BOEING 787 DREAMLINER

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Contributors

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The 2003 winner of the European Regions Airline Association award for excellence in aerospace journalism and previously a winner in the 2001 Royal Aeronautical Society Aerospace Journalist of the Year awards, Ian Goold has been involved in aerospace since 1964, and in aviation media since 1973. He was the last air-transport editor of Flight International magazine, where he enjoyed a 20-year career before turning freelance in 1993. He has contributed regularly to aerospace magazines in Asia/Pacific, North America, the Middle East, South Africa, and the UK.

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Guy Norris is the US West Coast Editor of the weekly Flight International and author of 14 books on aviation. He was named Aerospace Journalist of the Year in 1997 in the Best Systems and Technology category, in 2004 in the Propulsion category and was joint winner in 2005 in the Regional Aircraft category. Guy has also twice won the Aviation/Space Writers' Association award. He has appeared in numerous aviation television documentaries and has authored several educational projects including the interactive Aviation Knowledge Adventure CD-ROM and the aerospace section of the Encyclopedia of Science in Action. He lives in Southern California with Anna Ravelo and their children Chris, Daniel, Greg, Lia and Tom.

Technological advances make 787 'Dreamliner' a winner

(Interview by Ian Sheppard, January 2006)

2005 was make-or-break for the 787, says Walt Gillette, until May 2006 Boeing vice president airplane development and the chief engineer for the 'Dreamliner' programme. “In September we were able to firm up the aircraft's configuration, so by January we knew the size, thrust, locations, how to get systems fitted and so on, and could begin detailed design and move towards design release,” he says.

Getting the configuration inevitably meant taking test data into account, and so some targets were tweaked, but generally every goal the company set itself was obtained, says Gillette. An example was the 6,000ft cabin pressure, far lower than present-day aircraft and giving a far more bearable environment for the passenger.

In some areas improvements were made after testing, such as flight control laws to give better ride quality, while the interior sound environment will be a real advance over current aircraft. Boeing worked closely with engine supplier General Electric, NASA and Goodrich, the nacelle manufacturer, while lead customer

The requirement

By the mid-90, Boeing had successfully introduced the Model 777 and, in competition against Europe's Airbus, was working to understand industry demand for very large aircraft, which it had pioneered with the late 60's 747 design.

Airlines had a seemingly insatiable appetite for the Boeing's third-generation of the short/medium-haul Model 737 single-aisle twinjet, but the 767 - successfully developed into larger and longer-range variants - had been losing momentum against competition from the Airbus A300-600R and, subsequently, the A330-200 and -300. Meanwhile, airlines also were calling for ever-longer range, which seemed to provide an opportunity for a further 767 iteration. Boeing responded with studies of an enhanced development of the extended-range 767-400ER, which offered to carry almost 250 passengers over a distance of more than 5,500 nm (over 10,100km). Typically, as successive 767s had grown in size so flight distance range had been scaled back: the long-range variant of the initial 767-200 provided a 1,000-nm (1,850km) longer range than the -400ER, but with a payload of "only" about 180 travellers, compared with the later variant's almost 250-seat capacity. Airlines wanted to be able to carry this larger payload much further.

There was one basic drawback; the 767's 31-degree quarter-chord sweepback (in contrast to the 707's 35-degree sweep and the 37 degrees of the 747) left the aircraft with a relatively modest Mach 0.80 cruise speed: as the range increased so flight duration grew inordinately. With an order for three announced in March 2000, Africa's Kenya Airways was the only official taker for the "enhanced 767-400ER". Deliveries were expected to begin in May 2004,

with the aircraft offering "airframe and engine enhancements to provide greater payload and range capability to support continuing growth on long-range routes," although subsequently the airline took 777s instead.

Having emerged simultaneously, as individual solutions to what Boeing had discovered in the 1970s was two different requirements, the 767 and the smaller 757 single-aisle twinjet shared a common vintage and were both candidates for replacement or radical enhancement in the late 1990s. At that time, the company's penchant for responding to industry demand led to consideration of how new technologies - brought together from every discipline in a single vehicle - could meet requirements for medium- and long-range 200- to 300-passenger jetliners. With the 737 offering the prospect of increased capacity (now offered in the 215-seat -900ER), Boeing recognised the potential to rationalise its jetliner family by reducing the number of models offered while it considered what to do next.

Boeing decided it needed to really understand the market, which had developed to accommodate new aircraft performance almost as much as aircraft technologies were evolving to meet airline aspirations. Although classic markets such as U.S. continental services are geographically defined (United Airlines famously needs aircraft to reach "either coast out of Denver"), others have changed with the times. Long distance flights have been accomplished with ever-fewer technical stops to refuel, leaving emerging local markets less well served internationally.

