Maintenance costs are a crucial fleet planning consideration. The 787 and A350XWB families include a number of features designed to reduce maintenance costs. These extend task intervals and reduce the number of tasks, fault isolation time, and no-fault-found removal rates.

787 & A350 XWB: How do they reduce maintenance costs?

The need to reduce unit seat-mile and trip operating costs is a key factor in choosing an airline fleet. The 787 and A350 XWB families are the most advanced commercial aircraft to date. They have been designed to give airlines double-digit reductions in cash operating costs when compared to previous generation aircraft.

The two big contributors to lower operating costs are fuel and maintenance.

Aircraft Commerce has examined how the 787's and A350's maintenance requirements compare to those of earlier generation aircraft. The aspects of their designs that are intended to reduce maintenance costs are identified here.

787 family

The 787 Dreamliner family includes the 787-8, -9 and -10.

The 787-8 is the shortest member of the family. It entered service in 2011, and carries 242 passengers up to 7,355 nautical miles (nm) *(see table, page 18)*.

Airlines see the cabin interior as a differentiator in a competitive market, so this has led to different configurations in the 787-8 fleet. ANA is the largest 787-8 operator, with four different configurations ranging from 158 to 240 seats.

The 787-9 entered airline service in 2014 and can accommodate up to 290 passengers in a two-class layout. It has a range of up to 7,635nm.

The 787-9 is also operated in a range of configurations. ANA operates some 787-9s in a tri-class layout with 215 seats, and also has others on domestic services with 395 seats in a dual-class cabin. Other long-haul operators include United and Virgin Atlantic, which have 252 and 264 seats respectively.

The 787-10 is the largest member, with up to 330 seats. It is due to enter service in 2018 with a range of 6,430nm.

All three variants can be powered by General Electric GEnx-1B or Rolls-Royce Trent 1000 engines.

A350 XWB family

The A350 XWB family was initially planned to include three variants: the A350-800, -900 and -1000.

The A350-900 was the first to enter airline service when it began operations with Qatar Airways in 2014. This variant can accommodate up to 325 seats in a three-class layout, and has a range of up to 7,590nm *(see table, page 18)*.

The A350-900 is so far operated by three airlines. Vietnam Airlines has a 305-seat, tri-class configuration. Qatar Airways and Finnair have 283- and 297-seat arrangements respectively.

The A350-1000 will be the largest member, with up to 366 seats in a three-class configuration. It will have a range of up to 7,950nm and is due to enter service in 2017.

The A350-800 was the smallest member of the family and was designed to have up to 280 seats in a typical three-class layout. This variant is no longer being marketed, partly due to demand for the A330-900neo.

Rolls Royce is the exclusive engine provider for the A350XWB family with its Trent XWB series.

Current and future fleets

There are 329 787s in service. This is split between 273 787-8s and 56 787-9s.

The largest 787-8 operators are ANA (34 aircraft), Qatar Airways (23) and Japan Airlines (22). The largest 787-9 operators are United Airlines (10), ANA (8) and Virgin Atlantic (7).

The first A350 only entered service at the end of 2014. There are just eight A350s in service, all of which are -900s. These are operated by Qatar Airways (4), Vietnam Airlines (3) and Finnair (1).

The number of outstanding orders for 787 and A350 XWB family is almost identical. The order backlog for 787s currently stands at 779 aircraft. This includes 145 787-10s, 184 -8s, and 450 -9s. Etihad Airways has 66 787s on order, split between 787-9s (36) and 787-10s (30). ANA (40) and United (33) have the next largest order backlogs.

There are 781 A350s on firm order, including 16 A350-800s, 587 -900s, and 170 -1000s. There are an additional eight orders for which the specific model series is still to be confirmed.

Qatar Airways has the largest number of A350s on order, with 76 aircraft split evenly between the -900 and -1000. Singapore Airlines (67) and Etihad Airways (62) have the next largest outstanding orders. All of the Singapore aircraft will be -900s. The Etihad order is split between -900s (40) and -1000s (22).

