Technology update

Paris Air Show preview

There will be no disputing the star of this month's Paris Air Show at Le Bourget. It will be the towering, twin-deck **Airbus** A380-800 that will, quite literally, dominate the show. The organizers hope that the aircraft will take some part in the flying program. The A380, which will typically carry 555 passengers in airline service, represents the combined design and technology strengths of Airbus elements across Europe, plus the input of hundreds of suppliers in many parts of the world.

With more flying displays than in previous years and the presence of prestigious prototypes in the static and flying displays, the 2005 Paris Air Show will "reflect the renewal of business activity in all aerospace sectors," according to **PLBpe**, the show organizer and a wholly-owned subsidiary of **Gifas**, an association that brings together prime contractors and equipment manufacturers of the French aerospace industry.

Another all-new aircraft at the Le Bourget venue will be the latest member of **Dassault**'s Falcon family, the 7X business jet, which combines high performance and a 5700-nmi range. Its wide-body cabin has a "breakthrough environmental system" that includes advanced temperature monitoring to maintain a precise cabin temperature and an in-flight cabin altitude of 6000 ft, which Dassault claims is 2000 ft lower than today's norm of 8000 ft. To meet individual requirements, buyers can work with Dassault experts to digitally configure cabin layout and trim requirements, together with technology and systems.

Gulfstream's G450 and G550 will be at Paris. The G550, equipped with advanced cockpit avionics, can fly eight passengers and four crew 6750 nmi. Normal cruise speed is Mach 0.85, with 0.885 as a maximum. The cabin can be configured to take 18 passengers. To better facilitate customer decisions on specifications, computers and large-format projectors are used to help them visualize and select fabrics, carpeting, and upholstery to create a "premium interior." The interior may include showers, state rooms, galleys with countertop cooking, exercise bikes, surround-sound entertainment systems, multiple flat-panel video monitors, satellite phones, and DIRECTV.

On display at the Paris Air Show will be Embraer's new 108-seat EMB 195, which is powered by GE CF34-10E engines and is the largest aircraft the company has ever built.

The three-engined Dassault Falcon 7X has been designed to have an in-flight cabin altitude of 6000 ft. It will be equipped with fly-by-wire controls, which the company says is a first for a "pure business jet."

Other new or significant aircraft at the 46th Paris Show, which is open June 13 to 19 (general public admission is June 17 to 19), will include the **Embraer** EMB 195, the **Boeing** 767-300 tanker, and the long-range Boeing 777-200LR. **Aermacchi** will show its M346 advanced jet trainer, and **Kazan** the Mi-38 helicopter.

With 108 seats, the Embraer 195 is the largest aircraft built by the company. It is powered by two **GE** CF34-10E engines and can be configured for single- or dual-class operation. Maximum payload is 29,829 lb. Certification of the aircraft is slated for the second half of 2006. It is the fourth and largest of a four-member family of commercial jets specifically designed for the 70-110-seat market, says Embraer, and is expected to take part in the flying program at Paris.

Several UAVs will be at the show, including exhibits from **EADS**, **Sagem**, and **Northrop Grumman**, but the event's organizers say that none will be flown. This precaution is for safety reasons, as Le Bourget is close to urban areas. However, flight tests are to be carried out in coming months, mainly in the south of France, to decide if UAVs could be flown safely at the 2007 Paris Show.

As it was two years ago, the UAV sector will be an integral part of this year's show. Currently, some 300 UAV programs or UAV-associated programs are reported to be under way in more than 40 countries. While military uses for UAVs have been proven in a variety of scenarios, there is increasing interest in their applications in the civil sector, with potential roles including mapping, forest fire detection, crop spraying, and various surveillance tasks.

The forecast figure for exhibitors at Le Bourget this year is 1800 from 44 countries. More than 200 aircraft are expected to be present. The covered exhibition areas are enlarged this year from 50,000 to 52,000 m^2. External exhibition areas are down slightly to 33,000 m^2.

There will be an area dedicated to French and European SMEs (small and medium-sized enterprises). The space industry will also have a significant presence, with Helios II and **Syracuse** satellites. The U.S. presence will include a **Department of Commerce** pavilion, and major exhibitors other than Boeing and Gulfstream will include **Bell Helicopter**, **Lockheed Martin**, **Northrop Grumman**, and **Raytheon**, as well as the **Department of Defense**.

