier and ourselves had constantly extended the functionality of Statemate, the requirements for PowerDiff and their design and documentation also increased," says Randolph. "We are currently using Statemate models with a capacity of several thousand charts and a documentation of up to 100,000 printed pages." This rise in volume turned PowerDiff from the original comparison into a complete and total configuration management tool.

Dr Michael Randolph (left) and Dr Michael Sturm collaborated on the software development




PowerDiff comparison of versions

## PowerDiff in the field

PowerDiff can now highlight any changes made in a Statemate model consisting of up to 6,000 charts at the push of a single button. PowerDiff goes far beyond a mere graphical-visual display and even compares context and algorithms of the models. The development engineers can precisely adjust the type of changes to be compared. This includes a logical comparison of the chart elements as well as a detailed, type-specific display of the element's types of arrays.

A hierarchical diagram showing the differences in the form of a tree and an easily operated synchronized zoom and scroll function in the graphical displays can save employees a lot of time. The index assigns the altered Statemate objects to the charts defining them. Each object listed is connected with a detailed description of its changes.

A summary function listing all altered objects according to type in alphabetical order ensures high operating comfort. It even includes a link with detailed change descriptions. Modifications can therefore be easily detected and analyzed.

## Comprehensive PDF reports

The growing complexity of the Statemate models has also increased the importance of an efficient report function, as the documentation may easily comprise thousands to tens of thousands of pages. PowerDiff automatically generates PDF documentations of various types. These include displays of changes, graphical comparisons of charts, and comparisons of elementary attributes in table form.

A high level of operating comfort is achieved through the flexible layout of headers and footers, the selection of individual or several charts, as well as entire models and the clearly represented, color-coded marking of differences. PowerDiff also offers specific context information for emphasizing differences in the detailed change descriptions. In addition to the highlighted differences between 'before case' and 'after case', the comparison tool displays unmodified object attributes as context information.

"Developed in long-term close cooperation with Berner & Mattner, PowerDiff facilitates the specification of Statemate models and has brought about a quality leap in systems engineering," explains Randolph. "Together we have developed a standard tool for comparing the Statemate models, as inquiries from other industries using Statemate clearly demonstrate."

Today the engineers of the Avionics & Mission Systems department benefit from a fully automated change management and can therefore focus on engineering. PowerDiff reliably takes over the analysis of model changes, supports the transition from model to realization and documents object changes. MAS's project teams in Germany, the UK, Italy, and Spain can now analyze and retrace model changes much better. PowerDiff plays an important role in the quick and efficient development of complex systems. ■

*Michael Sturm is department manager at Berner & Mattner Systemtechnik GmbH*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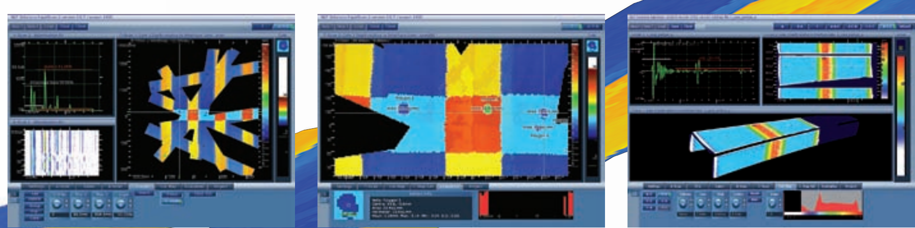

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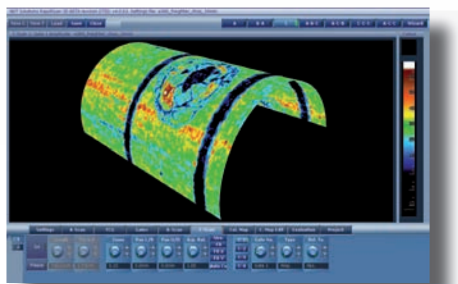

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A NEW SERIES OF COMBAT-CONFIGURED TIGER HELICOPTERS HAS JUST GONE INTO OPERATION IN AFGHANISTAN. IT IS THE CULMINATION OF EXTENSIVE TRIALS IN FRANCE AND AFRICA

BY DAVID OLIVER

By the beginning of September 2009, three Eurocopter Tiger HAP (Hélicoptère d'Appui Protection – helicopter for close protection) escort and fire support combat helicopters of the French Army's 5 RHC based in Pau, southwest France, were declared operational at Bagram Air Base in Afghanistan.

This was the culmination of a two-year trials program managed by Lt Col Jean-Baptiste Pouret, who has recently been appointed as the new Commanding Officer of the EFA, the Franco-German Tiger training center in Le Luc, southern France. Before the Tiger's deployment to Afghanistan, the French Army conducted a series of urgent modifications to its Tiger HAP helicopters.

Enhancements included the addition of improved air particle separators, rotor blade protection, and secure communications equipment. The aircraft also received additional ballistic protection for its pilots, the Sagem MPME digital mission planning and debriefing system, and external combat fuel tanks. The army assessed but rejected adapting the Tiger's ferry tanks for the latter requirement, and sought an off-the-shelf solution.