787s and A350s may be used to grow or replace fleets. Most will replace earlier types such as the 767, A330, A340 and 777-200. Others may replace larger aircraft, such as the 777-300 or 747-400 *(see Widebody fleet replacement options. Analysing the 777X, 787, A330neo & A350XWB, Aircraft Commerce October/November 2014, page 5)*.

Maintenance costs

The 787 and A350 XWB design features that could reduce maintenance costs will be considered from both the airframe and engine perspectives.

787 & A350XWB BASIC SPECIFICATIONS & FLEET DATA

	A350-800	A350-900	A350-1000
Two-class seating			
Three-class seating	280	325	366
Engine Type	Trent XWB	Trent XWB	Trent XWB
MTOW (lbs)	546,700	592,900	681,000
Range (nm)	8,200	7,590	7,950
In service	0	8	0
Order backlog	16	587	170
	787-8	**787-9**	**787-10**
Two-class seating	242	290	330
Three-class seating			
Engine Type	GEnx-1B/Trent 1000	GEnx-1B/Trent 1000	GEnx-1B/Trent 1000
MTOW (lbs)	502,500	560,000	560,000
Range (nm)	7,355	7,635	6,430
In service	273	56	0
Order backlog	184	450	145

Notes:
1). Seat capacity figures based on standard manufacturer examples. These will vary by airline.
2). In-service fleet and order numbers correct as of October 2015.
3). There are another 8 A350s on order with no specific model series identified.

Airframe maintenance

The maintenance planning documents (MPDs) for the 787 and A350 families were devised under maintenance steering group (MSG) 3 principles. Individual tasks have their own inspection intervals, rather than being grouped by letter check. The task intervals are based on usage parameters, including flight hours (FH), flight cycles (FC) and calendar time. Some tasks have combined interval criteria.

This allows operators to plan maintenance to suit their utilisation level. Some adopt a phased approach to maintenance, spreading tasks out over a series of smaller checks that require less downtime than a traditional C check.

Since many MPD tasks have similar intervals, 787 and A350 operators can group tasks into block checks.

Fewer MPD tasks, longer task intervals and more advanced fault monitoring and diagnosis systems will contribute to the 787 and A350 having lower maintenance costs.

Based on the limited data available, Boeing believes the 787-8 is meeting predictions with airframe maintenance cost reductions of up to 30% compared to previous generation types.

"The A350 will have an airframe direct maintenance cost (DMC) saving of about 25% compared to the A330," claims Bert Stegerer, head of aircraft operations marketing at Airbus. "The A350-900 can also demonstrate 10% lower DMCs compared to the 787-9."

Fewer maintenance tasks

The 787 and A350 will have fewer MPD tasks than previous generation aircraft.

"The 787 has one-third fewer equivalent MPD tasks than the 767," explains Courtney Makela, director of 787 services at Boeing. It is unclear if this includes a comparison of airworthiness limitation (ALI) tasks.

According to the draft maintenance review board report (MRBR), the A350 will have 40% fewer MPD tasks than the A330. This excludes fatigue tasks, which are currently not confirmed for the A350.

MPD airframe tasks fall into three categories of programme: structural; systems and powerplant; and zonal.

Structural tasks

The 787 and A350 have fewer structural tasks than older aircraft types. This is mainly a result of the use of more advanced materials in their construction.

The 787 has fewer structural tasks than a 767, although precise figures will depend on the models in question.

About 50% of the 787 is composed of advanced composite materials.

"The 787's composite structure resists fatigue, corrosion and damage better than a traditional metal one, so it needs fewer MPD inspection tasks," says Makela.

UK-based Monarch Aircraft Engineering (MAEL) offers maintenance, repair and overhaul (MRO) services for a number of aircraft types including the 787. MAEL points out that unlike older aircraft, ALI and associated structural inspection tasks are not included in the main body of the 787's MPD. These tend to be added after the aircraft has been in service a number of years.

"The ALI tasks were not included in the 757 and 767 MPDs until they had been in service for a number of years," explains Lee Burgess, head of engineering at MAEL. "Even when those tasks are added to the 787's MPD, it will still have fewer structural tasks than the 767."