Stuart Birch

metronom adds to accuracy

Manufacturing accuracy is a central issue throughout the aerospace industry. The Spatial Reference System (SRS) has been designed and manufactured by **metronom US** to verify and/or calibrate the accuracy of 3-D measuring equipment such as coordinate measuring machines, laser trackers, portable measuring arms, machine tools, and photogrammetry equipment. It has been supplied to **BAE Systems**' Salmesbury facility by **Inora Technologies** for use in the manufacture of elements of the **Eurofighter** Typhoon and the **Lockheed Martin** F-35 Joint Strike Fighter.

metronom's Spatial Reference System (SRS) tetrahedron is in use by BAE Systems for the manufacture of elements of the Typhoon and F-35. The unique structural setup of the SRS bars is said to guarantee no dimensional influence in measurements through variation in humidity or temperature.

SRS is supplied as a tetrahedron constructed from six carbon-fiber bars, each with a metallic end cap that connects to a sphere. Each sphere connects to three bars, creating the tetrahedron. The bars have a coefficient of thermal expansion of 0.1 μm/°C, so the effect to the SRS of changing, or different, temperatures is negligible, according to metronome.

The SRS is used to evaluate tool and measuring equipment performance in various ways and is described as a "perfect comparator" to first-principle calibration techniques. According to BAE, it cannot replace such techniques, but it can verify that they have been completed to a satisfactory standard. The data generated immediately after a calibration benchmarks the capability of the equipment and highlights the best and worst areas of performance. The data is subsequently used to monitor the equipment's capability on a regular basis (SRS health check measurements) and ultimately to predict when the equipment will drift out of acceptable tolerances, therefore providing predictive rather than planned maintenance values.

Data generated from regular health checks also support quick equipment evaluations after collisions. Traditionally, the evaluation of machines and measuring devices after collisions is a lengthy process involving granite squares, laser interferometers, etc., but the SRS can be used to very quickly check the performance of the equipment by comparing a new measurement to those taken previously.

The company uses a state-of-the-art technique it calls INORA (INtelligent Optimization, Regulation, Adjustment) to evaluate datasets in what metronom describes as "a crisp manner compared to traditional best-fit algorithms with their inherently disadvantageous smearing effects." INORA algorithms decrease the negative influence measurement uncertainty has on the capability study of the equipment, it claims.

SRS hardware is built using a patented method to create a "virtually perfect" structure without internal constraints There is no requirement for electronic equipment such as temperature or pressure sensors, or for compensations typically needed for machine tool calibration equipment such as lasers, according to metronom.

Stuart Birch

Missile testing reduces risk, cost

Lockheed Martin has completed initial F/A-18 E/F integration wind-tunnel tests of its Joint Common Missile (JCM),which is expected to provide pilots a precise, all-weather, low-collateral-damage weapon required to counter unconventional threats. The tests were conducted at **NASA Ames Research Center**'s 11-ft wind tunnel in San Jose, CA, and at the **Boeing** Vertol 20-ft wind tunnel in Philadelphia, PA.

Testing simulated the flight environments of the F/A-18 E/F Hornet in various carry configurations of the fire-and-forget JCM and its Joint Dual-Rail Launcher (JDRL). This testing builds on the JCM free-stream wind-tunnel testing previously conducted toward the development and integration of JCM onto its host aircraft.

In the most recent testing, a JCM scale model was mounted on a movable support system and positioned to simulate its in-flight position on the aircraft. Tests included high- and low-speed flight, weapon store separation, and aerodynamic loading. Test data and analysis are being used to further perform integration efforts on the fixed-wing platform.

"This [testing] is an efficient way to control costs and continue to improve our design. It will reduce risk and the number of flight missions, which also saves cost," said Steve Barnoske, JCM Program Director at Lockheed Martin Missiles and Fire Control. "Combined with our previous wind-tunnel testing, this [test] verifies the missile and launcher aerodynamic designs in the high-speed fixed-wing flight environment."

When fielded on the F/A-18 E/F, the JCM will be carried by the JDRL, which is provided by **EDO**. Prototype launcher electronics have already undergone initial integration testing in the **U.S. Navy**'s Advanced Weapons Laboratory at China Lake, CA, as well as fit-checks and uploads with models on aircraft at the Naval Air Weapon Station at China Lake.

"The Hornet will be able to carry up to 12 JCMs, providing far more lethality, especially against moving targets in adverse weather conditions," said Barnoske. "JCM provides more stowed kills than the Maverick missile it will be replacing. And due to JCM's lighter weight, that also means increased carrier 'bring-back' capability."

In addition to replacing the Maverick missile on the F/A-18E/F fighter, JCM will also replace the Longbow and Hellfire missiles for three rotary-wing platforms: the **U.S. Army**'s AH-64D Apache attack helicopter, the **U.S. Marine Corps**' AH-1Z Cobra attack helicopter, and the Navy's MH60-R/S Seahawk armed reconnaissance helicopter.