# Tiger earns its stripes

Environmental training for the Afghanistan deployment was conducted in Djibouti, near the Horn of Africa, and in the French Alps at altitudes up to 5,000ft (1,520m), and the service developed an immediate extraction technique that could see a downed pilot rescued by sitting on one of the Tiger's main wheels.

Procedures to transport the Tiger by air in a French Air Force C160 Transall and C-130 Hercules tactical transport aircraft were also validated, and the craft were airlifted to Kabul on Russian Antonov An-124 heavylift transport aircraft. After reassembly, the French Tigers were flown to Bagram to operate alongside French EC 725 Caracal multimission helicopters and Gazelle light helicopters used for night surveillance and reconnaissance missions. Earlier this year, the French Army conducted a test campaign using six MBDA Mistral air-to-air missiles fired from Tigers against drone targets. As well as its 30mm automatic cannon, the Tiger HAP is armed with 44 Thales 68mm unguided TDA rockets.

The French Army has logged more than 5,250 flight hours with its first 19 of 40 HAP-configured Tigers, based in Pau, Valence, and at the EFA at Le Luc. Only four of France's current fleet are in the Standard 1 configuration, which incorporates more than 270 modifications from the first Step 1 aircraft, delivered from April 2005. Its older examples will all be retrofitted to the operational configuration. The type's initial operational capability (IOC) was obtained in April 2009.

**"As well as its 30mm automatic cannon, the Tiger HAP is armed with 44 Thales 68mm unguided TDA rockets"**

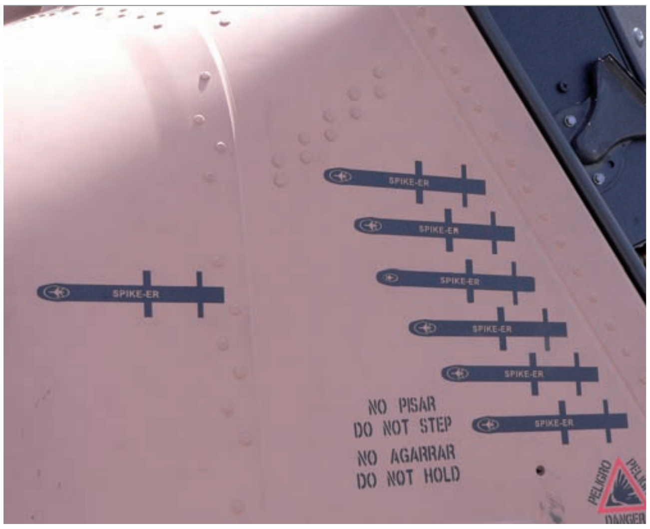
Meanwhile, Eurocopter is working toward the first flight of the Tiger HAD (Hélicoptère d'Appui Destruction/support destruction helicopter) multirole variant for France and Spain, which will be fitted with more powerful MTRI MTR 390-E engines. This aircraft, the first of 40 on order for the French Army, was scheduled to begin firing trials with the Lockheed Martin AGM-114 Hellfire air-to-surface missile from September 2009.

The French Army's specifications for the HAD variant were issued in 2003 and contracts were signed in November 2005. The first flight of a pre-production development HAD that was fitted with the original MTR 390 turboshaft engines took place in December 2007. Development testing will continue during 2009 into 2010 with qualification and evaluation to take place between 2010 and 2012.

The Spanish Army will also receive 24 of the 6.6 tonne Tiger HADs, including an interim batch of six HAP-configured aircraft that will later be modified to the enhanced standard. The first Spanish HAD is scheduled for delivery

Right: In Afghanistan the French Army Tiger will operate with Gazelle recce helicopters

Below: The prototype Tiger HAD used for Rafael Spike-ER anti-armour missile trials. (All photos courtesy David Oliver)

in early 2012, and the first French HAD soon after. The pre-production Tiger HAD has been used for live-firing trials of the Israeli Rafael Spike-ER anti-armor missiles that will equip the Spanish Tiger helicopters.

Playing an important part in the Tiger HAD trials is the French Flight Test Centre (CEV) that was established in 1944 at Cazaux. Its capabilities include the development, qualification, and acceptance of national aircraft – civil and military. Flight testing is supported by networks of experts and well-trained and qualified teams with flight test expertise.

CEV uses ground and inflight test and simulation facilities at the forefront of technical excellence. These include ground targets, flying test benches, tracking facilities, cameras, infrared and electromagnetic signature measurement, electronic warfare ground stations, firing range, and flight recorder analysis.

The Centre has its own test and acceptance flight crew school (EPNER) that takes on many French and foreign trainees from both state organizations and companies. Its 10-month rotary-wing experimental flight test course includes some 380 hours of ground lectures, covering the basic theoretical knowledge and all main topics dealing with flight test activity followed by around 85 flights on more than 12 types of helicopters. Student test pilots will fly solo on at least five different helicopters. The flight exercises cover three main fields: performance measurement, handling qualities assessment and systems evaluation.

**"The pre-production Tiger HAD has been used for live-firing trials of the Israeli Rafael Spike-ER anti-armor missiles"**

EPNER uses its own fleet of fully instrumented aircraft for all the basic in-flight exercises while specific flights, systems study and aircraft evaluation are performed on CEV's fleet of helicopters.