Generally, developing economies have fed the airline industry as more and more people can afford to fly and more and more business is conducted across "the global village". The search for economies and the need to fill aircraft of every size led airlines to develop hub-and-spoke networks, both locally within continents and internationally through global marketing alliances, so that larger aircraft connect major cities, which also are fed by smaller machines from regional airports.

For some, this has led to suggestions that the future lies in ever-larger aircraft connecting the world's capital cities, while others believe that growing economies will stimulate demand for more and more services to link secondary cities with preference for frequent connections requiring less-large machines. In truth, the most-popular cities will require high-capacity aircraft, since their runways have limited capacity while pressure for lower and lower fares means airlines need large aircraft to provide the best seat-mile costs.

Faced with lukewarm reaction to the enhanced 767-400ER, with the basic design making its age felt and with Airbus biting increasingly large

Boeing looked at more than 25 wing planforms, 50 nacelle shapes and 60 fuselage designs during 2001-02.

Design & Manufacturing

Boeing's thinking in terms of manufacturing took ideas which it had started to develop on the 737 and 777 programmes to a whole new level. It had adopted the mantle of systems integrator, utilising a range of best-in-class partners to produce complete sub-assemblies for an aircraft which it would then assemble in days rather than weeks.

There were several advantages to this approach - involve international partners and you are more likely to attract international customers; spread the risks and rewards and the company would be taking far less of a gamble; and use those internationally who are the best at what they do, and you get a world-class product.

One of the key elements was identifying organisations which could build the ambitious composite "single barrel" fuselage, composite wing box and other structures - in fact the aircraft Boeing wanted would be around fifty percent composite.

The first all-composite airliner

The 787 airframe represents the coming together of decades of experience in the use of composite materials in aerospace applications, to produce what is the most safety critical part of the aircraft - the airframe itself. Experience with the 777, which has a composite vertical and horizontal tail, helped to convince Boeing that it could build an entire airframe this way and gain far greater advantages in lowering maintenance costs, increasing airframe life and reducing weight.

Mike Bair, vice president and general manager of the 787 program, says that composites are

VSMPO-Avisma

Titanium for Dreamliner

It is much credit to any country and any company to be involved in the aircraft project which is referred to as nearly revolutionary due to its advanced and extraordinary material application concept. A great percentage of composites and a significant increase in titanium in the aircraft structure improve its serviceability. Boeing 787 Dreamliner is said to be the state-of-the-art commercial airplane in the world which ensures the highest comfort level for the passengers.

VSMPO-AVISMA Corporation, Russia, the world leading titanium manufacturer, is the primary titanium supplier for this unique aircraft. VSMPO-AVISMA Corporation is the vertically integrated company with the single process cycle from manufacture of sponge titanium to production of titanium alloy products.

Steadiness and stability of such a system can be proved by the fact that during hard times of the world titanium demand downfall, VSMPO-AVISMA Corporation being involved in the world economy, managed not only to survive, but to increase its output.

The fifty-year history of the titanium production origin and development in the Soviet Union is connected with VSMPO-AVISMA Corporation. It was the place where mastering of titanium processes started. Wide experience in development of new alloys and production lines has been gained in 50 years. At present, VSMPO-AVISMA Corporation is the only Russian company producing aircraft titanium mill products. It possesses unique scientific potential and processes, as well as equipment for mastering of titanium alloy production. More than one generation of talented highly skilled specialists have been brought up here, and they seem to feel this unique metal, its capacities, advantages and prospects.

Moreover, VSMPO was once the elite division of the country defense industry. High standards of operation and great sense of responsibility for products intended for the aerospace sector were developed in the company.

Therefore, the decision of the American company to select VSMPO-AVISMA Corporation as its partner was not accidental, but well-grounded and far-seeing.

Relations between Boeing and VSMPO-AVISMA sprang up in late 90s of the previous century. The contract signed with VSMPO-AVISMA in 1998 was the first Boeing contract with the Russian company. At that time, VSMPO ingot deliveries covered about 20% of the requirements of the aircraft building giant.

At present, VSMPO-AVISMA export consists mostly of value-added products. The Russian Corporation is the leading titanium supplier to several foreign companies. VSMPO-AVISMA titanium quality is recognized among the best in the world. The Corporation is integrated into the global aircraft industry and supplies its products to over 300 companies from 48 countries in the world and 1500 Russian customers.