Like the 787, the main body of the A350's MPD excludes fatigue tasks. The draft MRBR says that the A350 will have 160 structures tasks compared to 318 for the A330; a reduction of 50%. However, to provide a fair comparison this does not include fatigue tasks. When these are added to the A350's MPD, a full structural inspection comparison with the A330 will be possible. This is expected to reveal an even greater disparity between the two aircraft families, as the A350 is likely to have fewer issues with fatigue.

The A350 also has a higher percentage of advanced materials than previous generation aircraft. "The A330's airframe is 11% composite," says Stegerer. "The A350 XWB's airframe comprises 53% composites and 14% titanium," says Stegerer. "The composites include carbon fibre reinforced plastic (CFRP) used in the wings, centre wing box, tail cone, skin panels, doors, and frames, stringers and doublers. Titanium is used for high load frames, door surrounds, the landing gear and pylons. The composites and titanium will not suffer from corrosion, while the composites will not suffer from fatigue, so corrosion and fatigue tasks will fall."

Systems tasks

The 787 and A350 have fewer systems tasks than previous types.

787 systems

The 787 has one-third fewer systems and powerplant tasks than the 767. "The reduction in systems tasks on the 787 is a result of enhanced airplane system monitoring functions and the reduction in the mechanical nature of many systems," explains Makela. "There are fewer of the traditional functional or rigging checks because the aircraft can self-monitor, while a number of system control mechanism inspections have been eliminated where these systems are no longer controlled by mechanical means."

"Several mechanical systems that used to be standard on all Boeing aircraft have been replaced," explains Theo Bloemendal, type project engineer 787, KLM E&M. "The main system that has been replaced is the bleed air system. On previous Boeing aircraft, bleed air from the engines and auxiliary power unit (APU) was channelled via pneumatics and used for the cabin air-conditioning and pressurisation system, wing anti-ice system and engine start. These systems on the 787 have been replaced by electrical ones. Cabin pressurisation is controlled by four electrically-powered air compressors, while wing anti-icing is performed by electrical heater mats in the leading edge slat panels. Engine start capability is now provided by variable frequency starter generators (VSFG), or the APU starter generators (ASG).

"Another system change was made

The 787 and A350 feature advanced on-board fault and health monitoring systems that help to reduce troubleshooting time and NFF removal rates.

for the 787's brakes," says Bloemendal. "Aircraft brakes are usually hydraulically powered, but they are electrically actuated on the 787."

The 787 also features complete fly-by-wire (FBW) technology. "The FBW architecture replaces traditional cable and pulley systems that need a lot of maintenance," says Makela. "Replacing the engine bleed architecture removes a whole system of plumbing, sensors and valves, which have greater maintenance requirements and weigh more than the 787's electrical alternatives."

"These system changes mean that the 787 needs considerably more electrical power, and more powerful generators than previous models," says Bloemendal.

"There are no ATA36 pneumatic systems tasks on the 787 because the bleed air system has been replaced," says Burgess. "Bleed air is only used to provide an anti-ice function for the engine intakes on the 787. The number of systems with built-in test capability also makes system checks easier to perform."

A350 systems

According to the draft MRBR, the A350 will have 443 systems and powerplant tasks compared to 785 for the A330, a reduction of about 44%.

The A350 has several design features that will contribute to this reduction in systems tasks. Like the 787, there is an emphasis on replacing complex mechanical systems with simpler options.

"The A350 is a full FBW aircraft, so all actuators are controlled by electrical signals," says Stegerer. "All the primary flight control surfaces are hydraulically powered by one of two independent hydraulic circuits. All control surfaces, except for the outboard ailerons and some spoilers, are electrically powered by one of two independent electrical circuits. This '2Hydraulic2Electric' (2H2E) architecture is more robust than standard three-system hydraulic solutions, since the aircraft can be controlled even if all hydraulic circuits are lost.