Source: Boeing

Lockheed Martin recently completed wind-tunnel tests of the U.S. Navy's F/A-18 E/F in various carry configurations of the JCM and its Joint Dual-Rail Launcher. The JCM is a multi-target weapon with fire-and-forget capability and precision-strike targeting that is expected to replace the Maverick on the F/A-18 E/F, as well as Longbow and Hellfire missiles for three rotary-wing platforms.

JCM's advanced technologies provide similar missile procurement costs and reduced life-cycle costs compared to legacy missiles such as Hellfire, Longbow, Maverick, and airborne TOW, according to Lockheed Martin.

Jean L. Broge

Binary valves keep on working and working

A pair of **Camcon Technology** Binary Actuating Technology (BAT) valves that are currently undergoing laboratory trials have completed more than 25 billion operations, "making efficient jet aircraft noise-reduction feasible," the company claims.

Active control for aerospace engine-noise suppression demands high-speed, long-life valves capable of frequency and amplitude modulation. Traditional actuator and valve technologies used in the control of liquids and gases typically have a service life of 10 million operations. The Camcon digital valve is said to offer an improvement 2500 times that figure, an essential requirement for an efficient jet aircraft noise-reduction system.

According to Camcon, experiments at **Berlin Technical University** showed that its BAT valves reduce the front-end, high-pitched noise emitted by jet engine blades by more than 20 dB at critical frequencies.

The two demonstration BAT valves have been undergoing tests at Camcon's research and development facility in Cambridge since January 2002, each actuator driven at 526 changeovers per second (31,560 times a minute). At press time, the company said that neither actuator showed any sign of wear.

Stuart Birch

Source: Rolls-Royce

Camcon's binary actuator combines both permanent and electro-magnets, which minimizes the stress to the armature—the moving component within a digital actuator or valve that is typically the first component to fail. The long-life binary valves will contribute toward aerospace engine-noise reduction, the company believes.

A sound concept

Brüel & Kjaer has joined the Silent Aircraft Initiative (SAI), which was launched by **Cambridge-MIT Institute** (CMI) in November 2003 to develop a design for an airplane that is "radically quieter" than current passenger aircraft. The company will be helping project researchers working in the open jet wind tunnel at **Cambridge University**'s Whittle Laboratory. They will use beamforming and acoustic holography techniques to measure and analyze the trailing edge noise that will come from the wing of the concept aircraft.

CMI researchers are also experimenting with new drag-inducing devices using various types of mesh that could slow an aircraft on approach without generating the noise levels associated with current airliners. Precision noise measurements will be run on these devices using Brüel & Kjaer equipment and staff to compare noise performance to conventional devices generating the same drag.

"As trailing edge noise is the smallest element of [noise] produced by an aircraft and is very low-level, it is hard to measure," said Andrew Fraszer, a CMI researcher. "However, we need to be able to do so as it will set the benchmark for the minimum level of noise that the 'silent' aircraft will produce. Our collaboration with Brüel & Kjaer, and the experiment we will be running with their equipment and expertise, will help us gain this necessary insight and understanding."

The initiative involves an increasing Knowledge Integration Community of partners working together, according to CMI, with **Boeing** among its members. CMI researchers are also looking at the possibility of reducing the noise created by in-service aircraft. Test work involving, among others, **Marshall Aerospace**, is being conducted on current aircraft.

According to Ho-Chul Shin, another CMI researcher, until now the sheer physical size of an airliner had made it difficult to coordinate all the equipment necessary to measure precisely the noise generated during a test run. "Brüel & Kjaer's commitment to the project will now make measurements more efficient and easier to do," said Shin.

Possible configuration of the Cambridge-MIT Institute's "silent" aircraft, which is expected to undergo extensive engine and airframe design for a radically different look, and sound, from current aircraft.

Stuart Birch

Mustang flies for the first time

With not nearly the fanfare afforded the first flight of the **Airbus** A380, **Cessna**'s new entry-level business jet, the Citation Mustang, also made its first flight in late April. The 141-min flight began with a climb to 11,000 ft, where various stability and control tests were performed, including cycling of the landing gear, flaps, and speed brakes.

Cessna, a subsidiary of **Textron**, began engine testing and basic taxi evaluations on the Citation Mustang prototype in late March after having installed the aircraft's engines and FADECs to the prototype airframe in February.