In addition, the Tiger engine undergoes a stringent testing regime at CEPr, the French Ministry of Defence's aero-engine test center at Saclay near Paris, which employs more than 350 personnel. Trials of the more powerful MTR 390-E include those from sea level to altitude, cold and hot engine starts, engine performance, FADEC optimization, relighting engine in flight, icing and air intake testing with engine running, the qualification of fuel systems, and the qualification of the rotor blades.

Cold-weather testing of the Tiger and its engines take place at Barcelonette in the French Alps and hot-weather testing is conducted in Djibouti.

With its first operational deployment overseas, the Tiger can be said to have been well and truly tried and tested. ∎

# Noise is a problem

Sound and vibration specialist Brüel & Kjær has been making precision measurement microphones for more than 50 years, and has many firsts to its name. Now B&K is introducing the world's first multifield microphone – a high-quality measuring microphone with uniform response in any sound field.

In many practical situations the sound field can be unpredictable. It is rarely truly free or diffuse, but is made up of an unpredictable mix of the two. Until now acoustic engineers have been forced to make a choice between a microphone optimized for a free, diffuse, or pressure field, and this choice is often made without preceding knowledge of the sound field. But, when a compromise is made with the microphone, one can risk errors in measurements that could exceed 10dB at 20kHz.

One could argue that a quarter-inch microphone would be sufficient for most acoustic in-cabin tasks. These mics are relatively impervious to the type of sound field as their physical presence is not big enough to influence the sound waves. And, with a general trend in the aerospace industry toward higher frequencies, their useful frequency range seems to fit the bill. But, this is not the case. Noise is a problem.

## The sound situation

Unfortunately, the inherent noise in practical measurement microphones increases as the diaphragm diameter decreases. So, although the typical inherent noise of a half-inch measuring microphone (including its preamplifier) is typically just below 20dB(A), it is typically around 40dB for a quarter-inch combination. Also, when the cartridge sensitivity reduces, the inherent noise in the preamplifier contributes to the combined noise floor, making the situation even worse.

This is all well known, and it has not really been possible to increase the sensitivity of the cartridge while maintaining the stability of the microphone. One way to increase the sensitivity of a condenser microphone is to reduce the distance between the back-plate and the diaphragm. However, doing this makes the microphone sensitivity more susceptible to fluctuations in barometric pressure. Ideally, the microphone sensitivity is controlled by the diaphragm stiffness, and a smaller distance between diaphragm and back-plate means a higher stiffness of the 'air cushion' between the back-plate and diaphragm – and this would have a higher impact on the sensitivity than is acceptable.

For this reason the minimum distance between the diaphragm and back-plate in a measuring microphone is limited to approximately 20µm.

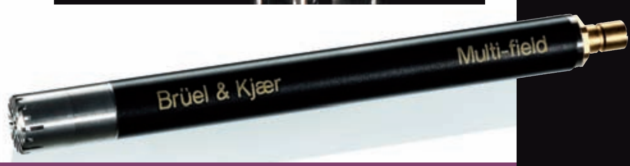
## Diaphragm mass and tension

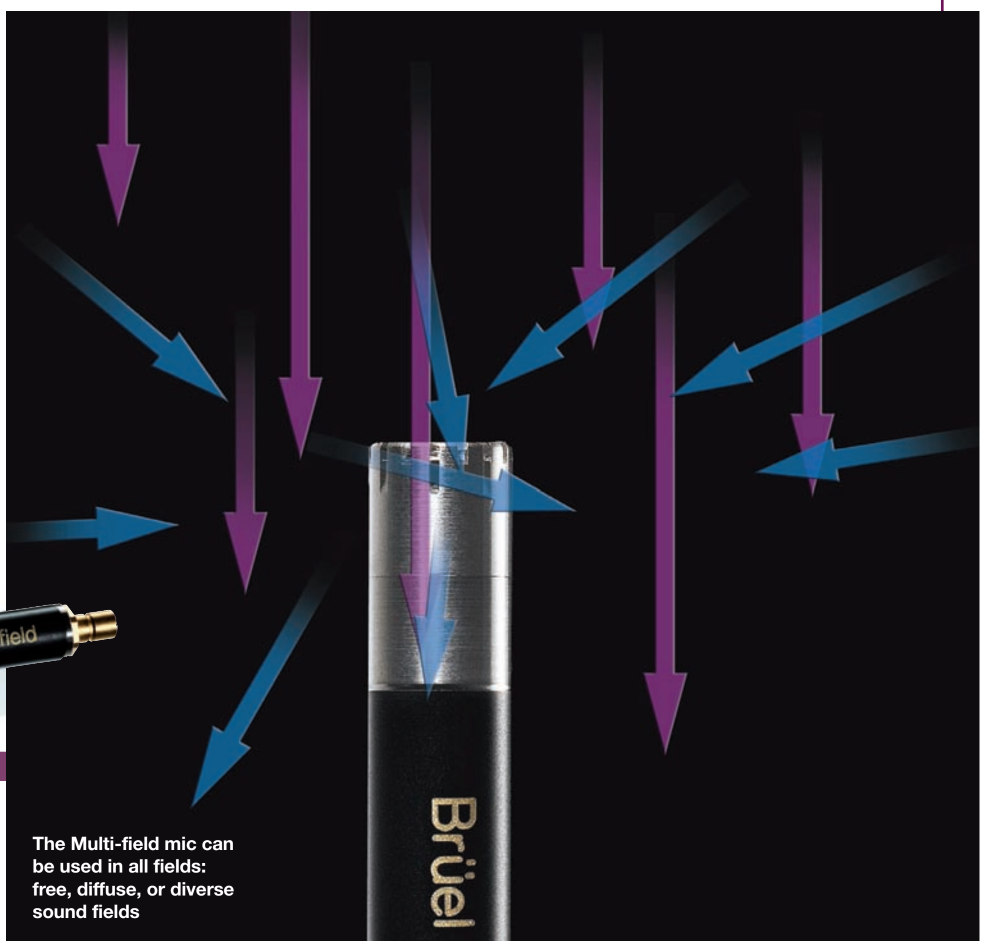
A lower mechanical tension in the diaphragm will also increase the sensitivity, but this results in a lower upper frequency limit, determined by the resonance frequency √(F/m), where 'F' is proportional to the diaphragm tension and 'm' is the diaphragm mass. The use, therefore, of a diaphragm material with lower specific mass will mean that the diaphragm tension can be reduced without the penalty of a reduction of the usable frequency range.

