The CF6-80C2 continues to operate in large numbers; powering more than 1,100 active widebodies. The engine is most numerous with the 767 and 747-400 families. Shop visit activity is expected to remain steady, despite the phasing out of some fleets.

CF6-80C2 series maintenance & support market

The CF6-80C2 engine has been a widebody workhorse since entering service in 1985, and still powers 1,131 active aircraft. While it is theoretically a member of the CF6 family, the -80C2's configuration has evolved and it has little commonality with other family members.

There are three main variants of the CF6-80C2, based on the same core engine. There are 19 sub-variants: nine with full authority digital engine control (FADEC) and 10 without FADEC. Use of the same core engine means commonality between them is extensive. Each variant is interchangeable between aircraft types.

Adapting an engine to suit a different application is possible by changing the rate of air flow, and therefore the thrust rating. This is achieved by altering the thrust setting on the FADEC. Engines without FADEC cannot have their thrust rating changed. Moreover, engines with FADEC cannot be interchanged with engines that do not have FADEC. Engines with the FADEC system are denoted by an 'F' in the last letter of the suffix of the variant name.

The -80C2A variant powers the A310-200/-300 and A300-600, the -80C2D1 powers the MD-11, and the -80C2B variant powers the 767 family and the 747-400. There are five sub-variants of the -80C2A, one of the -80C2D1, and 11 sub-variants of the -80C2B.

A major advantage of the -80C2, and adding to its popularity, was that it was certified for extended twin-engine operations (ETOPS) certification to 180 minutes for the 767, A300 and A310.

For an operator to consider use of any -80C2 variant, it needs to be assured that there is a current and continuing support available from engine shops, component repair shops and high-technology repair facilities. The capabilities offered by the engine shops and component repair agencies are surveyed later in this article and have been broken down into two areas: engine module overhaul and repair capabilities *(see tables, pages 44 and 46);* and component, specialist and high-tech parts and component repairs.

Currently there are nearly 3,000 active engines and just under 200 parked engines on 71 parked aircraft. General Electric (GE), the manufacturer of the CF6-80C2, states that 3,340 engines have been delivered since 1985, with 10% available as spares. Over the next few years, 118 new engines will be delivered, of which 82 will be on the last 767-300s to be produced.

CF6-80C2 market

With the engine still in production and a shortage of widebodies, a rapid retirement of the fleet is unlikely any time soon. The average age of the aircraft powered by the CF6-80C2 is 15 years, meaning that most are still well within their useful life. The oldest aircraft, however, will be reaching the end of their lives, at least as far as passenger configuration is concerned.

Many of the engines are still, however, with first-tier passenger airlines. In fact over 60% of relevant aircraft (726 of 1,201) are passenger-configured, with nearly a third (392) already configured as freighters. Other uses are for corporate or government use (30 aircraft), with the military (27), configured as combi aircraft (22) or as AEW/SAR/Patrol aircraft (4).

Fleet

First-tier passenger operators include All Nippon Airways (ANA), American Airlines (AA), KLM Royal Dutch Airlines (KLM) and Lufthansa. All these carriers operate more than 100 CF6-80C2s; mostly on their 747-400 and 767 fleets.

The largest two fleets, however, are with Federal Express (FedEx) and United Parcel Service (UPS); operating 220 and 173 engines respectively. Many of these aircraft are factory-built freighters, and so have several decades of operational life left. The CF6-80C2 is also used extensively on freighter-converted A300-600s and MD-11s. The 767 and 747-400 are also gaining attention, both as converted and factory-built freighters.

Smaller, but still important, fleets of 50-100 engines are operated by Air France, Asiana Airlines, Atlas Air, China Airlines, Continental Airlines, Delta Air Lines, Eva Air, Japan Airlines International (JAL), Lufthansa Cargo Airlines, QANTAS and Thai Airways International.

Over a third of the CF6-80C2 fleet is in North America (1,105 aircraft and 35%). At least a quarter of the fleet is in the Asia Pacific (899 aircraft and 28%) and a similar number in Europe (842 aircraft and 26.5%).

