In the wake of commercial aircraft

A pilot study recently conducted by the **Institute for Aerospace Research** at the National Research Council (NRC) of Canada measured the characteristics of en route commercial aircraft wake turbulence. Four flights using the NRC's **Dassault** Falcon 20 research aircraft were made at altitudes of 24,000 to 39,000 ft behind cruising aircraft at separation distances of 1 to 30 mi.

On several occasions, the Falcon experienced aerodynamic *g*-loading, flight path upsets, and an engine flameout when it became entrained by the trailing vortices. According to the NRC, the perturbations occurred at wake lengths of 8 to 13 mi, well within permissible separations, and were "large enough to knock anyone standing within the aircraft off their feet."

The National Research Council of Canada is outfitting a Lockheed T-33 to replace its Dassault Falcon 20 for more rugged wake studies.

Turbulence continues to be a concern for air transportation safety. "Every aircraft generates a pair of trailing wake vortices that undergo instability for a substantial length of time and distance," said Anthony Brown, Research Officer and Test Pilot at NRC. "An aircraft traveling through these wake instabilities could experience substantial aerodynamic loading and flight path upset. Our goal is to obtain data on the flow phenomena to clarify the risk and highlight the desirability, or the need, to develop wake vortex turbulence warning instrumentation that can be installed on aircraft."

Most wake vortex encounters occur during takeoff and landing, but sometimes occur with aircraft in the en route configuration. Such encounters are likely to increase with reductions being made in en route vertical airspace separation. The en route configuration is also increasing in frequency and density as departing aircraft climb earlier to reduce noise and minimize terminal airspace occupancy time. In addition, some experts predict that continuous descent approaches, where the aircraft remains in the en route configuration well into the base region, are likely to become widespread as they improve fuel efficiency while reducing noise and emissions.

In 2004 during the first phase of the two-phase NRC pilot study, a methodology for gaining wind perturbation data to identify vortex strength, location, orientation, flight path, and instability state was developed. During the recent second stage that took place in Ottawa, the Falcon 20 was vectored in by air-traffic control at about 5 mi behind commercial aircraft coming in or out of the North Atlantic Track System and the Polar Track to Japan.

Descending to the wake generator's altitude, the pilots carried out wake survey traverses around the trailing pair of wake vortices delimited by condensation patterns. By going around these vortices they avoided the large perturbations within the flight path, yet were able to collect the required data.

"On a number of occasions, however, the entrainment effect of the trailing vortices sucked the research aircraft through the vortex cores, causing us to experience loading and flight path disturbances," said Brown. "These perturbations occurred with wake lengths of eight to 13 miles, which is within the distance that an aircraft could legally be crossing or following a large wake generator. The fact that the substantial perturbations occurred at such distances indicates that more data needs to be gathered in this region to understand the flow mechanisms."

While Brown considers the Falcon 20 a rugged airplane, due to the nature of vortices the NRC will continue its research with a more rugged aircraft: a **Lockheed** T-33 that is currently being instrumented for flights in 2006. "This aircraft will give us more comfort when taking measurements in such a harsh atmospheric research environment," he said.

In the meantime, the NRC has initiated ground studies on passive sensing instrumentation to sense the presence of wake vortex flow fields around landing aircraft. If these studies are successful, the instruments will be modified and installed on the NRC T-33 for use in passive sensing of wake vortex flow fields during flight.

Jean L. Broge

Pi Research squares aerospace with motorsport

"Data acquisition is one of a number of technologies that is ripe for exchange between motorsport and aerospace," said Glenn Waters, Aerospace Program Manager at **Pi Research**, a specialist in motorsport data and control systems. "Motorsport is a very demanding environment that is constantly pursuing and finding higher-performance solutions in very short timescales. There are many similarities with the aerospace industry, itself seeking to drive down program timescales and costs."

Pi Research most often uses its electronics and software expertise for the motorsport industry, but it is also supporting the development program of the new GROB SP^n utility jet.

Today's flight-test regime demands near-absolute precision, reliability, and high-speed data acquisition from hundreds of sensors, generating huge amounts of data that must be processed, analyzed, and stored securely. Data acquisition and analysis is an intrinsic part of R&D programs, production tests, and pilot training, both in real and simulated environments.