The new Type 4961 Multi-field microphone is an all-titanium unit, with even the diaphragm made from titanium. Titanium has a specific mass of 4,500kg/m$^3$ versus 8,800kg/m$^3$ for the stainless alloys typically used nowadays.

This low diaphragm mass, in combination with a much lower tension and special aging techniques, is being used in the new B&K Multi-field microphone. A special mechanical design of the diaphragm/back-plate also yields an effective area that is more than 20% larger than that of a traditional quarter-inch measuring microphone.

Using innovative design, B&K is introducing the world's first multifield measuring microphone. Due to its small size, the angle of incidence is less critical than for a half-inch microphone, and for its size the multifield microphone has an exceptionally low noise floor. B&K believes that for unknown sound-field conditions, the multifield microphone is the best choice.




The Multi-field mic can be used in all fields: free, diffuse, or diverse sound fields

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# Maximize measured data

The amount of engineering data generated in the process of product validation is often huge. Engineers may use departmental file stores or tape silos to store data, the result being limited access for the rest of the organization. Even test departments can waste a large amount of time just looking for the right data. Further, the increased use of CAE models and computer simulations means that a wider group of engineers will request measurements to correlate their models. Additionally, data by itself even when accompanied by descriptive metadata or documentation is often not enough.

Further analysis is required to take gigabytes of measured data and extract useful information. The need to find the right data quickly and easily has never been greater.

In response to this need, the new 5.1 release of nCode Automation includes many new features that provide a higher level of flexibility for engineers needing to interrogate and learn from their test data. It offers a complete environment for engineering data storage, analysis, and reporting, and features new extensible solutions to drive collaboration and inform decision-making. nCode Automation provides a web-based collaborative interface for sharing test data and associated information throughout an organization and/or across the globe.

## Tag data

A new 'characteristic values' capability enables users to tag data with additional information that can be used for searching, trending, and reporting. These characteristic values can be calculated using analysis routines that can be added by end users. Calculations are very flexible and even enables retrospective analyses to be performed on existing stored data. This means that users can examine all aspects of the measured data for greater understanding of its dynamics.

Version 5.1 offers a Workgroup edition, an easy to deploy and cost-effective system for a single group or department. Easily installed, Workgroup provides an immediate off-the-shelf solution to begin managing and learning from measured data. The larger Enterprise edition integrates with Oracle and IBM WebSphere products to provide a corporate solution that enables secure global data access via the internet. Current automation clients include leading OEMs and suppliers from aerospace and automotive industries around the world.

## Case study

A major aerospace manufacturer uses nCode Automation to share engineering data from full-scale test articles of a next-generation warplane. In addition to the test data from over 4,000 simultaneous measurement locations, nCode Automation also stores associated documents and spreadsheets, which can be searched for content. It is also critical that global project partners can only access the data they are allowed to see, while also conforming to the required ITAR regulations. nCode Automation makes this collaboration between global partners rapid and secure.

"Maximizing the value of test data continues to be a challenge for many engineering departments. When collaboration is required between companies or across the globe, these problems are compounded," states Jon Aldred, product manager for nCode products. "This latest release provides a level of flexibility in how engineers can learn from their data that we believe is unparalleled in any other off-the-shelf product."


**nCode Automation 5.1 includes many new features that provide a higher level of flexibility for engineers who need to interrogate and learn from their test data (pictures courtesy BAE Systems)**

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# High-resolution scans

As fuel prices have soared in recent years, there has been an increased trend for airlines to replace older, fuel-thirsty aircraft with more efficient models that also allow more payload by the increasing use of lightweight composite materials. All this serves to further increase demand. This trend can be seen in the figures from aircraft manufactured in the USA and Airbus's projections for future growth.

However, whereas the failure mechanisms for traditional metal alloy airframes are well understood, the mechanism of composite material failure is very complex in comparison. For example, a small impact defect on the surface can hide a much larger flaw under the surface. This creates a need for testing methods to be adapted to 100% testing of the surface areas of composite material used in these new aircraft both in manufacture and MRO.

