

## Technology update

### GENx takes off on flight toward certification

The GENx engine that GE-Aviation has developed for the twinjet Boeing 787 continued in testing mode when it took off for the first time in late February on GE's 747 flying testbed. Ground testing of the powerplant began just last March, while engine certification is scheduled for this coming September.

January, and the GENx-1B engine was installed in the inboard location on the left wing of the aircraft in just one day.

Flight testing will continue at a rate of about three flights per week over the next couple months. The tests will evaluate the steady-state and transient performance of the engine, verify air re-starting capability, determine the combustor operability margins, validate



The GENX-1B is currently the best-selling engine for the Boeing 787, and the GENx-2B will power Boeing's new 747-8 passenger and freighter aircraft. These combined programs have total orders exceeding 660 engines from 22 customers.

During the four-hour flight in Victorville, CA, the GENx-1B engine demonstrated aircraft systems and instrumentation functionality, climbed to close to 40,000 ft, and established an engine-performance baseline for continued flight-testing while gaining additional information on the engine's capabilities.

Preparations for the first GENx flight began more than two years ago. The electrical system requirements for the 787 required that the 747 testbed be modified to manage the electrical load from the engine's two starter-generators and to provide the power necessary for electrical ground and air starts. The modifications were completed in

throttle response, and assess the nacelle and undercowl cooling characteristics. The majority of the flight tests will occur in Victorville, with hot-day assessments taking place in Yuma, AZ, and high-altitude takeoff evaluations occurring in Colorado Springs, CO. A second round of flight-testing later this year will focus on the engine-control system.

Three Pratt & Whitney JT8s are what make up the rest of the testbed engines, which came with the aircraft when GE bought it used. GE says the testbed is one of the last of that early model of 747 that is still in service, and it was designed for the JT8. At one time, GE considered replacing the engines with its



GE-Aviation has filed the GENx under GE's "ecomagination" product portfolio, which the company defines as its commitment to develop new, cost-effective technologies that enhance customers' environmental and operating performance.



Because all of the combustion air of the GENx enters through the dome and mixers, no dilution holes are required on its new liner, reducing distress and resulting in a longer line life and reduced maintenance.

CF6, which powers many later 747 models, but the advantages of doing so was somewhat outweighed by disadvantages.

Based on the GE90—which was initially certified in 1995 at 84,700 lb thrust and has since reached 127,900 lb during

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variant certification—the GENx engine will succeed the CF6 engine family for wide-body aircraft. It will deliver 15% better specific fuel consumption and payload performance than the CF6. GE-Aviation says it's also designed to stay on wing 30% longer, while using 30% fewer parts. The GENx's emissions are also expected to be about 95% below current regulatory limits due to lower, more uniform flame temperatures. The engines operate under a pre-mixing

concept that directs much of the airflow through swirlers and around nested fuel nozzles.

The GENx engine, with a thrust range from 53,000 to 75,000 lb, is currently claimed to be "the world's only" jet engine with both a front fan case and fan blades made of composites, which provide for better engine durability, weight reduction, and lower operating costs. The fan blades will use GE90 composite technology, with no routine on-wing

maintenance required and no in-service issues expected for more than a decade.

The **Rolls-Royce** Trent 1000 will also be called upon to power the 787, though both engine types will use the same standard interface with the airplane, allowing any 787 to be fitted with either engine at any time. In April, Boeing announced that it had received orders for 514 787s from 43 customers since its launch in April 2004.

Jean L. Broge

## Tanker teams drafted, take sides

According to a report put out by the **Lexington Institute** late last year, Eisenhower-era KC-135s make up 90% of the U.S. Air Force aerial refueling fleet. Citing readiness statistics, it reported that over the last 15 years KC-135 mission rates were anywhere from

April, with contract award targeted for the last quarter of 2007. Its KC-30 tanker team includes **EADS, GE-Aviation, Sargent Fletcher, Honeywell, Smiths Aerospace, Parker Aerospace, AAR Cargo Systems, and Telephonics.**

Northrop Grumman selected EADS

fuel than a KC-135 and is also designed to refuel U.S. Navy and coalition aircraft, as well as serve as a multi-role transport aircraft to move passengers, cargo, and medical evacuation patients. The KC-30 incorporates defense systems, precision fly-by-wire technology, and the ability to integrate a communications suite and a global support network. Final assembly of the KC-30 aircraft will take place in Mobile, AL, prior to being militarized in the adjacent Northrop Grumman facility. The A330 platform was selected in the last three tanker competitions to support the air forces of Australia, the UK, and the United Arab Emirates.

**Boeing** has also drafted a team to provide an option for the KC-X program, which includes **Smiths, Rockwell Collins, Vought Aircraft Industries, Honeywell, Pratt & Whitney, and Spirit AeroSystems.** Based on a new version of the 767-200, the KC-767 will include an advanced fly-by-wire system, new wing refueling pods, a centerline hose drum refueling unit, an advanced commercial digital flight deck, and a third-generation remote vision refueling system.