Yet test equipment in service in the industry can be bulky, expensive, and inflexible, adding to cost, weight, and program lead times. Waters believes that the aerospace industry is starting to look elsewhere for proven and transferable technologies and is finding motorsport an interesting source.

"Motorsport at professional and semi-professional levels is dependent on rapid analysis of data to find or verify performance, is increasingly cost and weight critical, and demands reliability to ensure completion of the event," he said.

The management control unit (MCU) for a typical system used in Champ Cars may run from 40-1024 channels of synchronous data sampled at up to 1 kHz in a box 150 x 140 x 40 mm and have a mass less than 900 g.

"The associated software and telemetry systems can allow real-time or near real-time analysis and comparison of live and historic data, enabling rapid progress through test programs," said Waters.

Such a system is highly configurable both in hardware and software, with the MCU and other core hardware items being effectively commercial off-the-shelf items, with systems capable of offering onboard data reduction, video overlay, real-time telemetry, and control. The control element could put fundamentals of a flight-test regime, such as drogue deployment, under software control for ultra-rapid and complex test program completion.

Waters said that Pi Research's products are "attracting the interest" of the developers of very light jets and business jets. The company has also built up a relationship with the U.S. National Test Pilot School in Mojave, CA, for flight-test training, and with **Flight Safety International**'s Systems Simulation Division in the area of data gathering for simulator model generation. A recent contract with an unnamed light jet developer had led to installation and first flight of a complex system of configured hardware and software in less than seven weeks from initial contact, he added.

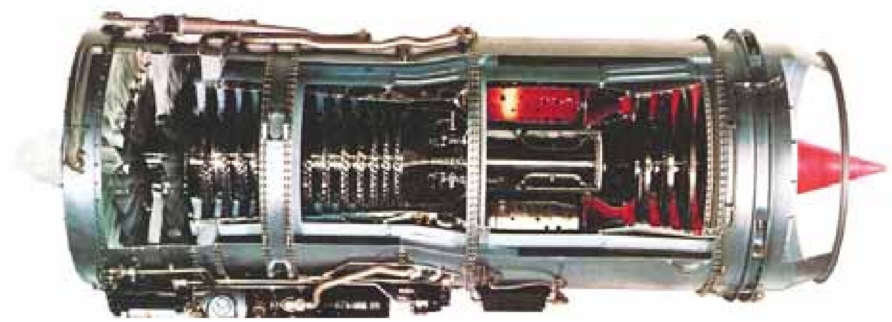
Stuart Birch

FAA proposes new damage tolerance assessment for engine parts

After nearly 15 years of study, the **FAA** has proposed new design and manufacturing standards for both rotating and static parts of an aircraft engine. Any part falling into a new category called "engine life limited part" would have to meet both an existing "safe life" standard plus a new standard on "damage tolerance." That additional standard is meant to prevent damage caused by material anomalies and manufacturing hiccups not accounted for in the long-standing safe life standard.

Engine life-limited parts typically include disks, spacers, hubs, shafts, high-pressure casings, and non-redundant mount components.

The FAA has been concerned about accidents caused by rotor malfunctions since the crash of a DC-10 airplane at Sioux City, IA, on July 19, 1989. The crash was caused by the presence of a material anomaly in the disk titanium forging.



The FAA's new proposed design standard for aircraft engines such as the Pratt & Whitney JT8D will require tests to establish damage tolerance.

When engines such as the Rolls-Royce Trent 1000 engine are manufactured, the FAA will expect greater coordination between the engineering and manufacturing teams.

After that accident, the FAA asked **SAE** to reconvene the Committee on Uncontained Turbine Engine Rotor Events to determine the number and the root cause of uncontained rotor events. The committee's report expressed concern that the projected 5% increase in airline passengers each year could lead to a noticeable increase in the number of aircraft accidents from uncontained rotor events. Soon after, an **Aerospace Industries Association** (AIA) Rotor Integrity Subcommittee began work on research into "best manufacturing processes" that might prevent future rotor mishaps. **AlliedSignal**, **Allison**, **GE**, and **Pratt & Whitney** participated on that subcommittee.