The CF6-80C2-powered fleet has average flight times of 5.7 flight hours (FH) and a daily utilisation of 10.9FH. Average fleet utilisation, for the past 12 months, is 3,961FH and 695FC.

The CF6-80C2A variants were some of the first -80C2s to be introduced on the A310 and A300-600 in the mid-1980s. There are 430 -80C2As. The largest number are operated in North

CFM56-3 GLOBAL FLEET BREAKDOWN

Engine Model	Africa Active	Africa Parked	Asia Pacific Active	Asia Pacific Parked	Europe Active	Europe Parked	Middle East Active	Middle East Parked	N. America Active	N. America Parked	S. America Active	S. America Parked	Total
CF6-80C2			10				2		24		6		42
CF6-80C2A	8		58	12	90	10	88		128	34	2		430
CF6-80C2B	40		774	12	620	14	50	10	638	92	102	4	2,356
CF6-80C2D	6		33		108		12		186	3			348
GEO-TOTALS	54	0	875	24	818	24	152	10	976	129	110	4	
	54		899		842		162		1,105		114		3,176

America because of Fedex's fleet of 45 A300-600Fs. A large number are also found in Europe and the Middle East.

Despite its increased age, nearly 90% of this fleet is still active, with half of the 56 parked engines being in North America. The average age of -80C2As is old, because the A310 and A300-600 are no longer manufactured.

Aircraft equipped with -80C2A engines have a lower utilisation, with average FHs for the past 12 months being brought down by a large portion of freighters in the fleet. The fleet operates short average FC times.

The CF6-80C2D1 variant is the only D variant, and powers the MD-11. This entered service in 1989. The variant is therefore one of the oldest in operation, and has an average age of 16.83 years. Like the -80C2A, the -80C2D fleet is old because the MD-11 is no longer manufactured.

The -80C2D accounts for 348 engines, with only three (on one aircraft) parked. The average FHs, FCs, and FC times and daily utilisation are all very similar to those of the general CF6-80C2 engine fleet.

The youngest fleet, with an average aircraft age of 13.83, is also the largest: the CF6-80C2B. The young average age is because the 767-300 is still in production.

The -80C2B variants have a higher utilisation compared to other CF6-80C2 fleets, with daily utilisation over the past 12 months being 11.2FH. Average FC are also a fraction higher at 5.8FH, because a large portion of the 747 and 767 fleets are used on long-haul operations.

Market trends

The two largest owners of aircraft equipped with CF6-80C2 engines are GECAS (67 aircraft) and ILFC (63). The next largest fleet owners are the operators themselves, in particular ANA, AA, Delta Air Lines, FedEx and UPS. A number of banks and national carriers own 10-30 aircraft each.

Total Engine Support (TES) predicts that the global market for CF6-80C2 shop visits will be above 600 for the next two years. The main removal drivers are performance restoration, life limited part (LLP) expiry, combustion chamber distress, and high pressure turbine (HPT) Stage 1 blade distress.

Air France Industries and KLM Engineering & Maintenance (AFI KLM E&M) has its own fleet of spare engines, so it can offer a value-added package to clients, although it tends to deal with just-in-time and material agreements. It does not expect any real decline in the number of CF6-80C2s in service until 2020. Tommi Valtonen, business controller for Finnair Technical Services, agrees, and says that while Finnair Engine Services deals with just 20 shop visits (SVs) per year, it expects this number to increase.

China Airlines deals with 20-25 SVs per year, and does not expect this number to fall in the coming years. To assist in the SV process it owns nine spare engines.

Conversely, Lufthansa Technik (LHT) sees its work decreasing by 3% per year over the next 10 years. It currently deals with about 80 SVs per year, across the LHT network, and has at its disposal a spare engine pool of CF6-80C2 engines.

MTU Maintenance expects the number of SVs to drop slightly in the mid-term to 60 per year, as some of its major customers phase out their CF6-80C2-equipped aircraft, and replace them with newer platforms such as the 787. Clearly the number of CF6-80C2 SVs will depend on how many new customers MTU Maintenance will be able to secure in the wake of the upcoming ownership changes. MTU Maintenance deals with about 70 SVs annually, through a number of different variants of the traditional time-and-material, power-by-the-hour (PBH) and total engine care contracts.