The tanker would be manufactured at facilities in Everett, WA, on an existing commercial line, and the installation of military refueling systems and flight activities would take place at Boeing's finishing center in Wichita, KS.

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Northrop Grumman's KC-30 Tanker aircraft refuels an F-35 Joint Strike Fighter in this illustration. Northrop Grumman is offering the KC-30 with fly-by-wire controls to replace the U.S. Air Force's fleet of aging tanker aircraft.

91% during Operation Desert Storm in 1991, to an average of 78% during Operation Allied Force in 1999, to about 86.4% in Operation Iraqi Freedom in 2003. The rates not being 100% make it clear that it is not an issue of whether the USAF gets a new fleet of tankers, but when.

**Northrop Grumman** is leading one of the teams intent on providing new tankers to the USAF to replace the current fleet of KC-135s and KC-10s. The KC-30 will be Northrop Grumman's entrant in the KC-135 Tanker Replacement Program, KC-X. A final request for proposal for the KC-X competition was in

as an exclusive partner and principal subcontractor in September 2005. EADS will provide the **Airbus A330-200** and the air refueling boom system for the KC-30. After what it describes as a "rigorous downselect process" to choose the best engine at the lowest risk for the KC-30, Northrop Grumman selected and consequently formed an exclusive partnership with GE-Aviation to provide the CF6-80E1. The CF6-80E1 engine has amassed more than 3.6 million flight hours powering A330 aircraft. GE engines currently power more than 80% of the USAF tanker fleet.

The KC-30 will carry 45,000 lb more

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### Preparing for fuel cells to take off

Boeing researchers and industry partners plan to conduct experimental flight tests this year of a manned airplane powered only by lightweight batteries and a fuel cell, which will convert hydrogen directly into electricity and heat without combustion and harmful airborne emissions as well as reduced noise emissions.

The systems-integration phase of the Fuel Cell Demonstrator Airplane research project, under way since 2003 at Boeing Research and Technology—Europe (BR&TE), was completed recently. Thorough systems-integration testing is now under way in preparation for upcoming ground and flight testing.

“Given the efficiency and environmental benefits of emerging fuel-cell technology, Boeing wants to be on the forefront of developing and applying it to aerospace products,” said Francisco Escarti, BR&TE Managing Director. “The Fuel Cell Demonstrator Airplane project is an important step in that direction.”

The Boeing demonstrator uses a proton exchange membrane (PEM) fuel cell/lithium-ion battery hybrid system to power an electric motor, which is coupled to a conventional propeller. The fuel cell provides all power for the cruise phase of flight. During takeoff and climb, the flight segment that requires the most power, the system draws on lightweight lithium-ion batteries.

Researchers involved believe the flight tests, which will take place in Spain, will demonstrate for the first time that a manned airplane can maintain a straight level flight with fuel cells as the only power source, though not necessarily in a straight level flight that will take 300 passengers from the east to west coast of the U.S.

“While Boeing does not envision that fuel cells will provide primary power for future commercial passenger airplanes, demonstrations like this help pave the way for potentially using this technology in small manned and unmanned air vehicles,” said Escarti. “It also gives us hands-on experience to complement

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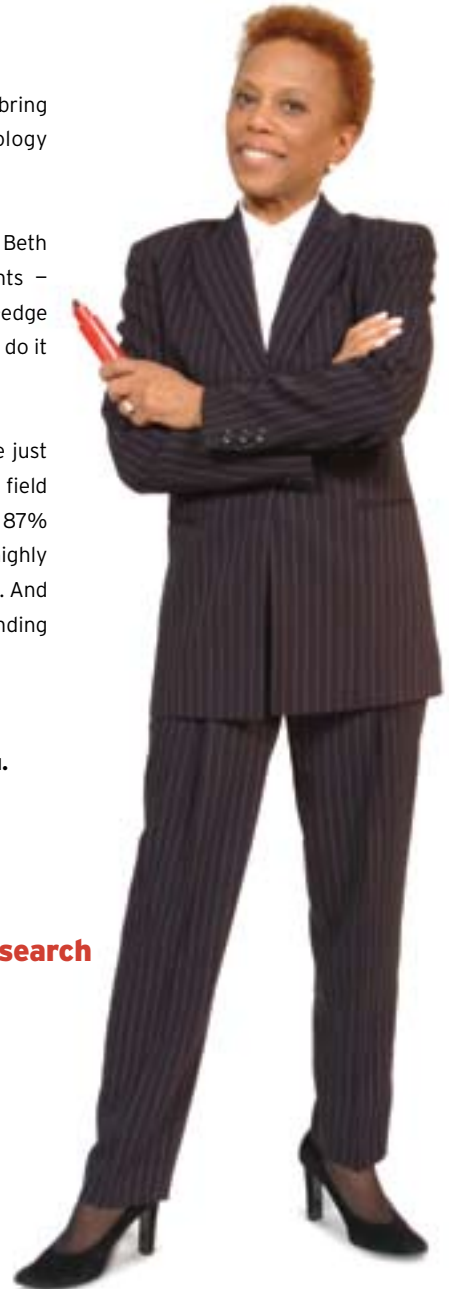
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Boeing and its industry partners will be conducting experimental flights this year of a fuel-cell-powered manned aircraft that will rely on lithium-ion batteries during takeoff and climb. The fuel cell will provide all power for the cruise phase of flight.

other fuel-cell studies being carried out throughout the company."