The current safe-life method determines the approved life of a rotor based on the minimum number of cycles required to initiate an approximate 0.030-in crack. The safe-life methodology is founded on the assumption that rotor components are anomaly-free. Consequently, the methodology does not explicitly address the occurrence of anomalies, although some level of tolerance to anomalies is implicitly built in by using design margins, and incorporating factory and field inspections.

The FAA-proposed rule announced in February would supplement the safe-life method by adding a requirement for an "appropriate" damage-tolerance assessment of engine life-limited parts; it does not specify what form the assessment should take. But the FAA would have to approve the tests.

Anne M. Wiskerchen, spokeswoman for the AIA, reports the rule "won't have much impact on the industry" because the proposed FAA damage-tolerance assessment, and some of the other requirements in the proposal, such as a closer link between engineering and manufacturing departments, parallel current requirements of the Joint Aviation Authorities (**JAA**) and European Aviation Safety Agency (**EASA**). These are the Joint Aviation Requirements-Engines and the Certification Specifications-Engines.

But while the FAA is attempting to harmonize its standards with those of the EASA and JAA, some differences will remain. For example, the FAA uses the term "engine life-limited parts" while the JAA and EASA rules use the term "engine-critical parts."

Some of these differences may explain why at least one industry observer who has done significant technical work on the issue disagrees with the AIA assessment that the new standard would have a minimal effect.

"To say the proposed rule is no big deal, and that nothing will change, I don't agree with that," said the expert, who asked not to be identified. "New calculations will have to be done, and those calculations will have an impact on design practices. I wouldn't call the changes revolutionary. But the proposed rule, once it becomes final, will have at several different levels the impact of encouraging companies to do things better."

Stephen Barlas

Testing for takeoff

New technology developed at **Worcester Polytechnic Institute** (WPI) uses ultrasonic energy to detect wake turbulence. WPI says the system can effectively detect the onset, strength, and decay of the pair of counter-rotating vortices that stream from an airplane's wingtips, information that could help air-traffic controllers shorten the spacing between landings and takeoffs at major airports. Reducing the standard waiting times by 30 s could save the airline industry $5 billion annually, according to the **FAA**.

WPI claims the technology is simpler and less expensive than other techniques that have been proposed for the real-time detection of wake turbulence, which can cause airplanes to roll or drop unexpectedly, or even suffer structural damage.

The risk to planes is generally greatest during takeoffs and landings, when there is little time or altitude in which to recover. To reduce that risk, air-traffic controllers have for years staggered landings and takeoffs by standard intervals based on the longest amount of time it would take for vortices from specific aircraft to dissipate, up to about 8 min for large jetliners. However, crosswinds often cause the vortices to dissipate or to be blown clear of the runway more quickly.

WPI's wake-turbulence detector uses reflectors on a tower and on the opposite side of the runway to direct high-frequency sound across a closed path. Vortices from an airplane are detected by sensing variations in the speed of the sound waves.

The patented WPI technology uses pulses of high-volume, high-frequency sound waves to measure the speed of rotating air. Two focused beams of sound travel the same triangular path in opposite directions. The path is created by bouncing the sound off of two reflectors, one located on the opposite side of the runway from the sound source, and one atop a 30-ft tower.

Rotating air causes the sound beams to either slow down or speed up, depending on whether the sound is traveling with or against the moving air. Monitoring the difference in travel times at several points along the runway enables the position and strength of vortices to be tracked over time. Having that data would allow air-traffic controllers to establish safe separation intervals based on the time it takes for the turbulence to subside.

The effectiveness of the technology was first demonstrated in wind tunnel tests at WPI. A prototype was then tested under varying weather conditions at an airport in central Massachusetts in the spring of 2005, using a small single-engine plane to generate the vortices. Further tests, with commercial and military jet aircraft, are planned for later this year, with the ultimate goal of commercializing the technology.

Jean L. Broge

A400M engine activity

A successful demonstration test of the first engine with propeller for **Airbus Military**'s A400M transport aircraft has taken place at the **Snecma** engine test facility at Istres in southern France.