Despite ownership changes, some maintenance facilities are developing their capabilities for the CF6-80C2. Kelly Aviation Centre in Texas, for example, already has CF6-50 capability, and is now adding the -80C2.

Design & upgrades

The CF6-80C2 is a high reliability turbofan engine with a high-bypass ratio of 5.0-5.3:1. The single-stage fan is followed by a four-stage low pressure compressor (LPC) and 14-stage high pressure compressor (HPC). Five stages have variable stator vanes. The HPT has two stages, and the low pressure turbine (LPT) has five.

During the initial, and subsequent, improvement and design processes, new ideas were incorporated. These included advanced cooling techniques and aerodynamic modifications to blades and vanes in order to reduce emissions and fuel consumption. Advanced materials and coatings were also introduced, resulting in specific maintenance needs.

Specifically, the CF6-80C HPT Durability Upgrade involved material, coating and cooling changes to the stage 1 HPT (nozzle guide vane (NGV), blade & shroud) and stage 2 HPT (NGV & shroud). GE estimates this upgrade will increase an engine's time on-wing by up to 20%. GE also estimates a saving of up to $150,000 per SV through a reduction in blade, shroud and van repair and scrappage.

Lufthansa Technik (LHT) comments that the CF6-80C2 is a mature engine, so all big programmes are over with. LHT recommends, however, variable stator vane (VSV) bushing on-wing change programmes to extend the on-wing life of an engine.

A specific service bulletin (SB 72-1405) and upcoming airworthiness directive (AD), according to MTU Maintenance, is that pertaining to the Number 3 bearing retainer seal.

AFI - KLM E&M agrees, along with also dealing with a fuel manifold inspection for chafing & loop clamp replacement (AD2009-05-02) and LPT case rework (AD2008-21-11/SB 72-1171).

Tim Boldt, marketing manager at Delta TechOps, adds that this involves adding deflectors to the LPT case. Other ADs that Delta TechOps feels have the most significant impact on the CF6-80C2 performance are: AD 2009-05-02; AD 2009-07-03 (one-time Eddy current inspection of the HPC stage 10-14 spool/shafts); and AD 2009-04-10 (enhanced inspection of selected life limited parts). The latter AD and AD 2008-21-11 are also dealt with by China Airlines.

Janne Pallonen, programme engineer

Despite the contraction of some fleets, the market for CF6-80C2 shop visits is forecast to remain above 600 per year for at least the next two years.

for Finnair Engine Services, comments that important SBs, both currently and previously, that have affected the CF6-80C2 include: SB 72-1195 (baffle ring); SB 72-1359 (HPC stage 11-14 spool); SB 72-1371 (roller bearing); SB 72-1222/-1152/-1153 (LPT stage 1,2,4 and 5 nozzle); and SB 72-1374 (inner liner brackets). Pallonen adds that the most recent AD modification is the 3-9 spool replacement programme.

Although there are a number of ADs and SBs related to the CF6-80C2, Boldt adds that Delta Tech Ops has not noted any significant demand for performance-related upgrades to the engine, but has instead seen SB incorporation demand focused on reliability improvements.

Engine removals

Many engines are managed with the objective of following a pre-arranged SV pattern. For the CF6-80C2 this consists of minor performance restoration of the core (HPC and HPT) at the first SV and a full performance restoration with the LPT and booster on the second SV.

The first SV, according to China Airlines, is generally after 27,000FH or 4,000FC; although intervals vary with variant and style of operation. The second SV, after a typical interval of 20,000FH/3,500FC, also includes inspection and repair of all parts. In particular, it can often include the overhaul of the fan booster rotor & stator and LPT stator.

AFI and KLM E&M has found that EGT margin deterioration and LLP limits have been the main removal causes, so they schedule engine removals at 20,000FH. This cost-effective policy allows them to optimise the time on wing and limit SV costs.