VSMPO-AVISMA Corporation participation in 787 project is not limited to increased deliveries of value-added titanium products. The Corporation is also involved in the project with the substantial research in the field of new alloys and processes. The new high-strength titanium alloy developed at the Russian company will be used for 787 aircraft. This case is the only one in the American aircraft building history! In addition, dozens of new die forgings are being mastered for B787. VSMPO-AVISMA titanium large-size die forgings for aircraft landing gear are unique all over the world. VSMPO-AVISMA titanium mill products will be used in Rolls-Royce and General Electric state- of- the- art engines intended for 787.

Boeing states, “VSMPO has proved to be a reliable supplier of high-grade titanium products. The Corporation continuously observes the contract terms using high quality standards. Cooperation with such a partner will contribute to Boeing further leadership in commercial aircraft building”.

VSMPO-AVISMA Corporation is proud of that recognition and is going henceforth to do its best to justify its partners' trust and uphold their confidence in the Russian titanium supplier.

Strode, who adds that: “a highly repeatable product means less labour in dealing with non-conformance issues, for example.”

The fuselage assembly will come together in two stages - firstly Global Aeronautica will integrate Section 43 from KHI and Section 44 from Italy, along with Section 11 (which comes from FHI in Japan attached to wheel-well structure, Section 45, from KHI) and Section 46, and ship that assembly by LCF from Charlotte, NC. Sections 47 and 48 are shipped from there separately. Meanwhile Spirit Aerostructures in Wichita dispatches the nose section by LCF to Everett, complete with nose gear, and again with all systems and equipment ready installed - “the aim is to have a level of integration before final assembly which reduces the risk of the line being held up because we're missing a small part”, says Strode.

Alenia either will put the horizontal stabiliser on the LSF via Charleston, or will ship it separately if an LCF is not available at the time, and the two outboard wing boxes are flown in from Japan. For the engines, both Rolls and GE will both ship directly and independently to Everett, while Goodrich will put the engine sub-assembly together at its facilities opposite the Everett plant.

At each plant there will be a special cargo loader to put the sections onto the LCFs - with two at Everett itself (one on the airfield and one to run into the factory). Therefore loaders will be in place at Charlotte, Japan's new Nagoya airport, at Grottaglie In Italy, and Wichita. Operation of the LCF fleet has been contracted to Evergreen International.

In terms of materials, Strode says that these are mainly being managed by Boeing which can then get discounts from 'aggregate buys' for all the partners together. In addition where special

Photo Courtesy: Rolls Royce

Selecting a Powerplant

With the Sonic Cruiser Boeing was keen to stress that the aircraft would use the same powerplants as the 777, with all the advantages of economies of scale that would bring. The idea was that aerodynamic design could slow the faster airflow, but windtunnel tests ultimately showed that would not be possible.

It was clear that a new engine would be required with larger core and a smaller fan and thus a lower by-pass ratio. GE developed the GEnx based on its GE90-115B (the powerplant for the new larger versions of the 777), while the other large engine manufacturers, Rolls-Royce and Pratt & Whitney, had similar studies.

When Boeing switched from the Sonic Cruiser to the 7E7, the engine makers were faced with

Photo Courtesy: Rolls Royce

Trent 1000 under test

from acquisition to disposal, and often had to make design trade-offs. For example, as the industry is already experiencing with other new engines, the materials used are often more expensive giving rise to greater costs in replacement parts, but the benefit to the operator in terms of lower fuel burn outweighs this maintenance cost penalty. For example the fuel burn of a brand new Trent 1000 is projected at a figure slightly higher than the GE engine - but Rolls opted to turn down the internal temperatures to get a longer engine life. The company set itself some difficult challenges but having promised three years ago that it would run an engine for the first time on 14 February 2006, it held good - offering it as a Valentines Day present for Boeing. When the Trent 1000 first enters service with ANA in Summer 2008, the Trent family will have around 35 million flying hours under its belt, giving Rolls confidence that it can hit many performance targets from the first day of operation with no nasty surprises - and drastically reduced operational disruption compared with the Trent 700 and 800 introductions ten years ago.

The 787 will be the first aircraft to attempt to have a short-haul variant and a long-haul variant under one common aircraft type, presented a unique challenge for the engine designers. Both GE and Rolls tried to mitigate the difficulties posed in different ways, but Rolls is satisfied that it has an engine that can handle all the variants including the proposed stretched 787-10.

The three-shaft design will be contra-rotating, which isn't new as this was the approach with the Pegasus (for the Harrier) and the Trent 900 for the A380, but GE has now adopted a contra-rotating fan too. Each engine in the Trent

represent another step-up in power consumption.