The powerplant consists of the TP400-D6 engine from **Europrop International** (EPI) fitted with **Ratier-Figeac**'s FH386 propeller. The three-shaft, high-performance gas turbine engine works with the 5.3-m diameter, eight-bladed, composite propeller to provide a power output of 11,000 hp. Airbus says the system will enable the A400M to attain cruising speeds and altitudes equivalent to today's jet-powered aircraft. The aircraft will use four of the turboprops.

The company chose a turboprop engine because it believes that design provides optimum performance and fuel economy across the spectrum of operational tasks of the aircraft, which

Ratier-Figeac's eight-bladed composite propeller was designed specifically to handle the high-power output of the 11,000-hp EPI engines that will be powering the A400M from Airbus Military.

Airbus claims that EPI's three-shaft, high-performance turbine TP400-D6 is "the most powerful turboprop powerplant in the Western world."

The A400M program was launched in May 2003 with 180 orders from seven European NATO nations. It is expected to first fly in 2008, with deliveries beginning in 2009.

will range from low-speed, low-altitude aerial delivery to high-speed, high-altitude refueling of fast jets while retaining the capability for autonomous ground maneuvers as well as fast, intercontinental logistic deployment.

GKN Aerospace will be designing, developing, and qualifying the engine's air inlet, which is believed to be one of the first applications of welded aluminum in such a severe, high-temperature environment.

The aluminum alloy used by GKN takes advantage of thermal heating to prevent the accumulation of ice when the aircraft is flying via jackets that line the back face of the intake duct. These jackets channel hot air from the engine over the air washed surface of the intake duct.

Critical design review of the inlet was scheduled for last month, with first test unit deliveries in June and initial production standard deliveries in August and September.

GKN is also supplying carbon composite technology for the A400M wing spars, as well as both metal and composite wing trailing edge subassemblies.

Testing recently began on the A400M at the new 5000-m^2 Airbus Fuel Systems Test Facility, which is also the site of tests on the A350 and A380 fuel systems. Tests are also being conducted to study improvements in fuel system simulation and modeling and fuel-tank inerting, as well as research into new and emerging technologies.

Design and supply of fuel systems is a key responsibility of Airbus UK, complementing its role as the center for wing design, with the wings having a dual role as the main fuel tanks. Challenges in fuel systems design include ensuring ground staff can carry out safe, rapid, ergonomic, and accurate refueling; reliably pumping fuel to the engines; redistribution of the fuel around the aircraft tanks during flight to achieve optimum aerodynamic efficiency and performance; and ensuring clear, reliable, and comprehensive data is available to pilots on the flight deck.

The new facility will allow Airbus to carry out integrated testing of the avionics computers and the fluid mechanical systems. It is comprised of three main sections: a building housing a 1000-m^2 internal test area, avionics benches, 600 m^2 of office space, and the facility's control room that monitors operations via closed-circuit television. Outside is an open but roofed 2500-m^2 fuel test area that accommodates the piping, pumps, and associated systems required for large-scale testing of dedicated test rigs. On site is also a fuel-services area where the fuel is stored and prepared, to replicate changes and processing during actual flight conditions.

The various ground and flight conditions that can be simulated on the individual test rigs include the effects of altitude up to 50,000 ft; fuel delivery rates up to 6000 L/min at pressures up to 85 psi; heating and cooling the fuel in a 110°C temperature range, between +55 and -55°C; and four pumps to replicate engine feed systems and engine speed.

The A400M will first fly in early 2008, with deliveries beginning in 2009.