## Ultrasonic array systems

In 2003 SONATEST NDTS and Airbus UK developed the RapidScan 1. It was further developed by Sonatest and released as RapidScan 2 in 2006. The RapidScan 2 is a 2D ultrasonic array system that uses a 128-channel pulser-receiver to generate beams of up to 32 active channels. This system has been integrated with a custom high-speed data capture card that controls the beam forming electronics and processes the raw ultrasound data to deliver high frame rate B-scan and rapid processing for C-scan data. Image frame rates of 100-300 times per second can readily be achieved, permitting fast, high-resolution scanning of large components.

SONATEST NDTS has now introduced the new RapidScan 3D, which has the capability to scan structures quickly and accurately using a coordinated measuring arm. The speed and ease of use of this system has revolutionized traditional NDT scanning methods, removing the need for expensive immersion tanks and associated tooling, and vastly reducing the time taken to locate and identify defects and anomalies.

The RapidScan 3D offers an integrated ultrasonic scanning system. Large area coverage is possible due to the combination of the high-resolution ultrasonic arrays used within the Wheelprobe, powerful workflows software and the measuring arm.

## Ergonomic design

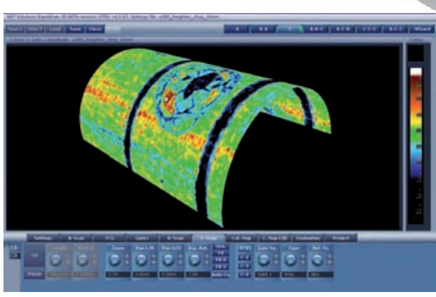
The system is ergonomically designed to follow complex 3D shapes, greatly reducing inspection time. The inspection of even large areas can now be achieved in a fraction of the time of traditional NDT methods. Accurate results are presented in the form of 3D images of the inspected part that can be cross-referenced to traditional 2D C-Scans. These results can be shared and understood even by those without NDT experience.

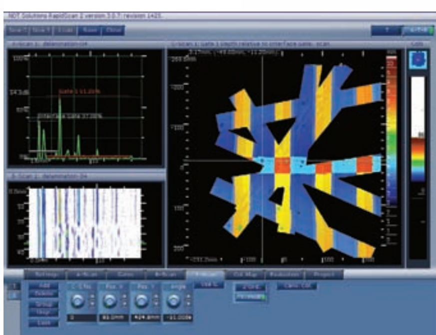
The RapidScan 3D comes with a complete suite of software tools, supplied as standard, enabling the storage of test measurements taken on location. Post-processing and results analysis can be performed off-line or even off site. Powerful analysis functions mean defects can be detected, sized, and reported.

The RapidScan software wizard enables the operator to quickly choose a specific part from a library stored on the instrument. These parts are supplied from a mixture of images based on specific 3D CAD models and parts generated from pre-defined stock objects. The wizard then presents compatible inspection tools for different regions of the test part. The library can be developed for many specific testing applications and environments, providing a selection of measuring solutions.

The RapidScan uses the Wheelprobe technology, which enables almost dry coupling and is well adapted to MRO use. This application is not just limited to the aerospace industry. The Wheelprobe capability of providing a fast 'C-Scan' whether used with the RapidScan or even with other industry standard equipment is being used extensively in corrosion mapping. The Wheelprobe is proving to be very successful in delamination detection, bond inspection thickness mapping, corrosion mapping, gap-fill detection, and elsewhere.

**Radpiscan 3D Arm with screenshot and the Wheelprobe**



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# No job too small

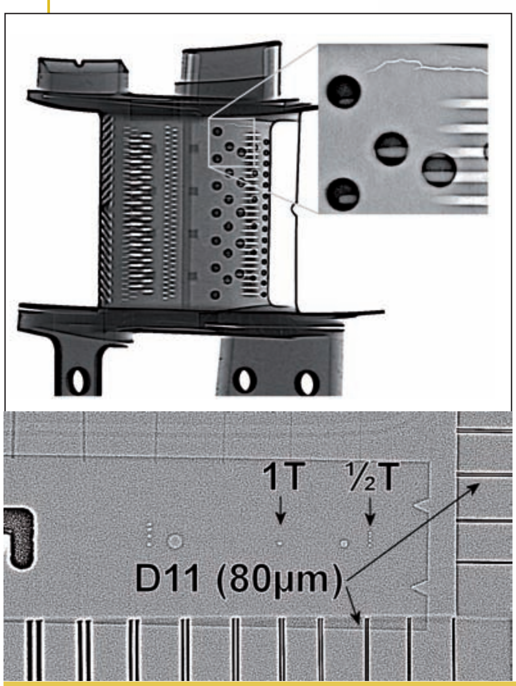
Quality standards in the aviation industry are very high, and many inspection procedures are used to ensure that they are complied with. Whenever components' inner structures have to be inspected on a non-destructive basis, digital radiography and computed tomography are the technologies of choice. The tiniest flaws in welding seams or turbine blades can be detected with the help of industrial x-ray inspection without destroying the inspection items. Yet the same applies to parts made of fiber-reinforced composites. In addition, computed tomography enables geometric measurements to be conducted and results in the precise, 3D analysis of inner structures.