"The 2H2E architecture was first installed on the A380, and has proven to be reliable while reducing weight and cost," claims Stegerer. "In addition to electro-hydrostatic actuators (EHAs) and electrical back-up hydraulic actuators (EBHA), the 2H2E architecture allows the removal of one hydraulic circuit.

"Like the A380, the A350 has two independent hydraulic circuits operating at 5,000psi, compared to a conventional three-system approach used on other types, including the 787," explains Stegerer. "On the A350 each engine has two engine-driven pumps (EDPs), with one pump for each hydraulic circuit to provide redundancy."

The A350's two-circuit hydraulic system has lower maintenance costs than three-circuit systems, since the number of hydraulic lines, connections and valves is reduced by one-third.

"The A350's fuel system has one tank fewer, fewer pumps, and a simpler distribution design than the A330, which reduces its maintenance requirements," says Stegerer. "The landing gear design is also simplified, since it has no shortening mechanism.

"The bleed air system installed on the A350 is based on proven technology developed for the A340-500/600 and A380," continues Stegerer. "The valves in this system are electrically rather than pneumatically regulated, which improves reliability significantly. A leak localisation system helps mechanics precisely identify where leaks are. This advanced bleed air system provides a 74% reduction in operational disruptions caused by bleed system faults and a 70% reduction in DMCs compared to conventional pneumatic systems."

Airbus did not adopt bleedless technology for the A350. Although the reduction in pneumatic systems offers obvious savings, Stegerer highlights how a bleedless system can increase maintenance costs in other areas.

"The bleedless technology on the 787 needs four heavy compressors to compress air delivered through two dedicated air inlets," says Stegerer. "The compressors mean that maintenance costs for air conditioning and pressurisation tasks (ATA 21) are higher for this bleedless system. The 787 also needs a more complex and powerful electrical network."

The A350 uses electrical system architecture that has been proven in service with the A380. "The A350 uses four variable frequency generators (VFGs), rather than integrated drive generators (IDGs)," explains Stegerer. "The VFG is mechanically a simpler solution than the IDG, which is coupled with the constant speed drive required to provide a constant frequency. The use of VFGs significantly improves reliability."

Stegerer suggests the A350's electrical systems should have lower maintenance costs than its contemporary competition. "The 787's bleedless architecture means that it needs three times more electrical power then the A350. It has five electrical networks compared to three for the A350, so the A350 has fewer electrical system components and lower associated maintenance costs than the 787."

Integrated avionics

The 787 and A350 both feature integrated modular avionics (IMA). In conventional avionics, dedicated line replaceable units (LRUs) are required to perform individual functions. In the IMA concept, these are replaced by a smaller number of uniform avionics modules that each host multiple functions, loaded on the modules as software applications.

Boeing refers to these applications as loadable software parts. "The loadable software parts are programmes created by Boeing and our suppliers, which are used to control the various 787 systems,"

The A350 has fewer MPD tasks than previous generation aircraft, such as the A330. The A350 features the same 2H2E architecture as the A380. This means the A350 only has two hydraulic circuits compared to three for the A330.

explains Makela. "Airplane loadable software can be quickly distributed to 787 operators, which avoids the cost of removing a system component."

The A350 has software applications that can be loaded onto avionics modules while they are on the aircraft.

"The advantages of IMA technology include a reduced part count, including spares requirements, and increased flexibility for future development, since only a software upgrade will be needed rather than complete LRU replacement," says Stegerer. "The IMA technology will lead to lower DMCs through man-hour (MH) and material savings."

Zonal tasks

"The 787 has the same number of zonal MPD tasks as the 767," says Makela.

The A350 will have 125 zonal tasks compared to 129 for the A330, according to the draft MRBR.

Longer task intervals

The 787 and A350 provide longer intervals between maintenance tasks and base checks than previous generation aircraft, thanks to the use of corrosion- and fatigue-resistant advanced materials, enhanced fault and health monitoring systems and more reliable equipment.

"The 787's base check interval is once every three years, compared to every 18 months or two years for previous generation types, such as the 767," explains Burgess. "For up to three years, most of the maintenance tasks required for the 787 can be performed on the line.

