787 DREAMLINER™ **UNMATCHED ECONOMICS, PERFORMANCE AND PASSENGER APPEAL**

The new-technology Boeing 787 Dreamliner, which makes extensive use of composite materials, promises to revolutionize commercial air travel.

In April 2004, All Nippon Airways launched the 787 program with an order for 50 aircraft. The Dreamliners are scheduled to begin replacing the Japanese airline's fleet of Boeing 767-200s in 2008.

Picture this: You're sitting in an economy-class window seat, jetting across the Pacific Ocean at 41,000 ft. The aircraft's widest point is at eye level, giving you a sense of spaciousness in and around your seat. When you turn to look out the window, you're doing just that—looking out, not down, with a vast view of sky and Earth. And as night descends, the wash of color on the ceiling deepens from sky blue to a deep nighttime purple. You take a deep breath of satisfaction and realize that, too, is different. The air feels cleaner and fresher, which leaves you more alert.

Sound like a dream? In fact, it will be the Dreamliner, Boeing's ultra-modern, high-tech 787. When it enters service in three years, the 787 will dramatically raise the bar in every aspect of flight: aircraft economics, fuel efficiency, systems design, maintenance, the passenger experience and more. This will be a whole new airplane in every sense of the phrase.

JUST THE FACTS

More specifically, the 787 will be a family of three airplanes. The baseline version, the 787-8, will carry up to 223 passengers 8,500 naut. mi. in a three-class configuration. The shorter-range version, the 787-3, will carry up to 296 passengers 3,500 naut. mi. in a two-class configuration. Assembly on the 787-8 will start in 2006, with first flight in 2007 and certification and entry into service in 2008. The 787-3 will enter service in 2010.

The final version, the stretched 787-9, will follow about two to four years after the 787-8, with the capacity to carry 259 passengers in a three-class configuration up to 8,300 naut. mi. The time between introduction of the first version and the third is Boeing's normal interval, which should enable the later model to achieve an additional 1% improvement in performance through study of the first model in real-world operations.

The airplane is designed to be super efficient, using 20% less fuel on a per-passenger basis than today's airplanes of this same passenger capacity. The 787 is expected to offer operating costs that are 10% lower than for today's similarly sized commercial airplanes as a result of the 20% savings in fuel, improvements in maintenance and lower weights (which are a factor in determining airport fees). On the revenue side, airlines will enjoy approximately 45% more cargo revenue capacity.

Environmental performance will be a key benefit of the 787. Since emissions are largely driven by fuel use, the 787 is designed to enable a 20% reduction in that area as well. By optimizing the design, the 787 will be quieter for communities, crews and passengers. Additionally, new manufacturing methods will result in a more efficient use of resources, with less waste in production and fewer hazardous materials.

The 787 will replace two Boeing aircraft—the single-aisle 757, which seats 200-280 passengers and is no longer in production; and the twin-aisle 767, which seats 181-345 passengers. The 787 will compete with Airbus's A330-200 and the recently announced A350. Ultimately, Boeing projects the market for aircraft in the 787 class to be 3,500 units worth about $400 billion during the next 20 years. The company anticipates winning more than half of those orders.

By February 2005, less than a year after the manufacturer began offering the 787 for sale, the aircraft had racked up 62 firm orders with four airlines and 193 commitments from 16 airlines. Also, Boeing has proposals out for 600 airplanes at approximately 30 customers.

All Nippon Airways (ANA) helped launch the 787 program when it announced its order for 50 aircraft in April 2004. Air New Zealand, Blue Panorama and First Choice Airways also have signed definitive agreements, for two, four and six units, respectively. Other announced commitments for the 787 include: Primaris (20), Japan Airlines (30), Continental Airlines (10), Vietnam Airlines (4), Ethiopian Airlines (5), Icelandair (2) and six Chinese carriers—Air China, China Eastern Airlines, China Southern Airlines, Hainan Airlines, Shanghai Airlines and Xiamen Airlines—which will take a total of 60 787s.

Notably, the 787 customer base includes a broad mix of operators—start-ups, charter operators, international airlines and long-established major carriers. They all cite the aircraft's anticipated superior economics as a major driver of their purchase decisions.

Ralph Norris, Air New Zealand's managing director and chief executive, says the 787 "will provide Air New Zealand with lower operating costs and improved financial performance over and above that which could be achieved by expanding the existing fleet of 10 Boeing 767s."

