Tech focus

This month's focus provides some insights and updates on various airplane makers' flight testing programs.

Hawker 4000 flight testing nears completion

As flight testing of its new Hawker 4000 business jet nears completion, **Hawker Beechcraft** is anticipating strong demand for a super-midsize business jet that, operating at maximum gross weight, was able to take off from a 4300-ft runway on the East Coast and make it to the West Coast without stopping in between.

As of early June, test pilots had logged about 4700 h of the total 5000 h of flight testing planned. The Hawker 4000 was certified in November 2006, and deliveries are slated to begin late this summer.

Marc Mannella, Director of Flight Operations for Hawker Beechcraft, has accumulated more than 1000 h in the plane. The degreed aerospace engineer and former **U.S. Marine Corps** test pilot spoke with *Aerospace Engineering* about the flight-test program. He noted that flight testing at this stage of the program is dedicated toward cabin-management systems such as the DVD player and heating/cooling control.

Handling-qualities and performance flight testing took place in the early stage of the program—between 2001 and 2003. Much of that early testing took place in Roswell, NM, because it is at a higher altitude than the company's Wichita, KS, headquarters. Test pilots did hundred of takeoffs and landings under differing conditions, such as light- and heavy-forward center of gravity and light- and heavy-aft center of gravity.

Those takeoffs were done with both engines operating and with one of them shutting down prior to rotation to see how much extra distance would be required. The takeoff and landings were done in a variety of environmental conditions.

Done in parallel with the handling-qualities and performance testing was automation testing. The Hawker 4000 is fitted with **Honeywell** Primus EPIC avionics with five panel displays. Also done in parallel was systems development testing.

Three Hawker 4000 test articles await flight on the ramp at Beech Field in Wichita, KS. The composite-fuselage plane is powered by two Pratt & Whitney PW308A engines, each delivering 6900 lb of thrust for a maximum cruise speed of Mach .84

Later came flight testing for heating/cooling, sound levels, and other features related to the plane's interior. Testing was done on S/N 4, the first Hawker 4000 with an actual interior installed.

"And that's a fairly typical business jet development program," Mannella said in overviewing the flight-test program. Stronger flap hinges were among the changes made to the plane as a result of the flight testing. The fairings around them were enlarged, but engineers were able to make the change in such as way that there was no appreciable increase in drag, he noted.

Another change relates to interior heating/cooling. It was found that with the air-cycle machine in the back of the plane, and with the air-delivery system starting there, the vents in the cockpit and front of the plane provided insufficient heating or cooling while the vents in the rear delivered more than needed. The fix was simple, said Mannella: install restrictors on the vent devices in the rear of the plane to more evenly distribute pressure throughout the system.

He noted that for every failure mode possibility with a probability greater than 10^{-9} or higher probability it must be demonstrated via either simulation analysis or actual flight that continued safe flight and landing is possible. In the Hawker 4000, there were 35 potential failure modes that could occur at a rate greater than that, according to Mannella. "We felt good enough to demonstrate every one of those cases in a test article," he said. "The aircraft exceeded our expectations, and each of the failure-mode test cases resulted in an uneventful landing that was well within safety margins."

Though simulation may be acceptable to address certain failure modes for new airplanes, "there's no substitute for being comfortable enough to demonstrate these cases in the airplane," Mannella said.

Regarding use of telemetry vs. an onboard data-acquisition (DAQ) system to obtain and store flight-test data, Mannella said that telemetry may not always be needed, or appropriate. The onboard DAQ systems on S/N RC 1-4 are sophisticated and able to monitor 1500 parameters in real time "at a pretty high rate," he said.

But when necessary—during initial flights of a new airplane type or for higher-risk-category flight testing—the company will use telemetry. Flutter testing, in which the airplane is tested at very high airspeeds and the airframe is dynamically excited by abrupt pilot control inputs or variable-frequency exciters mounted to the structure, is one instance when the company will use telemetry to monitor for undesirable airframe response.

"Flutter has led to a lot of mishaps in airplane testing," Mannella noted. "So when we do flutter testing, we incrementally increase the test airspeed. Engineers in the control room monitor the incoming data real time for trends that indicate reducing structural dynamic stability with increasing airspeed. It may be strain gauges, accelerometers, cameras, control surface position, vibration sensors, or a combination of indicators. When we do flutter testing, there is an entire team in the control room."

