Technology update

Boeing 787 systems all about efficiency

The flashy composite exterior of the 787 has been a legitimate focus of attention as a new technology, but the down-and-dirty technological guts of **Boeing**'s newest product deserve attention as well.

Mike Sinnett, Director, 787 Systems, threw a spotlight on the twin-aisle commercial aircraft's inside intricacies at a media event just prior to unit number one's unveiling in Seattle a couple of months ago.

Weighing heavily on the minds of engineers throughout development of the 787 was a mass-reduction imperative, he said. By relying more on electric than pneumatic and hydraulic power, engineers were able to remove weight and otherwise engineer the plane's systems in ways that cut the aircraft's overall fuel efficiency by about 3% compared with a conventional approach, he said. Total improvement in fuel efficiency of the 787 is about 20%, with better engines leading the way.

Patrick Ponticel

The most groundbreaking approach to design of the airplane was "broadening the playing field" to address not just the technical performance of the plane, but also financial and other impacts of design decisions on Boeing, its supplier-partners, airlines, and passengers, said Boeing's Mike Sinnett.

Patrick Ponticel

This mockup of the 787 cockpit shows the standard twin head-up displays (one retracted) and new seats with independently adjustable pans and backs.

Elimination of high-pressure pneumatics fed by bleed air was one way in which mass savings were achieved in systems. Sinnett noted that high-pressure bleed air systems, used for several purposes on conventional aircraft, drain hundreds of horsepower from engines in cruise. The 787 has two generators running off of each engine, as well as two running off of the auxiliary power unit (APU). Elimination of bleed air greatly reduces downstream piping requirements.

"And with an electric power generation system, you generate only the power you need, and you use only the power you generate," said Sinnett.

In a conventional setup, hot bleed air is piped from the engine to the wing leading edge and released through holes for deicing. With an electric approach, the piping is eliminated and replaced by smaller and lighter wires that deliver electricity to leading-edge heat blankets (six per slat) to serve in anti-icing, rather than deicing, mode. Another inefficiency of a bleed-air system is that more than half of the energy in the form of hot air is "dumped overboard" during deicing, Sinnett said. Energy consumption for the new system is half that of the conventional one, he noted.

In addition to its weight and energy savings, the new approach is more robust in that if one of the blankets fails, there are enough others that the anti-icing system remains effective. With a conventional system, Sinnett said, first failure means shutdown of an entire wing's deicing capability. And since one wing cannot be deiced if the other is not, the entire deicing system becomes unavailable.

Another use for high-pressure bleed air in a conventional approach is cabin pressurization/climate control. The problem with the conventional approach is that the bleed air must be cooled and reduced in pressure before it reaches the A/C unit, where the pressure

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Fewer suppliers were selected for the 787 program, but those that were had more responsibility than those on previous programs. Hamilton Sundstrand (whose auxiliary power unit for the 787 is shown above, on a test stand) has a large role in electrical power generation and distribution on the new airplane.

If the 787's swooping wings look "cool," it is no accident. "This is the first time we've ever specifically paid attention to 'cool,' " said Mike Sinnett, Director of 787 Systems.

is increased again for circulation in the cabin. In the 787, air for the A/C system comes via an intake duct on the forward wing-body fairing. Using electric compressors, air pressure is set for best performance of the A/C system. Cabin air pressure is lower (6000 ft) than other airplanes—enabled by the 787's strong composite fuselage.

A small amount of bleed air is used locally for anti-icing of the nacelle and cowl, said Sinnett, noting that some bleed offtake is helpful for low-speed engine stability.

Bleed air is also used for starting engines on conventional airplanes. Typically, Sinnett said, the APU provides bleed air for air-turbine starters on the main engines. He said the starters meet the definition of "ground-support equipment" yet are carried aboard, serving no additional purpose. On the 787, air turbines are replaced by electric generators that while in flight power electrical functions.

The 787's generators operate on a variable frequency and at high voltage (235 V) vs. the constant-frequency low voltage (115 V) of a conventional plane. Converting variable shaft input into a constant-frequency output requires use of a complicated, high-maintenance device called an integrated drive generator, according to Sinnett. The 787 uses advanced power-conversion technologies instead.