Boeing researchers see promise in other types of fuel-cell technology, including solid-oxide fuel cells that could be applied to secondary power-generating systems, such as auxiliary power units. This technology could be mature enough in 10 to 15 years for potential use in commercial aviation.

BR&TE, part of the Boeing Phantom Works, has worked closely with its col-

leagues in Boeing Commercial Airplanes, its Spanish partners, and with companies in Austria, France, Germany, the UK, and the U.S. to design and assemble the experimental airplane. The PEM fuel-cell system used on the flight demonstrator was designed and built by the UK-based **Intelligent Energy**.

The demonstrator aircraft is a Dimona motor glider, built by **Diamond Aircraft Industries** of Austria, which also performed major structural modifica-

tions to the aircraft. With a wing span of 16.3 m, the airplane will be able to cruise at approximately 100 km/h using fuel-cell-provided power.

The Madrid-based avionics group **Aerlyper** performed airframe modifications, as well as the mounting and wiring of all components; **Saft** France designed and assembled the auxiliary batteries and the backup battery; and **Air Liquide** Spain performed the detailed design and assembly of the onboard fuel system and the refueling station. The Electronic Engineering Division of the **Polytechnic University of Madrid** (School of Industrial Engineering) collaborated in the design and construction of the power management and distribution box, and post-integration bench testing is being conducted in a facility that belongs to the university. **SENASA** (Spain) will provide a test pilot and facilities for flight tests.

Other suppliers for the Fuel Cell Demonstrator Airplane include U.S.-based **UQM Technologies**, which supplies the electric motor; Germany's **MT Propeller** and **Gore**; and Spain's **Tecnicas Aeronauticas de Madrid**, **Ingenieria de Instrumentacion y Control**, **Indra**, and **Inventia**.

Jean L. Broge

## Joint Strike Fighter gets closer to fighting

**Lockheed Martin's** F-35 Lightning II underwent in February its final planned pre-production development wind-tunnel test for all F-35 variants prior to aircraft production at the U.S. **Air Force's** Arnold Engineering Development Center (AEDC).

"It was the culmination of more than

8600 hours and \$50 million worth of wind-tunnel testing the [F-35] over the past five years," said Ezra Caplan, AEDC Air Force Project Manager. "This aerodynamics test was the final entry in that series."

This test helped add new critical data for the U.S. Navy variant of the F-35,

said **Aerospace Testing Alliance** (ATA) Project Engineer Randy Hobbs.

"This particular test was about filling in the blanks other testing facilities hadn't obtained yet at the higher-end Mach numbers," he said. "The results from this test will go into the [F-35] program's aerodynamic database and complement the ground testing that will follow at Marietta, GA."

As part of the collaborative effort that is the essence of the next-generation fighter, "Lockheed Martin uses data taken at AEDC and from other facilities to complete the [F-35] aero database," said Marc Skelley, a USAF project manager at the center. "Lockheed Martin has a large, low-speed wind tunnel in Marietta where they do stability and

Shown is the 1/12th-scale F-35C Navy variant during a model change in Tunnel 16T. The "level plate," shown just ahead of the vertical tails, is installed during configuration changes to mount external instrumentation used to verify the model pitch and roll position.



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First Lt. Ezra Caplan and ATA Senior Project Engineer Charlie Smith examine a 12% scale model of the F-35C during a break in the final pre-production aerodynamics testing done on all F-35 variants.

*Photos by David Housch and Rick Goodfriend*



ATA Outside Machinist Carey Wofford checks the movement of the vertical stabilizers of a F-35 test article prior to resuming the aerodynamics test.

control testing at low speeds and with the landing gear down. Usually whatever test we did here was either preceded or followed by an entry down in Marietta."

According to Caplan, continuous improvements in testing methods and technology have resulted in significant reductions in cost and time.

"One of the benefits of testing here is that we're able to provide the data at near real time to the customer on site," he said. "This [benefit] reduces the number of model configuration changes that would have been necessary in the past to get the quality of data they would need before pressing on with the test."

AEDC workers have tested the F-35 in the center's wind tunnels and jet engine test cells for several years. The current multi-year test regimen for the aircraft's **Pratt & Whitney F135** jet engine is a \$200-million program.

The center's role in supporting the program dates back to 1997 when competing engine configurations were tested in propulsion test cells there. Aerodynamic and propulsion integration testing on the aircraft began the same year when the two competing prototype aircraft, the X-35 and X-32, were tested at AEDC.

A busy schedule with the F135 still lies ahead for center workers and some additional store separation testing also is planned for the near future.

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