Precise inspection results containing high-contrast, highly detailed images form the prerequisite for fulfilling safety standards. They contribute to increasing efficiency and improving quality within the production process, too. The quality of the image acquisition chain is decisive in achieving an optimum result. It consists of an x-ray tube, a detector, and image analysis software; the x-ray source in particular has a great influence on the quality of the results obtained.

## Quality from microfocus tubes

For the first time, the sealed variofocus x-ray tube makes it possible to generate x-ray images where previously the quality had been attained only by microfocus tubes. This variofocus technology offers a number of advantages over the technology employed in other x-ray tubes, especially when testing components or cast parts with different densities and thicknesses. As the name implies, variofocus can be variably adapted to match their requirements. Its attributes close the gap between microfocus and conventional x-ray tubes.

Using a minimal effective focal-spot size of 80µm, the variofocus x-ray system achieves a resolution that covers many of the required specifications called for in inspection tasks within aviation and aerospace. When a modern, digital flat-panel detector is deployed, a 'total unsharpness' of the image chain below 100µm is achieved at an x-ray output power of 1,000W. This means that details are being detected using variofocus technology that had previously been the sole domain of microfocus tubes. As was the case in comparison to standard x-ray tubes, the necessary CNR is being achieved in a shorter timeframe due to the variofocus system's higher output.





## Application test using Inconel

A great challenge in aircraft construction is the inspection of aircraft parts made of high-temperature-resistant materials such as Inconel. Jet engine parts, such as duct welding seams, are made out of these kinds of materials. The increasing demands for these materials to withstand stress is resulting in ever-greater strictness about the specifications to which welded seams must be tested.

In this example test, three-step wedges made of Inconel were produced in order to verify the required image quality for inspection items made out of the material. For analysis the steps were irradiated using thicknesses of 50 mil (1.27mm), 150 mil (3.81mm), and 250 mil (6.35mm) per hole-type penetrameter in compliance with ASTM E1025 (Inconel, size 5). Acquisition of the x-ray images occurred using an efficient flat-panel detector. A geometry typically found in the industry and a magnification of 4.5x was chosen. In an objective mathematical analysis procedure, Y.IMAGE 3500 software confirmed that the CNR of 2.5 necessary for an assured detection of flaws had been achieved. This finding demonstrated that it is not only 1T holes (10 mil, 254µm) that can be detected with certainty across all steps of the Inconel step wedge using the variofocus system, but even 127µm holes spaced 70µm from each other. The proof has therefore been supplied that the variofocus tube achieves the resolution required to detect very small structures.

In terms of detail detectability, the variofocus tube benefits from the fact that the CNR plays a role that is just as important as geometric resolution. In an effective focal-spot sector ranging from 80µm to 150µm, the variofocus tube has an output power of 300W to 1000W. This means that it achieves a distinctly better CNR than a microfocus tube at an identical exposure time. As a comparison, the integration time that the variofocus and microfocus tubes need to achieve a CNR of 2.5 – the figure required for assured detection of a 1T hole in 250 mil (6.35mm) of Inconel – were measured. With 0.5 seconds, the variofocus tube needs merely one-eighth of the time that a microfocus tube needs.

**High-resolution x-ray image of an HPT vane and Y.TU225-VF variofocus x-ray tube**

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# Validation at component level

Aerodynamic and acoustic validation at component level is a key factor to ensure the success of new products in the aero engine and gas turbine industries. These validation tests focus on improving efficiency while reducing emissions and noise. At the same time these tests allow the user to optimize existing designs and to fully understand the complete aerodynamics.

AneCom AeroTest offers the complete range of services to support its customers in this area including: mechanical and instrumentation design including analysis of the test vehicle; supply chain management for all necessary hardware; assembly, instrumentation and integration into the testbed; test execution, data acquisition and pre-analysis, and strip, inspection and rebuilds. The service is offered for the following areas: aerodynamic testing of fans, compressors, combustors and turbines; acoustic testing of fans, and calibration services for all kinds of aerodynamic probes.

To reduce customer administration, AneCom AeroTest has developed its unique 'one-stop-shop' concept comprising the project management of the complete engineering and testing package – one interface to the customer responsible for the complete service minimizing the effort on the customers' side.

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# Multi-role recorders

Acra Control has developed a new range of SSR-500 multi-role recorders that utilize plug-in modules to provide interfaces to analog and wideband data acquisition, avionics bus monitoring and video compression. They feature built in audio, IRIG/GPS timing and Ethernet and are available with different removable storage media (CompactFlash or SATA solid state drives), a number of plug-in module slots and display/mounting options. Control is via a 'start/stop' switch and an 'event' button or through external start/stop and event inputs or SNMP commands. A display indicates the memory and status of the device.

All of the recorders have simple set-up with a streamlined configuration. A PC sees the storage as a FAT32 drive – therefore the files are instantly accessible with no need for additional conversion software. The SSR-500 modules can be used in the KAM-500 data acquisition system from ACRA CONTROL and many modules from the KAM-500 range can be used in the SSR-500 units.