For Alitalia, the main causes of engine SVs have also been EGT deterioration and LLP expiry as well as extensive engine failure, with removals generally every 2,500EFC. "Alitalia has an exclusive agreement with AMS (formally Alitalia Maintenance Systems) in Rome," says Ciro Caiazza, maintenance services, strategic purchasing & sales manager at Alitalia. "The engine removal workscopes have been changing due to the phasing out of the airline's 767 fleet by the end of 2012. An on-condition criterion has been adopted with part monitoring on-wing. With the aircraft being phased out, the engine workscope is to align the engines with the lessor's specific re-delivery conditions. Our SVs therefore differ from the usual workscopes."

Alitalia has a more frequent removal rate, as it prepares to return the engines, than others listed in this survey. MTU Maintenance sees an average of 3,000-3,500EFC between intervals.

Boldt adds that Delta Tech Ops has had engine removals caused by high oil consumption and oil leaks, foreign object damage (FOD) and AD compliance. Kari Mustonen, CF6 shop engineer at Finnair Engine Services, lists similar removal causes and variables. This seems less than previously noted, but Mustonen adds this is their experience of the CF6-80C2D1F engine powering the MD-11. LHT on the other hand reports much longer intervals of 22,000EFH when the engine is used on long-range operations on the MD-11F and 747-400 fleets.

Shop module capability

For the purposes of *Aircraft Commerce's* support survey, the engine has been broken down by GE into five main module areas *(see table, page 44)*.

The first is the fan module comprising: the fan rotor, stator and frame; the inlet and transfer gearboxes; radial driveshaft; fan midshaft; and electronic control unit.

The second module is the core, including the HPC rotor & stator, compressor rear frame, combustor and HPT stage 1 nozzle.

The third module consists of the HPT rotor and stator. The LPT is the fourth module, with the LPT rotor & stator and the turbine rear frame.

The last module comprises the accessories, which include: the horizontal driveshaft, accessory gearbox, heat shield and engine accessories.

The locations of relevant repair shops for these modules are listed *(see table, page 46)*.

The only original equipment manufacturer (OEM) to offer capabilities on the CF6-80C2 is the engine's manufacturer, GE. Capabilities are offered at three wholly-owned locations, although none are in North America, where most CF6-80C2 engines are found. The busiest individual shop is GE Caledonian which has a share of just over 15% of SV contracts. Overall GE deals with 24% of global contracts on this engine type.

While the OEM has a large share of nearly a quarter of all contracts, those shops connected to airlines have about 50% of the contract market. The largest is LHT in Hamburg which deals with 12% of contracts. As a group, LHT has a share of nearly 14%, when LTQ Engineering is included.

Other large airline-related engine shops include the AFI KLM E&M partnership, Evergreen Aviation Technical Corporation (EGAT), and ANA Engine Services.

Independent engine shops are not so prolific in the maintenance and overhaul of the CF6-80C2 engine. MTU Maintenance Hannover still deals with 9% of the contracts market.

Asia Pacific

The second largest fleet, consisting of 899 CF6-80C2 engines, is in the Asia Pacific. An additional 12 engines will be delivered by 2015 on 767 aircraft. ANA

and JAL, recipients of the new 767-300 aircraft, both meet many of their engine shop needs in-house. ANA Engine Services also carries out work for Hokkaido International Airlines and Nippon Cargo Airlines.

The largest shop, in terms of contract market share, is EGAT with 8%. Customers include Air China, Air Hong Kong, Asiana Airlines, China Airlines, China Eastern Airlines and Eva Air, as well as surprise agreements with Garuda Indonesia and GE Caledonian. EGAT has an exclusive contract to repair Delta Air Lines' 42 CF-80C2B8F engines, despite Delta TechOps having its own engine shop.

EGAT is followed by ANA Engine Services and JAL Engineering with nearly 7% and 2.7%. Other airline-related engine overhaul facilities in the region are China Airlines, PKMRO and Thai Airways International. GMF AeroAsia was once the engineering arm of Garuda Indonesia, but with a split of the business in 2002, the company is now independent. For the CF6-80C2, GMF AeroAsia just deals with line replacement unit (LRU) parts and engine systems.