Similarly, ANA will reduce its operating costs by replacing its current fleet of Boeing 767-200s with the base 787-8 and short range 787-3 derivative. Its 787 deliveries are to begin in

20% less
fuel per person used by the 787 than today's aircraft

10% lower
operating cost than today's similarly sized aircraft

45% more
cargo revenue capacity than similarly sized aircraft

$400 billion
estimated size of the market for a 787-sized aircraft during the next 20 years

50%
portion of the 787 aircraft that will be made from composite materials

10%
percentage of composite materials used on the 777

2008, one year before the planned expansion of Tokyo's Haneda airport.

THE COMPOSITE EFFECT

The key to the 787's revolutionary design, economics, manufacturing technique and more lies in the extensive use of advanced composites. It has been written that the 787 is an all-composite aircraft; in truth, roughly 45% of the aircraft's structure is made of graphite composites and another 5% or so is composed of fiberglass, for a total of about 50% of the aircraft. The 777, Boeing's most recent model and the first in which composites were applied to the primary structure, is composed of about 7% graphite and 3% fiberglass, for a total of about 10% composites.

The use of composites in the 787 is expected to provide a 3% fuel savings over the 767. But one of the real economic advantages of the 787 will be the additional anticipated 17% in fuel-burn improvement, for a total of 20% savings over the 767. Boeing says the engines will contribute 8% of that number. An improvement in aerodynamics, including subtle changes to the curvature of the wing and the shape of certain fairings, contributes another 3%. The final contributors are systems (3%) and integration, and the cycling effect of optimizing every aspect of the aircraft from scratch (3%). Altogether, the 20% reduction in fuel burn should result in a 10% improvement in operating costs over the 767.

To determine where it would be best to use composites and where it would use metal, Boeing and its suppliers went through the airplane piece-by-piece.

The landing gear will be metal because its compression properties are better suited to that particular application.

But pretty much anything a passenger sees when observing the aircraft parked on the ramp will be composite—the skin, the tail, the wing box and wing skins—all the large surface areas of the aircraft.

A Boeing employee works on the nose section of the 787 high-speed wind tunnel model, which has been used to confirm the advanced aerodynamic characteristics of the Dreamliner.

"We looked at how each component would be asked to perform and what the right material was," says Tom Cogan, chief project engineer for the 787 program. Thus, highly loaded joints, such as where the wing connects to the body of the aircraft, will be made of titanium.

The advantages of using so much composite material instead of aluminum are far-reaching. For starters, there's the weight savings. The 787 is about 10,000 lb. lighter than it would be had aluminum been used instead of composites. That's the equivalent of 53 passengers. Compared to the similar-sized 767-300, the lightness of composites is expected to enable 3% in fuel savings.

Composites also offer innumerable advantages from a maintenance perspective. The aluminum used on aircraft flying today, for instance, corrodes and fatigues. Boeing protects its aluminum structures against corrosion, but "physics is physics," says Cogan. "If aluminum is repeatedly exposed to the environment, it tends to corrode." Likewise, it tends to fatigue with repeated pressurization. And it yields fairly easily. So if a ground service vehicle hits the side of an aircraft with any real force, the structure will dent. All those problems can be fixed, of course, but that costs money and requires airlines to pull planes out of service for repairs.

Composites don't corrode, and, in the design conditions for which they are being used on the 787, Cogan says they won't fatigue and are incredibly durable. Take the structural area around an aircraft door, for instance. If it were made of aluminum and hit with a 3,500 in.-lb. force—the equivalent of dropping a 10-lb. bowling ball from a three-story building—the damage would require repair. Apply the same force to a composite structure and any resulting damage would be insignificant, not requiring repair. "We typically talk in terms of composites having a 30% better strength-to-weight efficiency than aluminum," says Cogan. "That's in the lab. On the airplane, you get about a 15% strength-to-weight improvement by using composites."

Boeing estimates maintenance cost savings of 32% at maturity, thanks to the use of composites. Most of the savings will be realized after about the 12-year mark, when structural maintenance requirements become the real driver of airplane upkeep costs.

Those estimates are being proved out today on the 777, which has a composite horizontal and vertical stabilizer, as well as other composite components including floor beams, rudder and elevator, and gear doors. During D checks on all-metal airplanes, airlines typically find corrosion under galleys and lavatories, where leakage is almost impossible to avoid. On the 777, Cogan says airlines are finding no corrosion under the composite floor structure.

D checks on the 787, therefore, "will become much easier, and we may be able to push

General Electric's GEnx powerplant offers a host of benefits over current-generation turbofan engines, thanks in part to composite components, which make the GEnx lighter than comparably sized engines.