The six generators used on the 787 produce more electricity than the three generators on the Boeing 777, almost 1.5 MW vs. the 777's 0.3 MW.

Using constant-frequency on the 787 also would have required larger generators, which would have meant larger nacelle linings, which in turn would have negatively impacted the plane's drag and thus its fuel efficiency, Sinnett noted.

That is not the only case in which integration between different systems results in better fuel efficiency. Sinnett said the full-authority, three-axis, fully automated flight-control system allowed for a 4000-lb reduction in wing structural load. One specific measure was to transfer lift inboard of the wing whenever the outboard portion exceeds 1 *g* loading. Doing so reduces outboard structural strength requirements, he said.

Another example of integration involved aerodynamics and the electrical power system. Sinnett explained that a highly reliable and effective anti-icing system was a "must" for the airfoil, the effectiveness of which is diminished by ice or other "clutter," Sinnett said. The solution required a more reliable, electric approach to anti-icing. In that respect, "there is a symbiotic relationship between the power system and airfoil," he said. "And that is a very unique aspect of a very integrated [airplane] design."

The advanced flight control system also provides a smoother ride, reducing vertical excursions from between 10 to 20 ft to between 3 and 6 ft.

"The lift-to-drag ratio, which is an indication of the overall aerodynamic efficiency of the airplane, is better than any other we've ever done—or that anybody has ever done in commercial airplanes," said Sinnett.

The 787 features an open-architecture computing platform. One computer handles 90 functions—each of which, on a previous airplane program, would have had its own computer, Sinnett said. A new network approach has a lightweight fiber-optic bus running to remote data concentrators in various areas of the airplane, obviating the need for wiring from each sensor or effecter to the cockpit or to the nearby electrical/electronics bay.

Similarly, the power-distribution system features a number of electrical substations so that not every load on the plane needs to be wired directly to the EE bay. There is about 61 mi of wiring on the 787, compared with 91 mi on the 767, 87 to 105 mi on the 777, 150 mi on the 747, and 328 mi on the **Airbus** A380, according to Sinnett.

High-power hydraulics (5000 psi) allows for smaller actuators, smaller tubing, and less fluid.

Patrick Ponticel

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Alternative fuels will burn cleaner and reduce oil dependency

With environmental issues at the top of the agenda for aerospace in the coming decade, the race has begun to develop alternative fuels that will reduce dependency on fossil fuel, burn cleaner so they emit fewer noxious gases and particulates during combustion, and also be compatible with existing engine combustors.

Alt fuels will likely begin to come into their own at around the same time the industry rolls out a next-generation narrowbody aircraft in the 2015 time frame.

"Alt fuels will contribute prior to 2015, but the [formulations] that will be interchangeable with regular fuels will likely be seen in the post-2015 era," said Paul Adams, Vice President of Engineering for **Pratt & Whitney**.

It is cold in North Dakota in the winter, which is just the environment the U.S. Air Force wanted when it tested a new blended fuel that may reduce dependency on foreign sources of oil.

With the research in its infancy, engineers are not discounting any possibility and are exploring the pros and cons of synthetic fuels, biofuels, coal-to-liquid fuels, and blends that combine different types of fossil and non-fossil fuels. A number of technical questions must be explored for alternative fuels to be used in the aviation industry, including energy density, thermal stability (avoiding coking at high temperature), use at very low temperatures (freezing) or high temperatures, lubricating effect with materials used, and the availability of mass production facilities worldwide.

"I've seen a lot of activity in the last year," said Fay Collier, Principal Investigator, **NASA** Subsonic Fixed Wing Project, the U.S. government's primary effort to improve fuel efficiency, cut noise, and reduce emissions in both civil and military aviation between now and 2015. "We're looking at different fuels being developed to see what works for high-altitude, high-temperature applications. I think the focus on alt fuels is just getting started."

Still, studies into the viability of alt fuels have begun in earnest.

In mid-June, **CFM International** (a joint venture of **GE-Aviation** and France's **Safran**) said it had successfully run a CFM56-7B engine with a biofuel consisting of 30% vegetable oil methyl ester blended with 70% conventional Jet-A1 fuel. CFM says it did not make any technical changes to the engine. The test was run at **Snecma**'s Villaroche facility near Paris.