LHT has three facilities in the Asia Pacific, all with varying levels of capability. The facilities in Shenzhen and the Philippines are quite specific to small areas of the engine, while LTQ Engineering deals with full engine overhauls. LTQ Engineering is a joint venture (JV) between LHT and Qantas, the latter still retaining some component capabilities in-house.

Airfoil Services, a JV between LHT and MTU, specialises in repairing LRUs.

Fuel Accessory Service Technology is a JV between United Technologies International Corporation (parent group for Pratt & Whitney) and SIA Engineering Company. The company deals with fuel systems on the CF6-80C2, despite its parent companies having no other involvement in CF6-80C2 support.

GE has an LRU repair facility in Singapore (Airfoil Technologies Singapore) specialising in HPC airfoils, another Singapore facility specialising in turbine blades & nozzles and an engine shop in Japan. While the latter does not offer full overhaul capabilities, it does repair many of the component parts and accessories of the engine. Gameco and LHT Philippines, on the other hand, only specialise in hot section inspections of the CF6-80C2.

Other international organisations in the region, include Chromalloy, Nordam, Triumph and ST Aerospace.

Although over a quarter of the CF6-80C2 engine fleet is operated in the area, Asia Pacific only seems to account for 20% of the contract market. Having said that, a great deal of accessory and component repair is undertaken in Asia Pacific countries.

Europe

While Europe operates the third largest fleet of CF6-80C2 engines, it has nearly half of the contracts market for full engine shop visits. There are also a number of engine component and accessory repair shops, connected to international companies. These include Chromalloy, Goodrich and Nordam.

LHT has at least 10% of global engine overhaul contracts at its Hamburg facility. The fuel and lubrication systems are also dealt with by LHT Intercoat. LHT's many customers include Aerolineas Argentinas, Air Transat, Asiana Airlines, German Air Force, Iran Air, Lufthansa and Malev. LHT has an exclusive contract with Privatair to maintain their CF6-80C2B6F.

The AFI and KLM E&M partnership also deals with many contracts (for example Cargolux Italia, Kenya Airways, Royal Jordanian and an exclusive contract with Cargolux Airlines), as well as the maintenance of Air France's and KLM's engines. The two shops have nearly 9% of the market, with most of this work completed by KLM E&M. The two shops carry out 80 SVs per year for their parent airlines and customers. CRMA is connected to AFI and concentrates on electrical systems and LRU repairs. Other European airline-related engine shops include Alitalia Maintenance Systems (AMS), Finnair, My Technic and Turkish Technic.

MTU Maintenance is a large independent shop. Its facility in Hannover undertakes a number of contracts with a global market share of 9%. Clients include Air Atlanta Islandic, Air Canada, Air New Zealand, Saudi Arabian Airlines, and Yangtze River

CF6-80C2 - FAN MODULE CAPABILITY

Maintenance Provider	Fan rotor	Fan stator	Fan frame	Inlet gearbox	Radial driveshaft	Transfer gearbox	Fan midshaft	Electronic control unit
ADAT	M/R/O	M/R/O	M/R/O	M/R/O	M/R/O	M/R/O	M/R/O	M/R/O
AFI and KLM E&M	M/R/O	M/R/O	M/R/O	M/R/O	M/R/O	M/R/O	M/R/O	M/R/O
China Airlines	M/R/O	M/R/O	M/R/O	M/R/O		M/R/O	M/R/O	M/R/O
Chromalloy	M/R/O	M/R/O	M/R/O		M/R/O	M/R/O	M/R/O	
Delta TechOps	M/R/O	M/R/O	M/R/O	M/R/O	M/R/O	M/R/O	M/R/O	M/R/O
Finnair	M/R/O	M/R/O	M/R/O	M/S	M/R/O	M/S	M/R/O	S
GE Aviation, Svs-Cincinnati, Ohio			M/R					
GE Aviation - Tri-Remanufacturing			M/R					
GE Caledonian	M/R/O	M/R/O	M/R/O	M/R/O	M/R/O	M/R/O	M/R/O	M/R/O
GE Celma	M/R/O	M/R/O	M/R/O	M/R/O	M/R/O	M/R/O	M/R/O	M/R/O
Lufthansa Technik	M/R/O	M/R/O	M/R/O	M/R/O	M/R/O	M/R/O	M/R/O	M/R/O
MTU	M/R/O	M/R/O	M/R/O	M/R/O	M/R/O	M/R/O	M/R/S	M/S