**For further information contact**
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**or go to online enquiry card 106**

# Dual vibration amplifier

As part of the company's suite of rotating machinery signal conditioners, Precision Filters Inc has announced the new 28302B Dual Vibration Amplifier. The 28302B is designed to condition differential or single-ended charge sensors, IEPE sensors or remote velocity pick-ups. The card operates over a 0.3-20kHz bandwidth and is free from low frequency peaking that can occur from high temperature accelerometer shunt resistance. AC and DC outputs are provided in engineering units for acceleration, velocity, and displacement.

As part of the Precision 28000 System, the 28302B may be mixed with dynamic strain, bridge, temperature and F-to-V conditioners to address demanding turbine-machinery applications. Programming of the 28000 System is accomplished via the Ethernet or via the 28000 graphical user interface resident on a host computer. The built-in test hardware and software provide quick go/no-go tests, and rigorous factory acceptance tests to assure you that the 28000 meets your most stringent requirements for critical applications.

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# Great minds meet

In July 2009, one of three annual Nadcap meetings took place in Istanbul, Turkey. Nadcap is the leading worldwide cooperative program of major companies designed to manage a cost-effective consensus approach to special processes & products and provide continual improvement within the aerospace & automotive industries.

Nadcap delegates included: government agency representatives, aerospace prime contractors and suppliers, who participated in technical task group activities such as audit checklist development and revision and supplier development workshops. Attendees also had the opportunity to attend the Nadcap Management Council (NMC) and Supplier Support Committee (SSC) meetings, which provide an overview and discussion of the non-technical issues that are important to the industry, such as flowdown, standardization and globalization.

At the recent NMC meeting, several awards were presented: Mike Coleman of the Boeing Company accepted an NMC recognition certificate on behalf of outgoing NMC member Arne Logan; Steve Tooley of Rolls-Royce plc accepted an NMC recognition certificate on behalf of outgoing NMC member Quan Lac; Christian Buck accepted NUCAP awards for Ceramic Coating Center (SAFRAN) & Hispano-Suiza (SAFRAN).

In addition, at the SSC meeting, Kevin Ward, corporate director of Nadcap Special Processes at the Goodrich Corporation and Pascal Blondet of Procurement Quality at Airbus provided insight into their organizational position on Nadcap. Their presentations are now on the PRI website for public reference.

Nadcap meetings are free to attend and provide many benefits, not least the sense of contributing to the continual improvement of the industry through cooperation. Nadcap meetings summarize what the Nadcap program is all about: cooperation over competition for quality.

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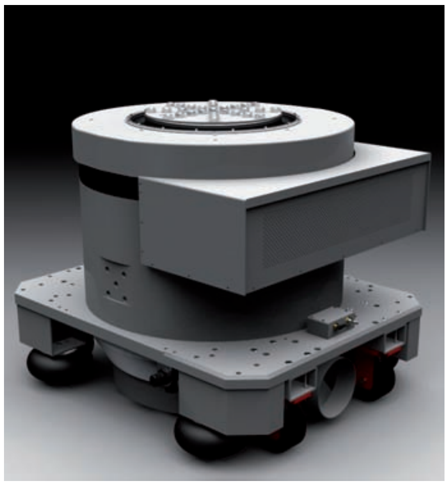
# Index to advertisers

# New Shakers meet Customer Specs



Two 100% air-cooled system configurations have been added to the popular R-Series family of vibration test systems from Unholtz-Dickie. The Model SAI60-R16C-2.5 (2.5in stroke) rated at 13,000 lbf Sine/12,000 lbf Random, and the Model SAI90-R16C-3 (3in stroke) 13,500 lbf Sine/13,500 lbf Random. With lightweight, 17.5in diameter armatures, the new R16 machines substantially increase test performance and flexibility, particularly for many of the demanding, low frequency transportation and shock pulse requirements commonly used by defense contractors and other related hardware manufacturers.

The R16C shaker incorporates a high strength, cast magnesium armature with multiple ribs for maximum stiffness and minimum weight. Eight highly damped flexural elements, four shear mount elements, and a robust center post bearing provide excellent off-axis restraint and guidance, under the most demanding test conditions.

The featured SAI90-R16C-3 Shaker System provides some impressive performance characteristics, further distancing it from competitive shaker systems. Performance highlights include 118g-pk Maximum Sine Acceleration, 80grms Maximum Random Acceleration, 193in/sec Shock Velocity, and 100g - 11msec Shock with 170 lb payload.

**For further information contact**
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**or go to online enquiry card 109**

# Lightweight miniature sensors

The US company, Philtec has announced the introduction of the FTS series of miniaturized sensors for flight test applications. Weighing just 175g, the sensor electronics feature a 25mm x 50mm x 75mm grounded enclosure with MIL-DTL-83513 Micro-D connector for DC input voltage and analog output voltage. The total system weight including a standard fiber optic probe is 220g.

Philtec provides customized non-contact fiberoptic sensors which are ideally suited for the extreme environments of many aerospace applications. Small probe size, wide sensor bandwidth and extreme temperature ranges are key advantages. These devices measure linear distance and displacement up to 50mm. Structural vibrations can be measured with submicron level resolution.