Each engine will be rated at up to 75,000lb thrust (at sea level, standard conditions), which is already more than the requirement for the 787-9, and the -3 will have engines de-rated to 53,000lb. It is also lighter than the GEnx, claims Rolls, although the difference is understood to be slight; has a 15 percent lower fuel burn than engines ten years ago; and 40 percent lower emissions than required by new international regulations.

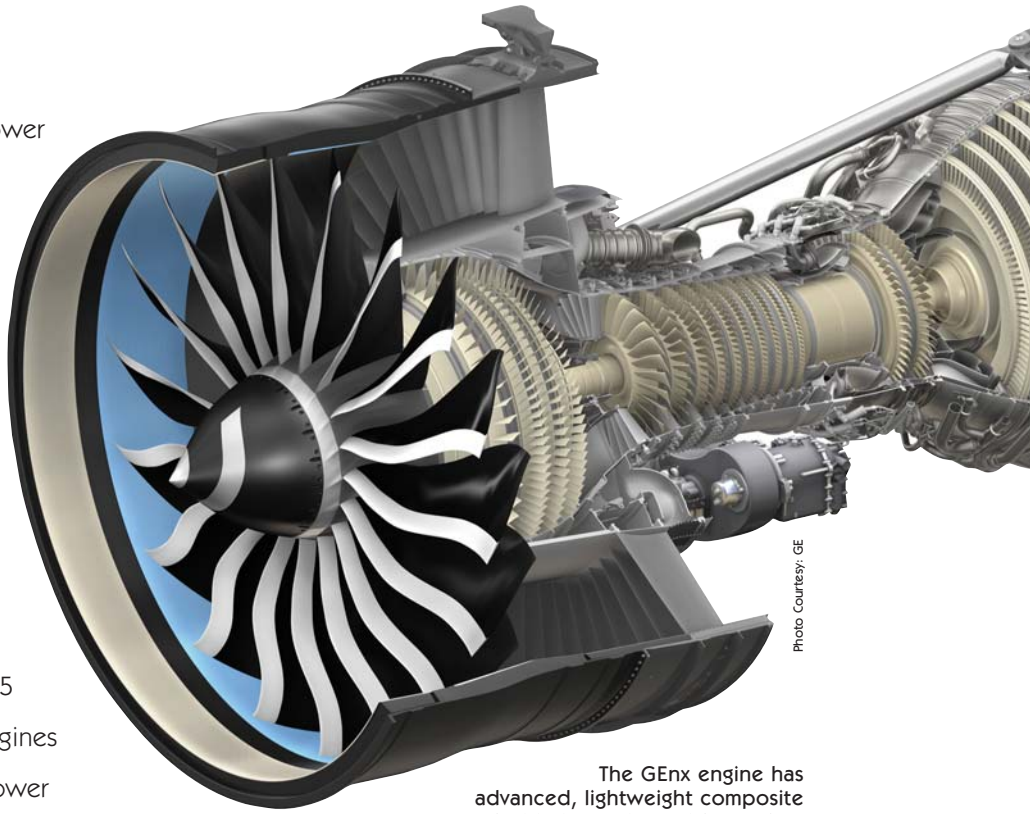


Photo Courtesy: GE

The GEnx engine has advanced, lightweight composite fanblades and novel fan casing.

Rolls has utilised new materials technology in the Trent 1000, such as the 'RR1000' nickel alloy for the high-pressure (HP) turbine blades. For the shafts, the low pressure (LP) shaft's job is to transmit torque and resist wear at the splines so to meet these two requirements it is bimetallic, welded so it is metallurgically one.

Cruise performance of the engine will be around 16 percent better (in terms of lower fuel consumption - or 'sfc') than GE's CF6 which powers the Boeing 767 (which the 787 will replace), and thus is around the same as the GEnx. With a wide range of missions optimising the cruise was a challenge, but by flattening out the sfc graph, there is less negative impact as the aircraft moves away from the engine's design point.

Other changes include what Rolls calls 'counter-intuitive aerodynamics' such as making the 'spinner' at the centre of the fan smaller - allowing the fan diameter and thus tip speed to be reduced. This in turn cuts down on shockwave losses and noise.

Thus the engine does not have the largest fan Rolls has ever made at 112" (the largest is the Trent 900 with 116") but it does have the largest blade, of which it has 20 - down from the 24 of the Trent 500.