In July, the *Sydney Morning Herald* newspaper in Australia reported that **Air New Zealand** and **Boeing** were working with New Zealand's **Aquaflow Bionomic** to develop a biofuel made from algae, in other words pond scum. Aquaflow's Web site says the company harvests algae directly from the settling ponds of standard effluent management systems and other nutrient-rich water. The process can be used in many industries that produce a waste stream, including the transport, dairy, meat, and paper industries.

The military is also interested in the potential of alt fuels as a way to reduce the approximately 3 billion gallons of jet fuel used by the **U.S. Air Force** each year.

The USAF has successfully flown a B-52 Stratofortess in which all eight engines were fed a blend fuel made from a 50:50 composition of traditional crude-oil-based JP-8 fuel and a Fischer-Tropsch fuel derived from natural gas. Fischer-Tropsch is a catalytic process to synthesize hydrocarbons and their oxygen derivatives by the controlled reaction of hydrogen and carbon monoxide.

This past winter, the aircraft underwent cold-weather testing at Minot Air Force Base in North Dakota. A complete test report analyzing the data from those tests as well as earlier ones at Edwards AFB in California was scheduled to be released this summer. The Edwards flight was the first time a B-52 had flown using a synfuel-blend as the only fuel on board.

"We are confident that the success of this flight will bring us one step closer to allowing a domestic source of synthetic fuel to accomplish the Air Force mission in the future," Air Force Secretary Michael Wynne said at the time.

Prior to testing on a manned B-52, the blended fuel first underwent 130 hours of testing in a T-63 engine.

The research is part of the Pentagon's Assured Fuels Initiative to find domestically produced alternative fuels for military use.

In addition to reducing the military's dependence on foreign supplies of fuel, the blended fuel has been shown to reduce exhaust emissions particulates because the Fischer-Tropsch process removes the aromatic compounds and sulfur from the fuel. The process also produces a fuel that burns well at low temperature, permitting aircraft to fly at higher altitudes.

Barry Rosenberg

Motorsport to aerospace technology transfer

A new report on technology transfer has revealed that 34% of UK motorsport companies sell some of their innovations into the aerospace industry. While the report states that more could be achieved, technology transfer between the two industries has been strengthening in recent years. In fact, a dedicated motorsport area was designated at the 2004 Farnborough Air Show.

Bob Gilbert of MDUK: "Motorsport is a good development testbed for experimenting with new ideas that can be transferred for use in other industries, including aerospace."

The report, Motorsport 100, was commissioned by **Motorsport Development UK** (MDUK) and carried out in May and June by independent researchers **Experian**.

It stated that development of transferable technologies, especially those related to energy-efficient and low-carbon innovations such as ultra-light materials and biofuel performance, needed to be more systematically marketed to non-motorsport markets, amongst which aerospace is seen as a key sector. However, the UK motorsport sector also

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Prodrive has built composite panels for Surrey Satellite Technology for use in space applications.

recognized that it needed to improve and extend its marketing skills and the ways in which it connects to other industries to systematically, comprehensively, and rapidly grow in non-motorsport markets, said MDUK Chairman, Bob Gilbert.

The situation is being addressed by MDUK, working to improve skills, make other sectors aware of the industry's potential, and create the climate for technology transfer, to create sustainable future success.

Energy efficiency and the 'carbon footprint'—once a challenge thrown at the motorsport industry—has been converted into a technology opportunity through the sector's thirst for innovation, said Gilbert, who believes that energy-efficient and low carbon developments will be at the heart of future transferable technologies coming out of the industry.

"One of the greatest challenges facing British motorsport is the environmental one, both in terms of fuels used and noise," he said. "Motorsport is a good development testbed for experimenting with new ideas that can be transferred for use in other industries, including aerospace."

Motorsport and automotive technology specialists, **Prodrive**, have been involved in making composite panels for space satellites, and in building actuators for aero engines. The company is currently researching and developing composite materials for further aerospace applications.

Stuart Birch