10,000 lb. reduction in the weight of the aircraft because of the use of composites	**32% savings** in maintenance costs saved at aircraft maturity due to composites	**350 lb.** weight reduction in the new GEnx engine due to use of composite materials	**11% less** fuel consumption for the Trent 1000 over the Trent 800	**30% more** time between overhauls for the GEnx compared to the CF6-80C2

them out in time so airlines won't have to do them as often," says Cogan. "We expect, working with the FAA, that maintenance intervals will be improved over the 767, possibly by as much as 60-100%." In other words, where a 767 inspection interval now may be at six years, the 787 D-check interval could be as much as 10-12 years.

ADVANCED ENGINES

The durability and maintenance advantages of composites also extend to the GEnx engine, one of the 787's two powerplants. Both the front fan case and the fan blades of the GEnx will be made of carbon fiber and epoxy resin composites, an innovation that will reduce engine weight by 350 lb. per engine while substantially boosting durability. Those fan blades have racked up more than 5 million hr. of operation on the GE90 during the past eight years. Only two blades have been removed, both for cosmetic reasons. Compare those numbers to statistics for metal blades, which have about a 0.01% removal rate. An engine type operating with metal blades likely would have experienced 50 removals during the same period of time, says Tom Brisken, general manager of the GEnx project at GE Aircraft Engines.

"The GEnx outer case and fan blades are maintenance-free," adds Brisken. "There are no life limits, no ADs, no service bulletins." At the same time, the engine has a 15% specific fuel consumption advantage over the 767's CF6-80C2. And the GEnx will spend more time on wing between overhauls—up to 25,000 hr., versus around 18,000 hr. for the CF6-80C2. Since the GEnx is a bigger engine, shop visits will cost about 25% more than the CF6-80C2, says Brisken, but the other advantages will make overall maintenance costs equivalent: It's a bigger engine for the same maintenance costs and substantially improved fuel savings.

Going head-to-head against the GEnx is Rolls-Royce's Trent 1000, which was selected by both ANA and Air New Zealand. The 1000 is the fifth member of the Trent series, the first of which entered service in 1995. By the time the Trent 1000 flies with ANA, previous versions of the Trent will have accumulated about 35 million flying hours. With so much operational experience behind it, Rolls-Royce has designed the Trent 1000 with the target of achieving a 99.95% dispatch reliability, says Richard Goodhead, Rolls-Royce's head of marketing for Boeing programs.

All Trents share the three-shaft design common to all of Rolls-Royce's large engines. The availability of an additional shaft compared to more traditional two-shaft engines has had significant benefits for the 787's more electric architecture. Rolls-Royce is taking power off the extra shaft to drive the plane's electrical power with a feature called IP (intermediate-pressure) offtake. By using the IP offtake, says Goodhead, "you're allowing the HP (high-pressure) compressor to do what it's supposed to do—compress air." The HP compressor, he adds, is more sta-

Rolls-Royce's Trent 1000 engine has been selected to power the 787s ordered by All Nippon Airways and Air New Zealand. The powerplant has been designed with the goal of achieving a 99.95% dispatch reliability.

ble and more efficient when you're not driving electrical power with it.

The IP offtake solution offers significant fuel savings. On a 500-naut. mi. flight, operators will use 6% less fuel with this solution than with a conventional two-shaft engine, says Goodhead. Over longer flights, the benefits are reduced. Nevertheless, the Trent 1000 on a 787 will have about an 11% improvement in specific fuel consumption over the Trent 800 used to power the 777.

The Trent 1000 is what Rolls-Royce calls an "intelligent engine." It will have its own health-monitoring capabilities and will be able to downlink key operating data to the ground. But even more significant is the fact that the powerplant will be able to differentiate between the types of cycles being put on the engine. A 500-naut. mi. cycle and a 5,000-naut. mi. cycle, for instance, affect engine components differently, says Goodhead. So by understanding not only the number but also the type of cycles, Goodhead says some components will be able to stay on the engine longer than they do today, driving down maintenance costs. In all, the Trent 1000 will have maintenance costs equivalent to the 767's CF6, with much increased performance and fuel burn.

Six Chinese air carriers—Air China, China Eastern Airlines, China Southern Airlines, Hainan Airlines, Shanghai Airlines and Xiamen Airlines—have placed orders for a total of 60 Dreamliners.

INSIDE THE CABIN

The shape of the 787's fuselage is more oval instead of the traditional round, putting the widest part of the cabin at seated eye level. After years of study,

ALENIA: FOUR DECADES OF AEROSTRUCTURE EXPERIENCE

Alenia Aeronautica S.p.A.'s extensive aerostructures experience spans more than 40 years and more than 6,000 commercial aircraft. Alenia perhaps is best known for its role in manufacturing the ATR series of 50-70-seat regional turboprops, of which more than 700 have been delivered worldwide.