Since April 2004, Cessna had accumulated over 210 hours of flight time on its engine testbed. Flight testing on the aircraft's **Pratt & Whitney Canada** (P&WC) PW615F engine took place on Cessna's engine testbed as well as on P&WC's flying testbed in Canada. According to Cessna, in addition to being the first 600 series engine P&WC delivered to any manufacturer, the PW615F also marks the first time a P&WC engine flew on an aircraft manufacturer's engine testbed prior to being flown on P&WC's **Boeing** 720 engine testbed.

The first Cessna Citation Mustang took flight in late April. The prototype is one of three Mustang airframes that will be dedicated to certification efforts, with the first delivery of the aircraft expected late next year.

The Mustang prototype that just flew is one of three airframes dedicated to certification efforts and will primarily be used for aerodynamic and system tests. The first production Mustang (serial number 001) will be used for avionics development and certification, while the second production aircraft (serial number 002) will primarily be used for function and reliability tests and post-certification service tests. Cessna anticipates first flights of the first and second production Citation Mustangs later this year.

"When we initially entered the business jet market, we expanded the market by providing customers with an entry-level jet that was quieter, simpler, safer, and less expensive than any other

Lewis Campbell, Textron's Chairman, President, and CEO, believes that the Mustang, which is expected to cost about half that of the lowest-priced business jet on the market today, "opens up the possibility of jet ownership for an entirely new range of customers."

business jet on the market at that time," said Jack J. Pelton, Cessna's Chairman, President, and CEO. "The Citation Mustang builds upon this legacy and opens the base of the business jet market further than before. The Citation Mustang will fill a void in the turbine

The Citation Mustang will fly with Garmin's G1000 integrated avionics system that presents flight instrumentation, location, navigation, communication, and identification data via large-format LCD displays.

aircraft market by offering customers a cabin-class, single-pilot business jet with impressive performance…at a price point nearly half the lowest-priced business jet on the market today."

The Citation Mustang was first announced at the 2002 National Business Aviation Association, and there are currently more than 200 orders for the $2.4 million aircraft, with first delivery anticipated late next year. It is currently being assembled at Cessna's Wichita facility. However, the Mustang is the first Citation that will be built at Cessna's Independence, KS, facility. Cessna will begin locating Mustang tooling at its Independence facility this summer, and will move full production to Independence in the fourth quarter of 2005.

The Citation Mustang will be certified as a FAR Part 23 aircraft, with an anticipated cruise speed of 340 knot, and maximum operating altitude of 41,000 ft. The two P&WC PW615F dual-channel FADEC engines each provide 1350 lb of thrust. The fully integrated, all-glass **Garmin** G1000 avionics suite features three glass displays—two 10-in PFDs (primary flight displays) and one 15-in MFD (multifunction display) at the center of the panel.

Jean L. Broge

A cool approach to a grindingly hot issue

A major element in the manufacturing process of jet engine compressor blades centers on the grinding technology applied. **Holroyd**'s solution to safe grinding of turbine blades while consistently retaining a single crystal structure is to use a technique that does not significantly raise the temperature of the workpiece but still facilitates rapid machining.

High-efficiency deep grinding (HEDG) is a relatively new machining technology that uses cubic boron nitride (CBN), super-abrasive grinding wheels at very high speeds.

"The result is that the heat generated by the grinding action is transferred to the metal being removed and is carried away from the workpiece so quickly that it does not have time to conduct into the material substrate," said Holroyd Director Paul Hannah. "Thermal damage is therefore minimized, if not eliminated, and although testing is still carried out, failure rates are effectively zeroed. Compared to more conventional creep feed grinding, HEDG has much higher specific removal rates: typically 50 to 2000mm^3/mm/s compared to 0.1 to 10mm^3/mm/s. In addition, the lower finished surface temperature of the workpiece also adds an overall improvement in the quality of the finish itself."

The use of HEDG technology has improved consistency and halved product cycle times, claims Hannah. The basic crystalline structure of metals is sidestepped when turbine blades are created, he explained. The metal, typically a derivative of inconel or waspalloy, effectively "grown" at a precisely controlled rate and temperature. Each ingot that is to be machined into a turbine blade is formed as one crystal. But metal fatigue occurs along crystalline boundaries, which explains why fatigue breaks create a ragged line delineated by the crystal boundaries within the material.

Because a turbine blade has no crystalline boundaries, there are fewer weak points in the material due to its structure. The result is that bending forces and temperature fluctuations—providing they are kept within a cer-

Holroyd's Edgetek superabrasive grinding machine for the manufacture of jet engine compressor blades uses HEDG (high-efficiency deep-grounding) technology via high-speed cubic boron nitride, super-abrasive grinding wheels.

tain safety boundary—cannot cause metal fatigue. Therefore, the blade's fatigue strength will not deteriorate due to usage, throughout its life. Another useful property of a single crystal structure is that heat expansion and physical behavior under stress are consistent and therefore predictable.