Another aspect which has advanced is the concept of the "intelligent engine", where the trend is towards linking engine data from numerous sensors back to Rolls-Royce's new operations room in Derby. What will be new with the Trent 1000 is how quickly that data can be turned around by processing into useful information from which decisions can be made by the airline and crew.

"Do we need more capacity to produce Trent 1000s and if so where" - Rolls-Royce

Testing…Testing…

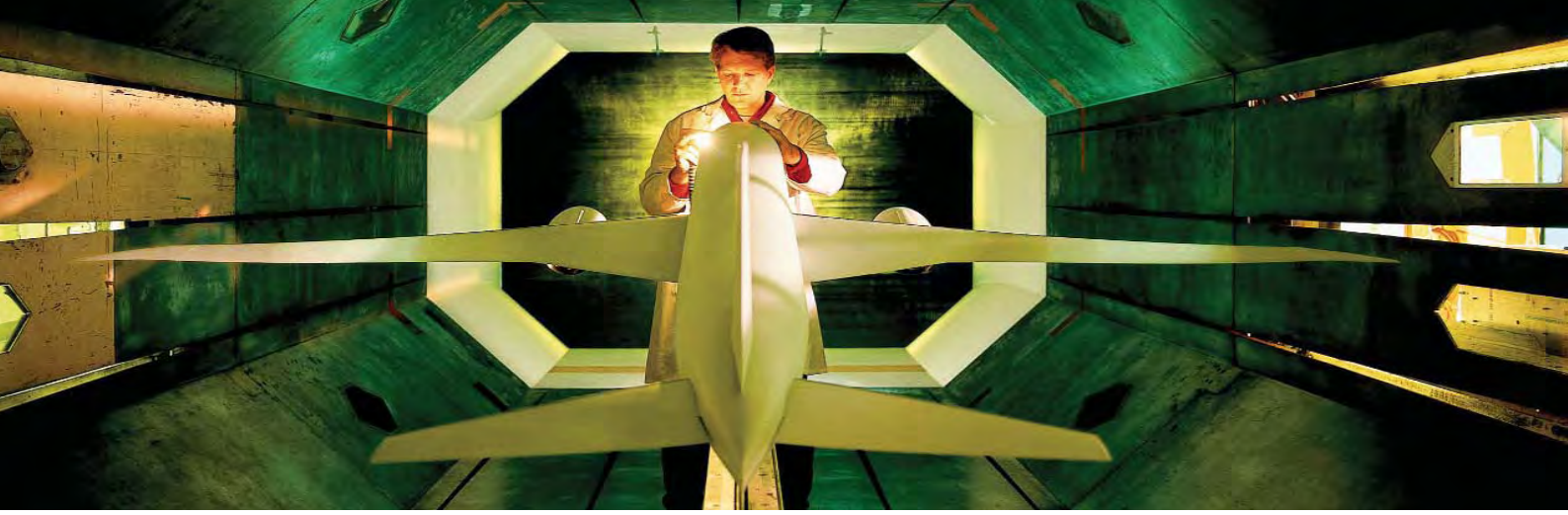
The job of developing the 787 is not only dramatically changing Boeing's traditional approach to design, partnerships, manufacturing and assembly, but it is also re-writing the rulebook on testing.

Based on many of the ground-breaking test lessons learned on the 777, Boeing is evolving its well-honed evaluation techniques to reflect both the new sophistication of the more-electric aircraft and the lower cost goals of the whole programme.

The 787 team partners have more responsibility for testing products and completed systems than on any previous aircraft. Hamilton Sundstrand for example, which has the lead on a wide array of environmental and power systems, developed a specially designed Airplane Power System Integration facility (APSIF) in Rockford, Illinois, to help test and perfect systems.

Unlike previous generations of aircraft, in which parts and sometimes large sub-systems were tested in isolation before being brought together by the aircraft manufacturer, the 777 development pioneered the first wide scale use of integration tests involving the suppliers up front. The 787 takes this a stage further by having the larger equipment makers and suppliers integrate and test systems before delivering parts to the final assembly line in Everett.