For the 787, Alenia will produce the center fuselage sections 44 and 46, as well as the horizontal stabilizer. The fuselage sections will be manufactured in Alenia's new 60,000-sq.-meter facility in Grottaglie, Italy, then shipped to Global Aeronautica, a joint venture between Alenia North America and Vought Aircraft Industries that has an integration facility in Charleston, S.C. Global Aeronautica will integrate more than 60% of the 787 fuselage, combining sections provided by Alenia, Vought and other partners. ■

EATON PROVIDES RAT PUMP AND ELECTRICAL CONTACTORS

Eaton Aerospace has won two 787 contracts, both in partnership with Hamilton Sundstrand.

Eaton Aerospace will supply the Ram Air Turbine (RAT) 5,000-psi pump, which provides back-up emergency hydraulic power to the aircraft's flight control systems.

In addition, Eaton Aerospace will supply the 270-volt DC electrical contactors for the 787's power distribution electrical system.

Eaton designs, manufactures and supports higher-pressure fluid power, fluid control and fluid conveyance, electromechanical motion control, electrical distribution and control, cockpit controls and displays, and fluid monitoring and sensor products and systems. Eaton's customer base is a global group of civil and military original equipment manufacturers and air carriers. ■

Oversized windows and overhead storage bins, a vaulted ceiling, wider aisles, special lighting and other innovative interior design features promise to make the 787 appealing to airline passengers.

Boeing has found the amount of space at seated eye level has the most direct correlation to passenger satisfaction, says Klaus Brauer, director of passenger satisfaction and revenue for Boeing Commercial Airplanes.

In other words, the historical quest by commercial aircraft manufacturers to provide more room at the armrest level was all for naught; passengers perceive a greater sense of cabin spaciousness if there's room around them at eye level, not at hip level. Thus, Boeing targeted an inside width of 205.6 in. at 50 in. above the floor, a number that makes the aircraft 14 in. wider than the competition at seated eye level.

Composites provided some additional advantages, most notably in the area of the cabin experience. It enabled windows that are 30% larger than on current commercial airplanes. "We wanted to reconnect passengers to the flying experience," says Brauer. "As we explored the window, we realized that what connects you to flying is looking down on the Earth and seeing sky touch land. Today's windows are good for looking down, but not for seeing the horizon."

So Boeing left the bottom of the window where it was and stretched the top by about 5 in., resulting in a window that is 19 in. tall and 11 in. wide. These numbers mean that the manufacturer's tallest reference passenger, a 6-ft. 3-in. person, sitting in a window seat, will be able to see 10 deg. above the horizon looking out. On today's airplanes, he would see sidewall. And since the top of the window will be above seat-top height, travelers

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The Passenger Experience

Boeing could create the lightest, most efficient and cost-effective commercial passenger jet ever made, but it would all be for naught if passengers weren't wowed enough to return again and again. That is why the 787 interior is designed to be just as striking to passengers as the plane's economics will be to airlines.

It starts with the first step onto the plane. The entryway will be a dramatically lit vaulted ceiling, designed to look infinitely tall, followed by a lower ceiling. The change in ceiling height is aimed at putting passengers into a different space psychologically, conveying to them that the problems associated with getting to the airplane are behind them and they now can relax.

The overhead bins were designed with the same goal—relaxation. Typically, passengers rush onto the plane at their earliest opportunity to secure a space for their bags somewhere near their seats. And if they don't find it, their stress level goes up. The 787's bins were designed to allow for one 11-in. x 16-in. x 22-in. bag for each passenger at his or her seat. The goal, say Boeing officials, is that when passengers at last sink into their seats, they are stress-free and ready to fly.

From those seats, passengers will notice several improvements over the aircraft cabins of today. First, the 787's interior will include a series of arches along the length of the fuselage, dividing it into smaller, room-like cabins that feel more spacious than a single long tube. The windows will be the largest on any commercial airplane. There will be more space at seated eye level, which should provide a sense of more personal space per passenger. And there will be more space in the aisles—typically 55 cm. of width in the 787's economy class, which is more than 6 cm. wider than for most two-aisle airplanes. In business class, the aisles will be 65 cm. wide, which will allow passengers to move past serving carts with ease. Finally, the lavatories will be more spacious as well, with each accessible by a standard-sized lav wheelchair.

Ever notice the ceiling on the aircraft you've flown? You will soon in the 787. It will be illuminated by arrays of light-emitting diodes, which flight attendants will be able to control to give passengers a sense of bright daylight or, to help passengers sleep, simulate a rich, dark nighttime sky. Flight crews also will be able to control the amount of light coming in the windows. During a movie, for instance, they will be able to lower the transparency level to around 5%, which will block most of the light coming in while still enabling passengers to see the passing terrain outside. And individual passengers will retain control of their window shading.