CF6-80C2 - CORE MODULE CAPABILITY

Maintenance Provider	HPC rotor	HPC stator	Compressor rear frame	Combustor	HPT Stage 1 nozzle
ADAT	M/R/O	M/R/O	M/R/O	M/R/O	M/R/O
AFI and KLM E&M	M/R/O	M/R/O	M/R/O	M/R/O	M/R/O
China Airlines	M/R/O	M/R/O	M/R/O	M/S	M/R/O
Chromalloy	M/R/O	M/R/O	M/R/O	M/R/O	M/R/O
Delta TechOps	M/R/O	M/R/O	M/R/O	M/R/O	M/R/O
Finnair	M/R/O	M/R/O	M/R/O	M/S	M/R/O
GE Aviation, Svs-ATI, Singapore	M/R	M/R			
GE Aviation, Svs-Cincinnati, Ohio			M/R	M/R	M/R
GE Aviation - Tri-Remanufacturing			M/R	M/R	
GE Caledonian	M/R/O	M/R/O	M/R/O	M/R/O	M/R/O
GE Celma	M/R/O	M/R/O	M/R/O	M/R/O	M/R/O
Lufthansa Technik	M/R/O	M/R/O	M/R/O	M/R/O	M/R/O
MTU	M/R/O	M/R/O	M/R/O	M/R/O	M/R/O

CF6-80C2 -HIGH PRESSURE TURBINE MODULE CAPABILITY

Maintenance Provider	HPT rotor	HPT stator
ADAT	M/R/O	M/R/O
AFI and KLM E&M	M/R/O	M/R/O
China Airlines	M/R/O	M/R/O
Chromalloy	M/R/O	M/R/O
Delta TechOps	M/R/O	M/R/O
Finnair	M/R/O	M/R/O
GE Aviation, Svs-Ohio & Singapore	M/R	
GE Aviation, Svs-McAllen, Texas		M/R
GE Caledonian	M/R/O	M/R/O
GE Celma	M/R/O	M/R/O
Lufthansa Technik	M/R/O	M/R/O
MTU	M/R/O	M/R/O

CF6- - LOW PRESSURE TURBINE MODULE CAPABILITY

Maintenance provider	LPT rotor	LPT stator	Turbine rear frame
ADAT	M/R/O	M/R/O	M/R/O
AFI and KLM E&M	M/R/O	M/R/O	M/R/O
China Airlines	M/R/O	M/R/O	M/R/O
Chromalloy	M/R/O	M/R/O	M/R/O
Delta TechOps	M/R/O	M/R/O	M/R/O
Finnair	M/R/O	M/R/O	M/R/O
GE Aviation, Svs-Cincinnati, Ohio			M/R
GE Aviation, Svs-McAllen, Texas	M/R	M/R	
GE Aviation, Svs-Singapore	M/R		
GE Aviation - Tri-Remanufacturing			M/R
GE Caledonian	M/R/O	M/R/O	M/R/O
GE Celma	M/R/O	M/R/O	M/R/O
Lufthansa Technik	M/R/O	M/R/O	M/R/O
MTU	M/R/O	M/R/O	M/R/O

CF6-80C2 - ACCESSORY DRIVE MODULE CAPABILITY

Maintenance Provider	Horizontal driveshaft	Accessory gearbox	Heat shield	Engine accessories
ADAT	S	M/R/O	M/R/O	M/R/O
AFI and KLM E&M	M/R/O	M/R/O	M/R/O	M/R/O
China Airlines	M/R/O	M/R/O	M/R/O	M/R/O
Delta TechOps	M/R/O	M/R/O	M/R/O	M/R/O
Finnair	M/R/O	M/R/O	M/R/O	M/R/O/S
GE Caledonian	M/R/O	M/R/O	M/R/O	M/R/O
GE Celma	M/R/O	M/R/O	M/R/O	M/R/O
Lufthansa Technik	M/R/O	M/R/O	M/R/O	M/R/O
MTU	M/R/O	M/R/O	M/R/O	M/S

In-house Shop visit levels
M-Minimum R-Refurbishment O-Overhaul S-Module sent away

Express.