Hamilton Sundstrand's APSIF is connected via high-speed data links with Boeing and with



Aircraft are responsible for the horizontal stabilizer, center fuselage and aft fuselage of the 787, the basic principles of the design and manufacturability of these large-scale composite parts was first proven using test piece barrel sections at Boeing. Eight fuselage barrels were produced overall, and the last were of "flight worthy quality" and could have gone into a real aircraft, according to Bair.
Five of those barrels were made at Boeing's Developmental Center in Seattle. Spirit AeroSystems in Wichita, Kansas, formerly Boeing's commercial operations site, made two barrels, both of them 787 nose sections.
Alenia was meanwhile contracted to perform static and fatigue testing of the horizontal stabiliser at its laboratories near Naples. The prototype composite wingbox and associated skin was first built and tested by Boeing in Seattle along with help from three Japanese "heavies" - Fuji (FHI), Kawasaki (KHI) and Mitsubishi Heavy Industries (MHI). Together they will supply about 35% of the 787 airframe, with MHI supplying the wing box, FHI the center wing box, and KHI wing parts as well as a fuselage section forward of the wing.
Parts from other suppliers, such as Saab Aerostructures, have also been provided for the start of full-scale barrel tests of the aft fuselage. The fuselage section will be subject to cabin pressure and simulated flight loads and will endure both static and fatigue loads. The barrel test doors from Saab were prototype designs developed early in the project to meet the requirements of this test. “For the production aircraft the large cargo doors have been further optimised for weight saving reasons", says Saab, which is gearing up to make seven different doors for each aircraft: two large cargo doors; one bulk cargo door and four access doors. Serial production of all the doors will start during the third quarter 2006.
Composite fuselage barrel sections developed to prove the manufacturing concepts for the Boeing 787 will now be used to help train mechanics following the successful completion of initial testing. One-piece barrels (OPB) 1 and 2, which were joined after manufacture to prove composite fuselage section joining techniques, were fitted with a mock-up vertical fin leading edge for radio transmission tests. Boeing says the work was aimed at “looking at how much metal was needed for the antenna characteristics“ and it adds that the tests "worked fine”.
Full-up testing of two complete airframes will also be conducted for static and fatigue life evaluation while flight tests will be conducted using an expected five airframes for the leading Rolls-Royce Trent 1000-powered 787-8 version,

787 Economics

The Boeing 787 was launched to improve revenue-generating capacity, passenger comfort and payload-range performance, and lower operating costs over current aircraft. Significant cost savings can now be realised in three key areas - fuel burn, maintenance and financing.

CHARLES WILLIAMS, editor of Aircraft Commerce, examines how the 787-8 and -9 are expected to perform against the 767-300ER and A330-200 on a trip cost and available seat-mile (ASM) cost basis.

The main feature to reach the 787's fuel burn and operating cost reduction targets is a high bypass ratio. The Trent 1000 will have a bypass ratio of 11:1, and have seven thrust ratings ranging from 53,200lbs to 73,800lbs. Overall, the Trent 1000 on the 787-8 is expected to have a 15% lower specific fuel consumption (SFC) than the 767-300ER powered by the CF6-80C2.

The GEnx engine has five thrust ratings ranging from 53,200lbs to 72,000lbs, and bypass ratios varying from 8.0 to 9.6. The engine will also have a 15% improved SFC over the CF6 engine.

The 787-8/-9's trip and unit costs per available seat-mile (ASM) can be compared with the similarly sized 767-300ER and A330-200. The four aircraft have been compared on a 5,000nm route. The 787 would be expected to achieve marginally higher utilisations of 4,750 flight hours (FH) per year compared to 4,500FH per year for the 767-300ER and A330-200. The average flight length of 5,000nm means the

Passenger experience

Not for nothing has Boeing called its new 787 twin-aisle twinjet the "Dreamliner", although company officials will quickly tell you that the aircraft has been named by the travelling public.

Nevertheless, immediate and positive reaction by airlines to the design has made it a dream project for the manufacturer as well.

After several years of coming second to Europe's Airbus in terms of airliner orders and/or deliveries, the new aircraft has put a spring back into the US manufacturer's step - especially after the false dawn offered by the still-born Sonic Cruiser project. Now, the 787 may prove to have stimulated a turnaround in the company's fortunes at a time when Airbus has foundered somewhat.

Cannily picking up on the increasing trend for people participation, Boeing conducted a survey to allow the public to "choose" a name for the aircraft. In reality they were limited to four Boeing-chosen epithets - Dreamliner, E-Liner, Global Cruiser, and Strato-Cruiser - with the former gaining widespread support.

The survey marks an apparent move by Boeing to put passengers first, such is the emphasis

"We believe the Dreamliner interior completely redefines the passenger experience," said cabin-interior specialist Brauer.

The manufacturer has selected PPG Aerospace to provide the windows, which represent the first commercial jetliner application of Gentex “electrochromic” technology that uses electricity to darken an electrically conductive medium. Dimmable panels are inserted between exterior cabin windows and interior plastic dust covers and passengers can select any of five levels of light, with manual override provided for the crew. Following production of prototype test units, volume shipments were expected to begin in 2007. PPG Aerospace will work with Gentex to produce the window units.