Finally, the interior was designed to maximize the potential for passengers to have an empty seat next to them—a phenomenon that makes people perceive their seats are 4.25-in. wider than they really are, and this has a huge impact on customer comfort and satisfaction, says Klaus Brauer, Boeing Commercial Airplanes' director of passenger satisfaction and revenue. The mock-up of the eight-abreast economy cabin shows a 3-2-3 seat arrangement that maximizes the use of empty seats. Airlines can opt for a 2-4-2 arrangement in the eight-abreast section, says Brauer, but at a load factor of 70%, there will be 12% more passengers seated next to empty seats in the 3-2-3 arrangement than in the 2-4-2 arrangement. The 787's nine-abreast economy-class cabin layout has 3-3-3 seating, which, says Brauer, is the most effective configuration in using empty seats.

With all these interior improvements, almost every passenger should have a better flying experience on the 787 than on the airplanes flying today. ◆

GOODRICH GETS SEVEN 787 CONTRACTS

Goodrich Corp. is a leading global supplier of systems and services to the aerospace and defense industry.

Goodrich has won seven contracts on the Boeing 787, including the electric braking system (which will be the first to fly on a commercial airliner), engine nacelles and thrust reversers, proximity sensing system, fuel quantity indicating system and fuel management software, exterior lighting and the entire cargo handling system (which includes the mechanical system, power drive units, electrical control system and floor panels).

In addition, Rolls-Royce selected Goodrich's engine control system for the Trent 1000 powerplant.

Goodrich expects these 787-related contracts to generate more than $7.5 billion in original equipment and aftermarket sales through 2028. ■

GREEN HILLS SOFTWARE USED TO DEVELOP FLIGHT CONTROLS

Green Hills Software, Inc., which is based in Santa Barbara, Calif., will supply its memory-protected Integrity-178B real-time operating system (RTOS) and Multi development tools to Honeywell International.

The software will be used to develop the 787's flight controls electronics system, including the new airline transport's fly-by wire system and autopilot.

The Green Hills operating system was designed from the ground up to meet the safety and performance requirements of flight-critical systems. Integrity-178B complies with the aviation industry standard Arinc 653-1 applications software interface and has been used in numerous systems certified to the most stringent avionics software safety standard, RTCA/DO-178B Level A. ■

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in the center of the aircraft will at last have views.

"I think we'll get a big buzz from the windows," says John Feren, vice president marketing, sales and in-service support for the 787 program. "It will be a visual cue that there's something different about this airplane." In focus groups, Feren says passengers consistently gave higher ratings to cabins with larger windows than to cabins with smaller ones, even though they weren't consciously aware of the size difference.

"They know they had a good experience with Airline X, and given two flights that suit their schedule and have similar fares, they'll choose the one on which they had a good experience."

Since composites don't fatigue like aluminum, the 787 cabin will be pressurized at 6,000 ft. instead of the 8,000-ft. level on most commercial airplanes flying today. In studies done during the past four years at Oklahoma State University and the Technical University of Denmark, Boeing looked at various levels of pressurization to determine where the greatest benefits occurred.

"In the past, the penalty to pressurize at 6,000 ft. was too high—several thousand pounds of structural weight to overcome the fatigue problems. But with a composite fuselage, fatigue is not one of the driving concerns."

— Mike Sinnett, chief systems engineer for the 787 program

"We found a real knee in the curve at 6,000 ft.," says Mike Sinnett, chief systems engineer for the 787 program. "In the past, the penalty to pressurize at 6,000 ft. was too high—several thousand pounds of structural weight to overcome the fatigue problems. But with a composite fuselage, fatigue is not one of the driving concerns."

Finally, passengers can thank composites for an anticipated increase in cabin pressurization and humidity, which means they should arrive feeling more alert, more refreshed and less fatigued than they do today.

As with the windows, travelers may not know why they feel great about their experience on the 787, but Boeing argues that a positive image will mean future bookings and increased revenues for operators.

"We believe that a good experience casts a halo over the whole airline," explains Brauer.

At the same time, humidity is expected to be higher because the 787 will have fresh, outside

MOOG TO PROVIDE PRIMARY FLIGHT CONTROL ACTUATION

Moog Inc. will supply the primary flight control actuation system for the 787. The Moog system will control all of the primary flight control surfaces on the airplane, as well as the spoilers and the horizontal stabilizer.

Shipsets will include 30 actuators and associated control electronics. Design and development of the equipment will be done at the company's East Aurora, N.Y.; Salt Lake City; Torrance, Calif.; and Tewkesbury, England, facilities.