MTU Maintenance also has a small facility that deals with LRUs in Poland. Additionally, MTU Maintenance has a number of spare engines that are leased to customers while their engines are in MTU's shop.

Another independent is Snecma's MRO Division. Snecma often works with OEMs on manufacturing, but it operates an independent engine shop with regard to maintenance.

The OEM, GE, has a number of direct and indirect facilities in Europe. The main one is GE Caledonian in Scotland with 15% of contracts. Customers include Aeromexico, Continental Airlines, LOT Polish Airlines, Monarch Airlines, UPS and Virgin Atlantic Airways. A second facility in Hungary just repairs LRUs. Central European Engine Services is also a GE facility; a JV with LOT Polish Airlines, that undertakes hot section inspections.

There is a facility in Hungary that deals with fan components (like spinner cones, blade platforms & retainers, outlet guide vanes and booster case) and shroud support.

Independent AEM is a large accessory and component maintenance company, with three facilities in the United Kingdom. It salvages and repairs electrical and electronic parts from most of the accessory systems.

Jet Technology Center Ltd (JTC) is an independent component supply and repair facility in Ireland. It supplies and repairs fuel components, and offers a component lease & exchange service, asset management and PBH. JTC specialises in LRUs and the fuel system.

Auxitrol, part of Esterline, deals with LRUs, the thermocouple systems for measuring inter-turbine and EGT, optical pyrometers for turbine blade surface temperature measurements, and mass flow sensors.

Middle East

Just three main maintenance facilities have come out in this survey in this region. This, however, is understandable as only 5% of the engine fleet is operated here. With less than 1% of engine shop visit contracts held by Middle Eastern facilities, however, much of the work is sent to other regions, such as Europe.

ADAT is very much a one-stop shop for the CF6-80C2. As well as offering full engine overhaul, it also has a number of airframe capabilities. Various costing programmes are available such as fixed price shop visits, and PBH, for which one customer is Turkish carrier Onur Air.

All areas of the CF6-80C2 modules are dealt with, with only the horizontal driveshaft being sent away to be repaired.