"We believe the Dreamliner interior completely redefines the passenger experience," said cabin-interior specialist Brauer. "Passengers are the foundation of travel, and in a competitive market airlines will meet demand for more non-stop service to destinations with longer-range, efficient and comfortable airplanes - not very large ones," according to Boeing commercial-airplane marketing vice-president Randy Baseler. "[The 787] best meets the requirements of both passengers and airlines." Truly a Dream machine.

787 Flight Operations

The pilots who fly the 787 will experience a step-up in functionality, ease of use and situational awareness, not to mention the pride in being amongst the first to fly this high technology jet.

Mike Carriker is chief pilot of the 787 programme. A former military pilot, he has flown many types and spent a couple of years at Boscombe Down's Empire Test Pilot School (ETPS). He worked for Boeing on the Sonic Cruiser programme and has seen the aircraft make the step-change into the ultra-efficient 787.

The flight deck Boeing has designed for the aircraft made its public debut at the IFALPA conference in August 2005. "We started with a clean sheet", says Carriker - who adds that designing the Sonic Cruiser had certainly needed that, and was "very interesting".

Three design aspects were targeted - operational commonality, simplicity, and growth (in terms of technology), with commonality being the thing of most value to customers as a product more like other aircraft it operated, in particular the 777, would greatly simplify flight training. "There's no value in reinventing the wheel", says Carriker. There was also the value in terms of flight safety.

To some extent choosing the 777 "kind of went

787 will have two full-up ISS cabinets, providing redundancy, and incorporating all the invaluable safety systems developed by the industry over the past few years - such as EGPWS and TCAS.

Even the flight recorder configuration of the 787 will be different, after Boeing decided that it would be better to have the flight data recorder and cockpit voice recorder in a single unit (the EAFR - Enhanced Airborne Flight Recorder), and then have two such units - one forward and one aft. Thus if one is destroyed the other is quite likely to survive.

Boeing also considered putting cameras in the cockpit but decided against it - it being a very emotive issue with pilots closely guarding this domain, fearful of monitoring by their employers and possible accusations from over-zealous law-enforcement officers where the culture of no-blame (in the first instance) is critical to disseminating safety lessons to the rest of the industry.

Another huge step in aircraft design is being taken with the more electric architecture. Essentially it is more efficient to take electricity for aircraft systems from the engines rather than bleeding air to drive the systems, with then resultant losses through inefficiency. Electrical offtake can be designed to take only what it needs, whereas bleed air is another fixed design point scenario, leading to wasted energy when excess bleed air is created only to be rejected because it is not needed. Boeing also concluded that the 'equivalent horsepower extraction' argument fielded by many in the industry was erroneous, and that electrical offtake does enhance efficiency and lower fuel consumption by extracting fewer horsepower.

One of several flight deck mock-ups used in development - this one is a full-systems validation rig.

Simplification is an important aspect of the 787 flight deck and avionics. The number of primary line-replaceable units (LRUs) will be reduced to eight from the 777's 15, for example.

Commonality will come in, for example, the flight management computer (FMC) having the same interface as in the 777, but with more display space. HUDs will be included as standard for both pilots - increasing the level of crew situational awareness.

There is a moving map for ground operations, greatly improving pilot awareness thanks in part to the larger displays. The vertical situation display is also added - this has been an option on the 737 for several years now.

Another huge step in aircraft design is being taken with more electric architecture

Maintenance

The 787 will be thirty percent cheaper to maintain than the aircraft types it is replacing, that is predominantly the Airbus A330 and Boeing 767.

Justin Hale, Boeing 787 deputy chief mechanic, says that there are four area which are major contributors to this - the most obvious one being the composite airframe. Then there is the 'more electric' systems architecture, on-board computing (making the aircraft “smarter” for example) and a less onerous scheduled maintenance programme. The latter factor involved close liaison with regulators, primarily the FAA but also EASA in Europe among others, as well as the future operators of the aircraft. Boeing is using the MSG-3 process for developing the maintenance programme - and in particular involves in-depth analysis before maintenance intervals can be established.

Hale says that at first Boeing “took a lot of heat from the airlines”, who were wary that the company's claims for what could be achieved for the 787 was merely marketing hype. However they are now becoming far more comfortable that the manufacturer was right, as

same has been recommended for the wing - which essentially means that no disassembly is required. For the 787, visual inspection is defined as being in normal lighting from a distance of five feet, and there will be no mandated non-destructive inspection techniques utilised.