The company also will supply rotary actuation components to Smiths Aerospace for use in the high-lift system of the 787.

Moog's high-performance actuation products also control military aircraft, spacecraft, launch vehicles, missiles, automated industrial machinery and medical equipment. ■

PARKER HANNIFIN TO SUPPLY 5,000-PSI HYDRAULIC SUBSYSTEM

Parker Hannifin Corp., a leading maker of motion and control systems, will provide the hydraulic subsystem for the 787 through its Abex Div. The subsystem will operate at 5,000 psi, reducing equipment size and weight compared to the 3,000-psi systems on commercial aircraft today.

Parker's Nichols Airborne Div. will supply liquid-cooling pumps and reservoirs for Hamilton Sundstrand's 787 primary electronics cooling air management system. And Parker's Gas Turbine Fuel Systems Div. is working with both 787 engine suppliers. With GE, it is working on new low-NOx combustor technology. For Rolls-Royce's Trent 1000, Parker will supply and manage the fuel system, including the fuel atomization nozzles. These contracts are worth in excess of $1.2 billion. ■

Continental Airlines was the first major U.S. carrier to order the 787. The Houston-based airline is scheduled to begin taking delivery of its Dreamliners in 2009.

air brought in on a per-passenger, not a per-seat, basis. When that very dry air is brought in on a per-seat basis and there are few passengers to restore humidity, relative humidity can be as low as 5%, says Sinnett. Flight attendants will ensure incoming fresh air is always in balance with passenger loads using the 787's digital environmental control unit.

Also, less moisture is expected to escape from the fuselage since less heat is transferred through the composite fuselage. Plus, there's higher moisture content in 6,000-ft. air than in 8,000-ft. air—enough to make a 4% difference in relative humidity. Boeing's goal for the 787 is 16% relative humidity at 6,000 ft., a number that would feel like 20% at 8,000 ft.—substantially higher than the 5-15% relative humidity in aircraft today.

Still, Boeing engineers discovered that the impact of higher humidity by itself wasn't that great. The real driver of passenger well-being is the removal of organic compounds from the air. "Removing compounds had much more of an impact on the symptoms associated with dehydration than did humidity," says Sinnett. "Removing the compounds was like raising relative humidity 25-30%."

So like today's airplanes, the 787 will remove particulates down to the viral and bacterial levels, but also will use gaseous filtration to remove alcohol—found in everything from drinks to hand wipes—as well as perfumes and other gases. "When these contaminants are removed through purification," says Sinnett, "some of the symptoms of dehydration are relieved."

SYSTEM INNOVATIONS

Systems will contribute a 3% savings thanks to a new architecture that reduces the power required of the engines and reduces the structural weight, says Walt Gillette, vice president for engineering, manufacturing and partner alignment on the

ROCKWELL TO PROVIDE PILOT CONTROLS, COMMUNICATIONS/ SURVEILLANCE SYSTEMS

Rockwell Collins, a leader in communications and avionics, will provide the 787's pilot controls through its Kaiser Electroprecision business in Irvine, Calif. In addition, Rockwell will supply the aircraft's head-up and head-down displays, communication and surveillance systems, and the core network, which include advanced VHF, HF and satellite communication radios, terrain awareness warning systems, weather radar, and traffic alert and collision avoidance systems.

All the file servers, routers and avionics interfaces are included in a single cabinet, with growth slots for future enhancements. Rockwell also is assisting Smiths Aerospace on the development of the common data network. The awards could be worth up to $3.5 billion over the life of the program. ■

VOUGHT AND PARTNERS TO SUPPLY 60% OF THE 787 FUSELAGE

Vought Aircraft Industries offers a full range of design, testing, manufacturing and support capabilities to aerospace manufacturers. On the 787 program, Vought is positioned as a Tier I Integrator, filling the gap between prime contractors and traditional subcontractors by providing large, integrated aerostructures on a turnkey basis.

For the 787 program, Vought and Alenia North America formed a joint venture called Global Aeronautica, which will join and integrate fuselage sections from Vought, Alenia and other structural partners. Together, the sections represent more than 60% of the 787 fuselage. Vought will produce its aft fuselage sections 47 and 48 in a new 340,000-sq.-ft. building co-located with the Global Aeronautica integration facility in Charleston, S.C. ■

Modern aircraft engines generate about 60 kilovolts of electricity to power today's electrical systems...in the 787, they will generate more than a megawatt, which is enough to power 250 homes in the middle of a Phoenix summer.

— Tom Brisken, general manager of the GEnx project at GE Aircraft Engines

787 program. For starters, the 787 combines roughly 80 functions into one computer system, more than any aircraft previously. Altogether, there are just 30 separate computer systems on the 787, compared to 80—with about 100 different devices—on the 777.