Jean L. Broge

Scientists see 3-D nanostructures

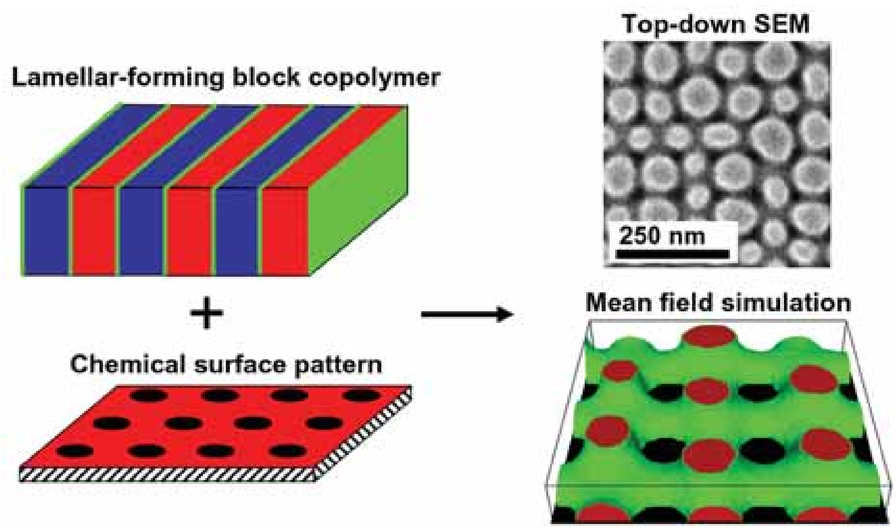
An international team of scientists affiliated with the **University of Wisconsin**-Madison Nanoscale Science and Engineering Center has coaxed a self-assembling material into forming "never-before-seen," three-dimensional nanoscale structures, with potential applications ranging from catalysis and chemical separation to semiconductor manufacturing.

Led by UW-Madison chemical and biological engineering professors Paul Nealey and Juan de Pablo and colleagues at **Georg-August University** in Germany and the **Paul Scherrer Institute** in Switzerland, the team has discovered that materials known as block copolymers will spontaneously assemble into intricate 3-D shapes when deposited onto particular 2-D surface patterns created with photolithography.

The result demonstrates a promising strategy for building complex 3-D nanostructures by using standard tools of the semiconductor industry, said Nealey. Those tools, particularly lithography, already allow the making of devices with dimensions substantially smaller than 100 nm (4 μin). But photolithography is also limited because it is essentially a 2-D process, he noted.

"What we've done by using self-assembling block copolymers is to extend photolithography to three dimensions," said Nealey. "And the structures we've fabricated are completely different from the same block copolymer materials in the bulk."

Also important to manufacturing, the



Thin films of a block copolymer that assumes a layered (lamellar) morphology in the bulk (top left) form complex 3-D nanostructures when deposited onto 2-D surfaces patterned with a square array of spots (bottom left). Top-down scanning electron micrographs (top right) show that a series of spots arise on the surface. Results from a mean field simulation (bottom right) indicate that both copolymer domains (the blue domains were removed from the image for clarity) of the self-assembled morphology are continuous and align with the lithographic pattern. The black spots indicate the position of the underlying surface pattern and the green represents the interface between the blue and the red domains.

new 3-D nanostructures are said to be stable, well-defined, and nearly defect-free over large areas.

"This research shows that lithography combined with block copolymers is more versatile and powerful than we thought. We can now create completely new structures that will no doubt have new properties and new applications," said de Pablo. "Exactly what those structures will be is anybody's guess … The important thing is they open up a new field of exploration, both for these materials and this technology."

The specific structures the team produced were composed of two tightly interwoven, yet independent, networks of channels and passages—all at the atomic scale. The networks are in perfect register with the photolithographic pattern underneath, which allows scientists to know exactly where each channel ends and gives them ready access to channel openings. A gas, for example, might be introduced through the openings to react with a catalyst deposited on the walls of the network. Nanoscale materials have massive surface areas compared to their volumes; thus, catalysis would be extremely efficient, according to the researchers.

Another use would be chemical separation of substances of different sizes. "This process gives us exquisite control over the dimensions of pores," said de Pablo. "So, we could easily make membranes that are permeable to substances smaller than the length scale of the material."

The researchers study specific block copolymers consisting of long chains of two different types of molecules, which alternate with each other in blocks. At high temperature, block copolymers are molten and randomly mixed. But when cooled down, the material spontaneously assembles into alternating layers of molecules.

The **National Science Foundation** Nanoscale Science and Engineering Center at the University of Wisconsin and **Semiconductor Research** supported this research.

Ryan Gehm