Electrical systems are sometimes checked prior to a flight test.

Another possible use of telemetry is for efficiency. "There may be nothing particularly high-risk about the test that requires real-time monitoring," Mannella said. But the alternative to real-time monitoring is "flying the plane; plotting the data; fine-tuning the control laws, for example; and flying again. And doing three iterations of that. Then maybe real-time analysis is more cost-effective. If the cabin is large enough to be outfitted with flight test engineer and design engineer workstations, this can usually be accomplished by the crew without outside assistance."

Mannella said there is nothing new about use of telemetry as a flight-testing aid. But since the cost of the equipment has fallen so greatly over the years some companies tend to use it more than others.

"It's a philosophy thing," he said. "You can let the DAQ collect data that you don't need in real time and look at it after the fact. Or you can dedicate engineers to real-time analysis as a general rule. It's always safer to have extra sets of eyes looking for bad trends."

Mannella estimated that the data-storage requirement on a typical flight for the aircraft is 4 GB. "Engineers plot the data and might say, 'look at this trend,' or 'look how close we came to that limit,' or 'look at the fact that we could do this operation without coming close to a limit.' That conclusion is what makes flight test have value."

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Flight testing in progress

While some makers of aircraft have recently completed flight testing, others are just putting their flight programs together and still others have one or more models in the sky.

One of the more celebrated programs, **Lockheed Martin**'s F-35, is in the initial phase. Flight testing began in December. The first Lockheed Martin F-35 Lightning II continues to expand its performance envelope and has successfully tested a wide range of systems during flight testing in Fort Worth, TX. The aircraft is currently undergoing software updates and general maintenance during a planned lay-up period called Flight Test Update 2. It is expected to return to flight in mid-July.

The F-35 is expected to return to the air in mid-July after a brief break for software updates and general maintenance.

The Lightning II, a conventional takeoff and landing F-35A, so far has flown at 38,000 ft and has achieved speeds of Mach 0.8 and an 18° angle of attack. The 19 flights that the aircraft had logged through early May also served to calibrate the air-data system, evaluate basic maneuvering with the landing gear both retracted and extended, and test aircraft performance during banks, rolls, and progressively increasing *g*-loading. "The Lightning II flies just as our engineers predicted. It's a marvelous airplane that's very powerful, smooth, and respon-

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As of May, Eclipse Aviation had surpassed 2000 flight-test hours (300 in May alone) for the Eclipse 500 and completed the majority of required FAA certification testing. FAA certification is "on the horizon."

Pilatus Aircraft's next-generation PC-12 is in the midst of its heaviest flight-testing period, with a focus on the Honeywell Primus Apex avionics system. Even after initial certification, expected later this year, Pilatus will continue flight testing for development and certification of some enhanced functionalities of the avionics system.

The first conforming test article of the Adam Aircraft A700 flew for the first time in April, with three others joining the flight-test fleet by fall. Testing has focused on evaluation of the production configuration of flight controls, landing gear system, avionics, and data-acquisition system used for flight testing.

Cessna Aircraft anticipated that it would begin flight testing of the XLS+ with "full-up avionics" this month. Rockwell Collins will certify the avionics while, simultaneously, Cessna certifies the engines.

sive," said Jon Beesley, F-35 Chief Test Pilot.

Midway through the fifth flight, Beesley lit the afterburner for the first time and unleashed 40,000 lb of thrust—more power than any fighter engine in history, according to Lockheed Martin.

The F-35 test fleet will fly exclusively with the **Pratt & Whitney** F135 engine until 2010, when the **GE Rolls-Royce** Fighter Engine Team's F136 enters the scene. The engines will be interchangeable and are being built to the same set of performance specifications.

The F-35 cockpit is the first in a production fighter to use a virtual head-up display that projects information onto the pilot's helmet visor. The F-35 Helmet Mounted Display System first flew on the F-35 on April 4 and is now a permanent fixture in the flight test program.

Brief updates on the flight-test programs for various other aircraft are provided in the photo captions for this article.

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