"Some operators use phased maintenance programmes for 787s, where labour inputs are spread over a three-year period of successive smaller line checks, according to individual task interval criteria," explains Burgess.

One of the first 787 operators was Norwegian. "Norwegian's maintenance has been tailored into a phased programme to utilise the maximum task intervals and take the aircraft's utilisation into account," explains Makela.

"Some individual 787 MPD task intervals are longer than for previous generation aircraft, continues Makela. "The structures programme has longer intervals, due to the composite structure's fatigue-, corrosion- and damage-resistant properties. Some systems programme task intervals have increased due to advances in on-board health monitoring."

"The A350 XWB maintenance programme offers maximum flexibility with the longest potential inspection intervals," says Stegerer. "It allows airlines to plan maintenance around their specific operation, and carry it out during the aircraft's natural downtime."

The A350 does not need maintenance at intervals shorter than 10 days. Its target interval for a first line visit is 1,200FH compared to 800FH for the A330. Its base check interval will be three years, rather than two for the A330. The A350 should only need a major structural check every 12 years. The A330 needs an intermediate structural check at six years, followed by a heavier one at 12 years.

One of the extended task intervals on the A350 involves inspecting cabin floor structures under the wet areas, such as the toilets and galley. On previous generation aircraft these tasks were carried out at six-year intervals, with corrosion often found on seat rails. The A350 has titanium seat rails and it has implemented the A320's corrosion-free interface between the floor panel and cross beam. Application of an enhanced corrosion-prevention compound has extended the inspection interval from six to 12 years.

Advanced on-board maintenance systems

The 787 and A350 families have more advanced on-board maintenance and health monitoring systems than previous generation aircraft. These advanced systems sit within on-board information networks. Compared to previous generation central maintenance computers, the 787's and A350's on-board maintenance and health systems can reduce troubleshooting time, no-fault-found (NFF) removal rates and non-routine maintenance requirements.

787

"The 787 has central maintenance computer function (CMCF) and aircraft condition monitoring function (ACMF) systems," explains Bloemendal.

"The CMCF and ACMF interface with the 787's core network system, which acts as the aircraft's information management hub," explains Makela.

"The CMCF provides ground test control," continues Bloemendal. "A large number of system tests can be initiated via the CMCF. It also processes fault data and generates fault reports."

Most systems on the 787 have built-in test equipment (BITE). "The CMCF receives fault reports from the aircraft systems when anomalies are detected," explains Makela. "It can alert operators to dispatch-critical items via the engine indication and crew alerting system (EICAS)."

The CMCF assigns a code to each fault to help engineers identify the cause. It provides links to relevant sections of maintenance manuals, such as the fault reporting manual. This helps to reduce troubleshooting time by identifying the work and components required to resolve a specific defect. It also helps to reduce the number of NFF removals.

"The ACMF records aircraft data that can be used with back-office tools to analyse performance trends, such as oil consumption, and for troubleshooting purposes," explains Bloemendal.

The 787 demonstrates a reduction in the mechanical nature of many systems. Several mechanical systems that used to be standard on Boeing aircraft have been replaced. The bleed air system, for example, has been replaced with bleedless technology.

The use of ACMF trend analyses should help operators to perform more preventative maintenance, thereby reducing non-routine requirements.

Some previous generation aircraft, such as the 777, do have similar on-board maintenance systems, but the 787 monitors many more parameters.

"According to Boeing, the 787 CMCF monitors three times as many fault parameters as the 777," says Bloemendal. "The 787 has more ACMF parameters." This means the 787 will have a greater reduction in troubleshooting time, NFF removal rates and non-routine maintenance.

"Data from the 787's CMCF and ACMF can be accessed on the aircraft via the flightdeck multifunction display, maintenance laptops or the installed electronic flight bags (EFBs)," explains Bloemendal. "Fault and health data can also be monitored remotely by the operator's maintenance control centre (MCC), and viewed via the aircraft heath management (AHM) system."

CMCF and ACMF data are stored on the aircraft, but may be transmitted to the AHM via wireless or cellular connectivity systems while the aircraft is at the gate. Some operators permit transmission of data during flight, usually via the aircraft communication addressing and reporting system (ACARS) over radio or satellite communication networks.