"This factor allows internal compressor stages in the engine to be constructed using many blades that are simply slotted together and 'key' into each other to make a complete fan," said Hannah. "As the engine is brought up to working temperature, heat expansion locks the blades together and the fan becomes a single rigid structure, also retaining uniform and predictable thermal and stress characteristics."

But the alloy is extremely hard and difficult to machine. The hardness means that each blade has to be ground rather than milled, a process that creates heat, and if the workpiece is heated beyond a certain temperature boundary the crystalline structure changes. The single crystal can revert to a lattice structure that can include multiple crystal boundaries and is immediately susceptible to fatigue breakage, said Hannah. The temperature boundary is critical, which means that the grinding of turbine blades is normally a lengthy and involved process using vitrified-type grinding wheels, which, unless very tightly controlled, may cause both mechanical and heat damage to the metal surface.

Because a damaged part is often not immediately detectable, exhaustive safety checks are carried out using elaborate testing procedures such as nital etching and X-ray stress analysis.

"Holroyd's solution to the problems of safely grinding turbine blades and consistently retaining a single crystal structure is to employ the HEDG technique that does not raise the temperature of the workpiece significantly, but is aggressive enough to quickly machine the hard material," said Hannah. "The process also imparts desirable surface qualities such as high compressive stress, which improves the creep life of the material."

The Holroyd Edgetek machine is fitted with a very stiff grinding spindle, which uses hybrid ceramic bearings that facilitate the very large cuts possible with HEDG. In addition, the specially designed and formulated granite polymer composite base is described by Hannah as offering "excellent" damping properties, "virtually neutralizing resonant frequencies within the machine that could impair its accuracy."

Stuart Birch

Micromachining gets even smaller

Precision Micro has embarked on a technical collaboration with a UK university to further develop micro- and nano-scale structures and components for a variety of aerospace applications including sensors and actuators. **Birmingham University**'s Electronic Devices and Microsystems (EDM) Research Center is a pioneer of nanotechnology solutions, and Precision

Precision Micro and Birmingham University are collaborating on nanotechnology applications for the aerospace industry to take advantage of technologies such as focused ion beam systems, which are accurate enough to print logos on a human hair.

Micro has extensive experience in a combination of manufacturing technologies in micro- and milli-scales. The company is seeking ever smaller solutions in response to industry needs.

Anthony Marrett, Precision Micro's Managing Director, said the alliance with Birmingham University and the addition of micromachining to its technology capability represented a significant advance in the production of miniature components, with joint capability now also covering precision electroforming, surface modification, and surface marking. Equipment includes focused ion beam (FIB), inductive coupled plasma etching, and electron beam lithography systems. The FIB can mill a 7-nm trench, depositing nanostructures, taking SEM (scanning electron microscope) images of nano features, and making material composition analysis.

Birmingham University has developed a new route for producing high aspect ratio (40:1), thick resist structures for molding miniature metallic structures using electroforming in nickel and other plating metals, or low-temperature sintered ceramics. Precision Micro can use the technology commercially. The university is also involved in miniature engine projects, nano-scale switches and sensors, micro-mixers, and microwave filters, as well as phase sifters that combine superconducting materials with micromachined structures.

Stuart Birch

High-pressure testing

With pressures of up to 5000 psi, testing the hydraulic systems of the **Airbus** A380 is an important aspect of the aircraft's development and manufacture. **FR-HiTEMP** has installed two special **Carbolite** thermal cycling chambers for testing the hydraulic system components it supplies for the aircraft. Some of the hydraulic pipe-work and associated components are positioned around the aircraft's engines, with other sections in the wings. The different locations of the systems necessitates covering a temperature range of -55 to +90°C.

The thermal chambers are used to replicate these in-service temperatures while components are subjected to pressure impulse testing up to 6000 psi, sometimes for several days at a specific temperature. The chambers, measuring 1000 mm^3 internally, have a thermal range of -70 to +150°C and are heated via mineral-insulated metal sheathed elements, with a low surface watt loading to prolong service life. Cooling the chambers is achieved by directly injecting liquid nitrogen. Temperature stability and uniformity are said to be better than ±5°C.

Thermal cycles of up to 99 days can be programmed. A cutout is triggered if pre-set temperatures are exceeded.

Stuart Birch

The internal chamber and door of the Carbolite chamber that FR-HiTEMP is using to test hydraulic systems for the A380 are fabricated from 304 stainless steel and are insulated to ensure safe outer case temperatures.