Just as important, those computer systems have been designed to a common standard—Arinc 653—rather than a proprietary standard, which is expected to reduce dramatically the cost of change downstream. Say, for instance, technology evolves one day to allow pilots to see and avoid clear air turbulence (CAT), says Sinnett. CAT software would be written to Arinc 653 standards, which means airlines essentially will be able to plug in the new software overnight. In today's airplanes, installing new software means "tearing the airplane apart and putting in 30 different boxes," Sinnett says. So the 787's open, common architecture is designed to enable it to keep up with technology changes in everything from avionics to passenger entertainment.

Most striking, however, may be that the 787 virtually will have eliminated an entire aircraft system, replacing the traditional engine-bleed-air-driven pneumatic architecture with a more efficient electric-motor-driven air-compression system. Rather than using engine bleed air as the power source for the environmental control systems, the 787 will use electric power. Only the engine nacelle heat and cowl anti-ice will be provided by engine bleed air.

The shift is huge: Modern aircraft engines generate about 60 kilovolts of electricity to power today's electrical systems, according to GE's Brisken. In the 787, they will generate more than a megawatt, which is enough to power 250 homes in the middle of a Phoenix summer.

The biggest advantage of an electrical system over a pneumatic system is that operators will be able to match the electricity they generate to the energy they need, says Bob Guirl, director of 787 programs at Hamilton Sundstrand, which has won eight contracts on the 787, more than any other company. During cruise,

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Manufacturing Success

If composites make so much sense, why have they not been used extensively in commercial aircraft before? Quite simply, it's been a matter of cost. The lay-up work for high-performance composites has been done manually, which is fine for applications such as satellites and fighter jets where performance is paramount, but the process didn't make sense for commercial aircraft. No airline would have paid the sky-high price tag for a manually produced composite aircraft.

The trick for Boeing was to figure out a way to automate the composite lay-up process. In addition, the airframe manufacturer wanted machines to lay down composites at a rate of 10-30 times faster than previously possible, while still producing the highest-quality material. In mid-January, Boeing unveiled proof it had reached its goal with the rollout of the first full-scale composite one-piece fuselage section.

Building the 22-ft.-long, 19-ft.-wide section started with computerized lay-down of composite tape on an enormous mold. That mold was mounted on a tool that rotated the barrel as the tape was applied. Then the structure was wrapped and placed in Boeing's autoclave for curing. The final steps were unwrapping the structure, inspecting it and removing tools.

That single structure has enormous implications for aircraft assembly. Had the same section been constructed of aluminum, it would have been made out of many pieces with "hundreds and hundreds" of rivets, says Walt Gillette, vice president of engineering, manufacturing and partner alignment on the 787 program. In all, the switch to composites is enabling a reduction of thousands of parts and tens of thousands of rivets.

The fuselage sections will be built by various Boeing partners and shipped to Seattle for assembly. One of the partners is Alenia Aeronautica of Italy, which is responsible for constructing center fuselage sections 44 and 46 and the horizontal stabilizer. Soon the European company will break ground on a 60,000-sq.-meter facility in Grottaglie, Italy, where it will build the two fuselage pieces. The facility will be finished by early next year, and the machinery to make the parts will start being delivered in April 2006, according to Alenia officials.

Alenia then will ship its fuselage sections to Charleston (S.C.) International Airport, where Global Aeronautica, the joint venture of Vought Aircraft Industries and Alenia North America, will join and integrate fuselage sections from Vought, Alenia and other structural partners, which together represent more than 60% of the 787 fuselage. From there, the assemblies will be sent to Seattle, where Boeing will join the parts, hook up the systems and put in the interior.

The sections will be transported in Boeing's new Large Cargo Freighter, a modified 747-400F that will serve as the primary means of transporting 787 major assemblies from partner locations around the world to the final assembly line.

The freighter airplane's design enables the entire aft fuselage to swing open, thus allowing 787 fuselage and wing components to be loaded more easily. The expanded girth of the Large Cargo Freighter will hold 300% more cargo above the main deck than the current -400F.

Gillette says final assembly is as easy as it sounds because carbon fiber structure is very stiff and holds its shape. With metal, which tends to flex, assembly workers often have to install shims to make everything fit. That won't be the case with composites. "It will be like Fisher-Price on Christmas Eve. The parts just snap together," says Gillette.

Consequently, final assembly time for the 787 will be cut by a third to a quarter, compared to metal airplanes. For airlines, that means a longer time for making decisions.