Typical applications include valve and actuator dynamics, turbine-shaft and blade-tip dynamics, as well as satellite component testing in cryogenic chambers.

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# The first civil jet (pt II)

BY FRANK MILLARD

In 1953 the Comet was withdrawn from service pending an inquiry following a succession of crashes involving the aircraft, which had appeared to break up in flight.

The inquiry took 22 days and heard the testimony of 68 witnesses.

On October 21, Sir Arnold Hall, director of the UK's Royal Aircraft Establishment, Farnborough, dramatically described the results of an experiment where a one-tenth-scale model of the Comet's cabin containing seats and dummy passengers was placed in a chamber evacuated to simulate an altitude of 40,000ft and subjected to 8.5 lb above external pressure (*The Times*). This caused a fracture in the fuselage.

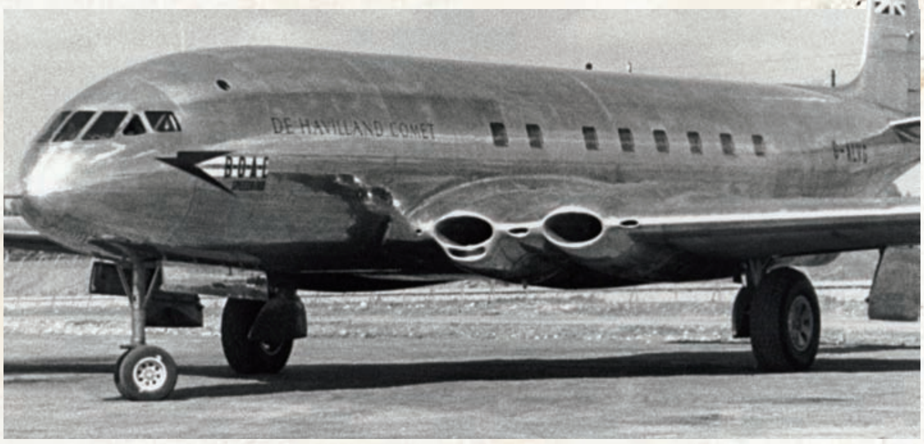
Hall reported that after one-tenth of a second, "Complete chaos developed in the cabin." In time-lapse photographs, dummy passengers were seen hitting the roof. He believed that something like this had happened in a Comet that had crashed off Elba, Italy. "On another photograph, one could see one of the dummy passengers going straight through the hole in the cabin without touching." Hall said he believed that, "The first disruption took place in the region of the top center of the fuselage, and that there was a very violent disruption of the pressure cabin."

The inquiry heard that the evidence of marks made by parts of the cabin when it blew sideways confirmed that the first disruption took place in the pressure cabin.

At Farnborough, a new type of test was employed that applied cycle air loads on the wings and fuselage simultaneously. The aircraft was completely submerged in a tank of water, and the fuselage was also filled and internal pressure applied by pumping in more liquid. Pressure switches controlled the cycling action. The peak pressure was 8.25psi during a loading cycle that took approximately 65 seconds.

When fatigue cracks were found during visual inspections, they were observed continuously with an inverted periscope. Prior to the test, strains were measured at the corners of selected windows and escape hatches using resistance-wire strain gauges.

The Ministry report states: "A total of 11,319 pressure cycles of 0-8.25psi, to 0 were applied to the fuselage. Fatigue cracks occurred in the skin at the corners of nine windows and two escape hatches, 16 corners being affected."




The Comet's thin metal skin was composed of advanced new alloys

The test revealed that fatigue cracks occurred soonest and mostly around the windows in the center section. The report noted that the general level of stress at the corners of the apertures was some two to three times that found elsewhere in the fuselage.

The report went on: "All the fatigue cracks originated at the countersunk rivet holes in the skin at the window and escape hatch corners. Those cracks, which eventually became catastrophic, started at outer-row rivet holes. The few cracks that originated at holes in the inner row grew inward to the edge of the aperture and did not become catastrophic. No cracks originated at the edges of the apertures."

Investigations that followed the Comet crashes provided valuable data for test engineers and aircraft manufacturers around the world, and advanced not only the design of jet airliners but also the technology involved in testing them.

However, aviation writer Robert J. Serling writes that even before the Comet crashes, Boeing and Douglas were already designing jet airliners with thicker skins, extra strength, metal bracing, and rounded windows.

He reveals that, "The most important insurance against catastrophic decompression [in the new Boeings] were the small metal tabs or 'stoppers' strategically placed throughout the fuselage so that if a fatigue crack should develop, its path would be blocked before explosive decompression could occur."

The Elba Comet had flown over a million miles without any mishap. What surprised the authorities was that if the crashes were due to metal fatigue, this had not been picked up during rigorous testing of the aircraft prior to commercial service.

Jet airliners were new technology and were subject to new stresses. Existing knowledge and contemporary testing procedures could not be relied upon, therefore, to predict every eventuality. In retrospect a fuselage design that grew out of and was similar to conventional styling, featuring panoramic square windows appealing to the passenger flight experience, could have been examined more closely. Based on the knowledge of the time, the tragedies of the Comet crashes and the subsequent damage to the aircraft's reputation (despite exhaustive tests, reinforcements, upgrades, and redesigns) could hardly have been avoided. ∎

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