"Performing remote fault monitoring via the AHM system means operators can start troubleshooting while the aircraft is airborne," says Bloemendal.

Boeing's optional electronic logbook (ELB) can be accessed and operated via the installed EFBs by flightcrew to log technical defects, and by ground crew to log corrective actions.

A350

The A350's on-board maintenance system (OMS) is hosted by its on-board information management network, referred to as the Avionics Full-Duplex Switched Ethernet (AFDX). This interconnects various avionics computers.

The OMS includes a centralised maintenance system (CMS) and aircraft condition monitoring system (ACMS). The CMS records and reports faults, while the ACMS monitors performance.

Like the 787, many of the A350's systems feature BITE. "Faults are reported with a BITE fault code as they occur," explains Sebastien Schumacher, licensed aircraft engineer at Lufthansa Technik. "The CMS gives the engineer a direct interactive link to the sections of the dedicated aircraft maintenance manual and trouble-shooting manual relevant to the fault code. These are known as maintenance procedures (MP) and aircraft fault isolation (AFI) manuals on the A350. There are hotlinks in the manuals for any necessary systems tests."

Up to 20,000 system parameters can be monitored by the A350's ACMS function via the AFDX network. Its ACMS recording capability is twice that of the A380, and eight times that of the A330.

Airbus says the A350's OMS reduces the time required for fault isolation, and likelihood of non-routine maintenance. It believes the A350'S NFF removal rate could be 50% lower than that for a previous generation aircraft.

The A350's OMS also has a dispatch function linked to the master minimum equipment list (MMEL). This notifies pilots of any defects that could affect aircraft dispatch. It prioritises fault messages to reduce troubleshooting time. Airbus claims that the dispatch function differentiates it from the 787.

Fault and health data from the OMS can be accessed on the flightdeck via a dedicated on-board maintenance terminal (OIT) or the pilot's on-board information system (OIS) displays.

Data from the OMS can be accessed remotely via Airbus's aircraft maintenance analysis (AIRMAN) software. This makes the parameters and fault information for the A350's main systems available to back-office staff, such as the MCC, in real time if the aircraft has the appropriate connectivity systems. At the gate, the data could be sent from the aircraft using WiFi or cellular connections. In the air it will probably be sent via ACARS over radio or satellite communication channels.

Airbus believes that AIRMAN helps to provide real-time trouble-shooting, proactive maintenance and failure anticipation, so that maintenance staff can prepare to rectify faults before the aircraft arrives at destination.

MH and materials

The airframe design features discussed here mean the 787 and A350 will need fewer maintenance MH and materials than previous generation aircraft.

Airbus believes the A350 will require 38% fewer scheduled MPD MH than the A330-300.

The 787 and A350 will require fewer routine and non-routine MH than previous generation aircraft.

Savings in routine MH will come from fewer structures tasks resulting from the use of corrosion- and fatigue-resistant materials. Systems tasks will be reduced as some complex mechanical systems are removed or simplified. "Advanced health monitoring is also a factor," say Burgess. "On-board monitoring will now say if there is a partial system failure, whereas this might not have been discovered in the past until a routine system operation or function check was performed during a maintenance visit."

The fall in structures and systems tasks will also directly reduce non-routine requirements. The largest reduction in non-routine MH is likely to be due to the corrosion-resistant properties of the 787's and A350's composite materials, and the subsequent lack of corrosion findings

The GEnx-1B provides comparable or slightly lower maintenance costs than a CF6-80C2. The GEnx-1B should achieve a similar time on-wing but fewer parts compared to the CF6-80C2.

during routine inspections.

"On previous generation aircraft a large percentage of the non-routine MH were associated with corrosion issues," says Burgess. "This includes removing floor beams and blending out corrosion. This will be reduced for the 787."

Non-routine MH, troubleshooting time and NFF removal rates should also be reduced due to the predictive maintenance capability provided by advanced on-board maintenance systems.