"Today, airlines have to make final decisions almost a year in advance of delivery," says Gillette. "These manufacturing initiatives will cut that time at least in half." ◆

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engines today bleed off air in excess of their needs, which ultimately means engines are burning more fuel than they need to. Now, says Guirl, "you'll use only the fuel you need to run the generator to support the loads you require."

The switch in systems was possible because of recent advances in electrical systems, most notably on the industrial front. Hamilton Sundstrand engineers went to sister United Technologies company Otis Elevator Co. to examine the work it was doing to electrify hoists and lifts in elevators, and from that they were able to put together affordable motor-control solutions for the 787. More importantly, "we're getting out of an environment where we're making aerospace-unique solutions and aligning with a technology path that is driven by a broader industry," says Guirl. "This will allow us to harvest the benefits and the technology advances that occur to allow for lower-cost solutions."

HAMILTON SUNDSTRAND POWER

Hamilton Sundstrand is responsible for three of the electrical system's four main work packages: the electrical power generation and start system, the primary power distribution system (in partnership with Zodiac ECE) and the remote power distribution system. (The fourth package, awarded to Thales, is for the conversion system.) In short, Hamilton Sundstrand will generate, distribute and use the power, as well as cool the loads on the 787. And as a result, it has found ways to optimize solutions and eliminate redundancies in ways that would not have been apparent in a single-system environment.

Boeing's new production system for the 787 will include air transport of many major assemblies via the Large Cargo Freighter, a modified 747-400F that will feature an aft fuselage that can swing open during loading and unloading operations.

Take the company's modular design for the motor controllers. "We will use like design practices and circuit applications in the motor controls for the electric motor pump controllers, the main engine start controllers and the APU start controller," says Guirl. "This helps ensure common requirements flow down, which drives re-use across the airplane, resulting in ease of use in service, standardized diagnostics, common spares and simpler repair, all of which push the cost of ownership down."

THE SUPPLIER CONNECTION

The fact that Hamilton Sundstrand won so much of the electrical work was no coincidence; it represents a conscious shift by Boeing to reduce the number of Tier 1 suppliers and become more of an integrator/architect, with partners providing more of their own development, design and manufacturing funding. Suppliers on the 787 program are true partners, offering their innovation and expertise to bring a superior product to market.

As a result, Boeing reduced its supplier list from hundreds on the 777 to fewer than 50 for the 787, including internal Boeing division suppliers. And it selected most of its suppliers about a year and a half earlier than on other programs so they "could influence the Boeing team on making the best design decisions for the lowest cost" from the outset, says Gillette.

Boeing works with its suppliers in a real-time collaborative environment, with every supplier using the same methods, procedures and software.

"If we want to discuss a part of the fuselage with Alenia, Vought, Kawasaki and Mitsubishi, we link in digitally to every part of the world," says Gillette.

Every participant sees on a computer the component being discussed, every participant talks, and everyone else hears what is said. Any participant can modify parts until everyone agrees and the final design is locked in. At the same time, every change made cascades downstream, altering everything that would be affected by the change right down to rewriting codes for the robots that will eventually build the part. So if Boeing changes a single door, everything associated with that door is changed automatically; even its manufacturing process is digitally redefined. Just as important, every partner knows about it.

Boeing's Global Collaboration Center in Everett, Wash., is a virtual workspace that enables engineers from partner companies around the world to make concurrent design changes to the airplane in real time.

Traditionally, partners designed their parts on their own systems and then shipped them to Boeing for integration. The method took time and sometimes resulted in communication errors.

"With everyone working in the same way, in the same environment with the same systems, the problems associated with the transfer of information, with the integration of parts, are eradicated," says Michel Tellier, Dassault Systèmes' vice president of services for PLM Americas. Dassault Systèmes calls the 787's worldwide, single-system environment the Global Collaborative Environment (GCE).

PUBLIC INPUT, TOO

Boeing extended its global collaborative efforts to the public as well, calling on a group of about 140,000 aviation enthusiasts, who are part of what Boeing calls its World Design Team (WDT), to weigh in. It was the public, for instance, that picked the name Dreamliner.

When the name of the aircraft was announced at the Paris air show two years ago, Rob Pollack, vice president of branding for Boeing Commercial Airplanes, summed up the meaning as follows:

"The name Dreamliner reflects a new airplane that will fulfill the dreams of airlines and passengers with its efficient operations, enhanced cabin environment and the ability to allow profitable connection to more cities without stopovers. The name also demonstrates how the airplane's economics will enable more people around the world to fulfill their dreams of traveling to new places, experiencing new cultures and staying connected to one another."

For operators worldwide, perhaps the name Dreamliner will mean the ability to increase profit margins through Boeing's creation of a new standard of efficiency demanded by today's ultra-competitive marketplace. ◆

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