For accidental damage testing has shown that for everyday bumps and bruises (not vehicle collisions) composites are more robust than aluminium. There is a higher threshold before any damage is caused too. By allowing accidental damage to size the structure, a visual-inspection basis for maintenance becomes possible. Therefore door surrounds are beefed up, as catering trolleys are likely to be smashed into them, whereas the windows of the aircraft can be bigger. “If someone pushed a fully loaded galley cart into to door surround, you want to be sure that it won't ground the aeroplane,” says Hale, who suggests this is not purely a composites issue and is “a design approach which makes good sense regardless of the material system being used.”

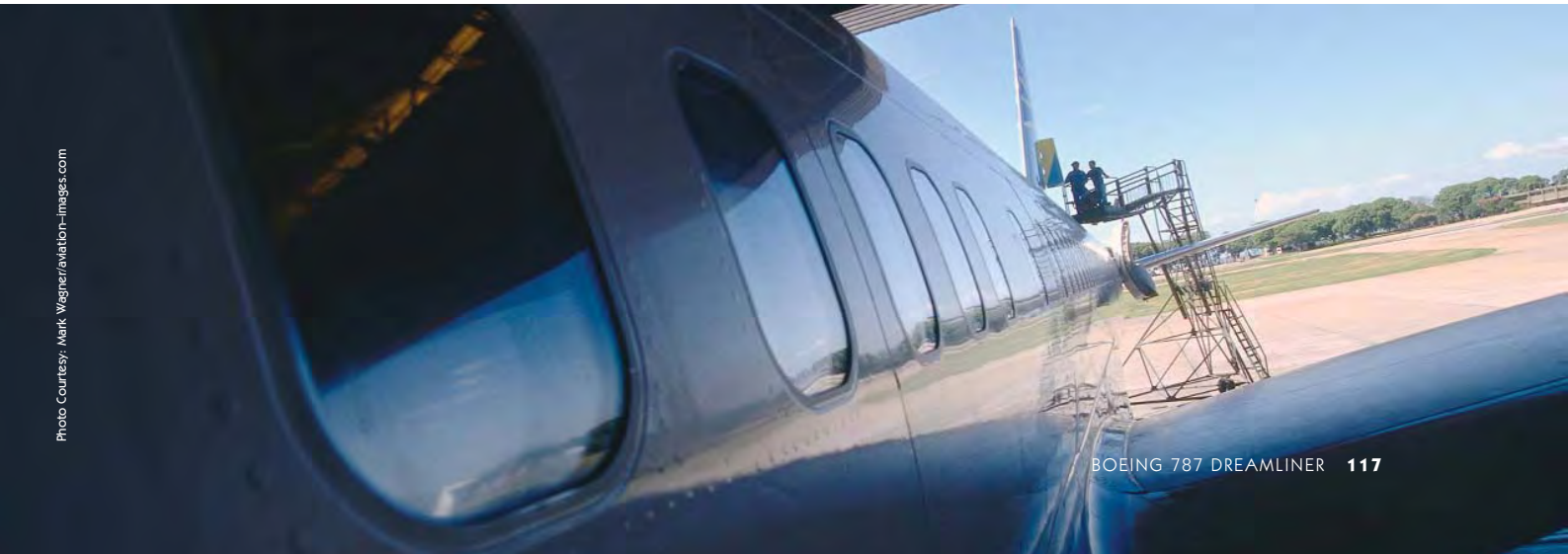
Another way in which maintenance costs will be lowered with the 787 is inherent in its 'more electric' systems architecture, and in particular the elimination of the pneumatic system.

“Chapter 36 [of Air Transport Association guidelines] is one of the most troublesome areas because these systems are purely mechanical and operate at very high temperatures, and are thus prone to failure, despite the advent of digital controls,” remarks Hale. Another disadvantage is that having lots of high temperature air about means having protection systems, such as duct leak/burst and overheat detection systems, and there are lots of possible failure points.

According to Airbus's FAST publication, during 2004 more than eight percent of all in-flight interruptions were attributed to Chapter 36, 60% of these being attributed to bleed air duct leak detection or bleed air over-temperature regulation (leading to single or double bleed loss).

Boeing therefore “decided on a clean sheet approach” for the 787 - Hamilton Sundstrand had been proposing a move towards the 'electric aircraft' concept for a number of years, says Hale, and had been developing and testing the technology predating the 787 program - Industry experience with the more-electric approach includes applications in smaller aircraft as well as in military aircraft.

Their logic was that the industrial use of electric motors had been pushed by other industries and now was at a point where it exceeded the reliability of any other mechanical system, even if you have to convert the energy back to



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