Material costs will fall due to the reduction in mechanical systems and introduction of IMA technology. The reduced structural tasks will mean fewer consumable materials are needed when reinstalling an aircraft's interior after a deep access inspection.

Engines

Engine maintenance costs are also an important consideration.

787 operators can choose between the GEnx-1B and Trent 1000 engine families. The passenger-configured fleet of 787-8s currently includes 188 aircraft powered by the GEnx-1B and 85 powered by the Trent 1000. The 787-9 fleet includes 23 aircraft with GEnx-1B engines and 33 with Trent 1000s.

All A350s will be powered by the Trent 1000 WXB.

GEnx-1B

GE says that the GEnx-1B provides comparable or slightly lower maintenance costs than its previous generation CF6-80C2 that powered types including the 767, A300, A310 and 747.

"The GEnx-1B engines have similar time on-wing, but fewer parts than the CF6-80C2," explains Tom Levin, general manager of the GEnx and CF6 product lines at GE Aviation. "This helps our customers reduce their maintenance costs to be equal to, or slightly less than, those of the CF6-80C2.

"The GEnx-1B has a dispatch rate of 99.9% and our customers are pleased with its reliability," continues Levin. "The GEnx family has several new features that help lower maintenance costs. The composite fan blades do not require scheduled re-lube, and have fewer removals than titanium blades. Removing titanium airfoil dovetails from the compressors' blisks reduces part count in an area that can be a common source of maintenance costs. In addition, the stage 1 blisk is removable while the compressor is assembled.

"The rear high pressure compressor (HPC) case was simplified to improve clearances and reduce maintenance cost, and the ceramic coating on the variable stator vane bushing reduces wear," adds Levin. "The engine has 30% fewer parts than the CF6-80C2. "The GEnx's design also eliminates the threat of damage to the compressor from foreign object debris (FOD)."

The GEnx family also features more advanced engine health monitoring (EHM) capability to help with preventative maintenance and reduce trouble-shooting and NFF removal rates.

The GEnx family has 30 sensors measuring parameters compared to 22 for the CF6-80C2. "The GEnx family has a dedicated engine monitoring unit (EMU) tied in with the engine's full authority digital engine control (FADEC) to gather a richer set of information from the 30 sensors on the engine," says Levin. "The sensors measure 300 parameters at a rate of 16 samples per second. The EMU receives 150 million pieces of data per flight, on the health of the engine's gas path, fuel system, lubrication system, mechanical elements and controls. These data are evaluated using on-board algorithms and compared to historical data to detect any anomalies. Further analysis can be performed once the data are downloaded from the aircraft.

Trent 1000 and XWB

"The Trent 1000 and Trent XWB-84 will offer a reduction in DMCs at a given thrust compared to the first generation of Trent engines," claims Iain Dudley, head of marketing for the Trent 1000 at Rolls-Royce (RR). "The Trent 1000 has had a dispatch reliability of 99% since entering service on the 787, and the Trent XWB is ahead of reliability targets in its first year in operation on the A350-900."

RR claims that several features contribute to lower maintenance costs for the Trent 1000 and Trent XWB, including fewer airfoils.

The Trent XWB has 15% fewer fan blades, 9% fewer compressor blades, 28% fewer high pressure turbine (HPT) blades, and 10% fewer high pressure nozzle guide vanes (HP NGVs) than the original Trent engine.

The Trent 1000 and Trent XWB also feature more advanced EHM capabilities. "EHM capability have evolved across the Trent engine range, with advances in the volume of parameters and data gathered during the flight cycle," says Tim Boddy, head of marketing for the Trent XWB at RR. "The Trent XWB provides some real-time monitoring of engine health with data delivered to the ground via the aircraft's ACARS system. Bulk data are stored on the engine and retrieved post-flight through the aircraft gatelink system.

"The EHM on Trent engines is designed to monitor the parameters of that individual engine and alert the operator to any anomalies," continues Boddy. "RR uses a complex series of algorithms to diagnose and predict potential maintenance issues. This can minimise disruption and prevent secondary issues from developing that could increase engine maintenance costs." AC