Jordan Airmotive is an independent

FACILITIES WITH CF6-80C2 REPAIR CONTRACTS

Facility	Engine O/H	HSI	Acc. drive gearbox	Elec. system	Fuel system	LRU	Lubrication system	Thrust reverser
Asia Pacific								
Airfoil Services Sdn Bhd						Y		
Airfoil Technologies Singapore						Y		
ANA Engine Services Co Ltd	Y	Y						
China Airlines	Y	Y						
Evergreen Av. Tech. Corp. (EGAT)	Y	Y	Y	Y	Y	Y	Y	Y
Fuel Acc. Srvcs. Technologies					Y			
Gameco		Y						
GE Engine Services - Japan			Y	Y	Y	Y	Y	Y
GMF AeroAsia				Y	Y	Y	Y	
LTQ Engineering	Y	Y						
Lufthansa Technik Philippines		Y						
Lufthansa Technik Shenzhen			Y			Y		Y
QANTAS			Y	Y	Y	Y	Y	Y
ST Aerospace Systems				Y	Y		Y	
Thai Airways International	Y	Y	Y	Y	Y	Y	Y	
Triumph Aviation Services Asia			Y	Y	Y	Y	Y	Y
Europe								
AEM Ltd			Y	Y	Y	Y	Y	
Air France Industries	Y	Y	Y	Y	Y	Y	Y	Y
Alitalia Maintenance Systems	Y	Y	Y	Y	Y	Y	Y	Y
Auxitrol S.A.				Y		Y		
Central European Engine Svs		Y						
Chromalloy Holland					Y	Y	Y	
CRMA				Y		Y		
Finnair	Y	Y	Y	Y	Y	Y	Y	Y
GE Caledonian Ltd		Y	Y	Y	Y	Y	Y	
GE Engine Services - Hungary						Y		
Goodrich (Prestwick)								Y
Jet Technology Center Ltd					Y	Y		
KLM Engineering & Maintenance	Y	Y	Y	Y	Y	Y	Y	
Lufthansa Technik AG	Y	Y	Y	Y	Y	Y	Y	Y
Lufthansa Technik Intercoat					Y		Y	
MTU Aero Engines Polska						Y		
MTU Maintenance Hannover	Y	Y	Y	Y	Y	Y	Y	
MyTechnic	Y	Y						
Nordam Europe Ltd								Y
Sinaer		Y						
SNECMA (MRO Division)	Y	Y						
Turkish Technic	Y	Y	Y	Y	Y	Y	Y	
Middle East								
Abu Dhabi A/C Technologies (ADAT)	Y	Y	Y	Y	Y	Y	Y	Y
AMES						Y		Y
Jordan Airmotive	Y	Y						
North America								
AA-MRO	Y	Y	Y	Y	Y	Y	Y	Y
AAR Component Services-NY			Y	Y	Y	Y	Y	
Chromalloy Dallas						Y		
Chromalloy Los Angeles						Y		
Chromalloy Nevada						Y		
Chromalloy Texas						Y		
Chromalloy Windsor						Y		
Component Repair Technologies						Y		
CTS Engines	Y	Y						
Delta TechOps	Y	Y	Y	Y	Y	Y	Y	Y
First Wave MRO Inc.								Y
Flight Test Associates		Y						
GKN Aerospace Chem-Tronics						Y		
Goodrich (Foley)								Y
Goodrich Aerostructures								Y
Hawker Pacific Aerospace (LAX)					Y			
Honeywell Canada (PEI)					Y			
JFJ Industries						Y		
Middle River Aircraft Systems								Y
Nordam Repair Division								Y
PAS Technologies		Y				Y		
TCI					Y	Y		
The Fuel Cell					Y			
Triumph Airborne Structures								Y
Twin Manufacturing			Y			Y		
Woodward Governor Co.					Y	Y		
South America								
GE Celma Engine Services	Y	Y	Y	Y	Y	Y	Y	Y
TAMPA		Y						

Source: ACAS and directly from maintenance facilities

maintenance facility that was privatised from Royal Jordanian in 2000. It undertakes engine overhauls and HSI.

AMES is a JV between Aircelle and AFI. It deals with nacelle components only.

North America

Despite operating over a third of the CF6-80C2 engine fleet, only 7% of the overhaul market share seems to have been retained in the region.

Europe has benefited most from other regions' operators. Air Canada, for example, sends work to MTU Maintenance in Germany.

Contracts formed directly with GE Engine Services see many SVs carried out at their facilities in South America or Scotland.

The North American GE facility has just under 3% of the overhaul contract market share. Its customers include Aeroflot-Russian Airlines, Air Hong Kong, China Cargo Airlines and the Qatar Amiri Flight. The client list also includes a number of South American Airlines. Within North America, GE has a number of facilities that deal with piece parts such as rotor blades, stator vanes, nozzles and frames and cases.

Another large engine shop in North America is that of Delta TechOps, which estimates it deals with at least 40 SVs per annum. The share of global contracts is the same as GE Engine Services, at just under 3%. Despite a large number of SVs, this shows how many CF6-80C2 engines are being removed more frequently as the engine matures.

Delta TechOps is an important CF6-80C2 maintenance supplier in North America, with extensive airframe and management programme capabilities. This includes a pool of spare CF6-80C2B6, -80C2B6F and -80C2B8F engines. Customers include Delta AirLines, S7 Airlines, Star Air and World Airways. Star Air in fact only uses Delta TechOps, in an exclusive PBH complete fleet services contract, likely to be worth $55million. Other commercial terms include PBH and time and material.

Within this region, the only other facility that offers similar extensive services is AA-MRO, which also grew from within an airline to become a standalone maintenance facility with an engine shop. Understandably the main customer is AA.

Complete Turbine Services (CTS) Engines, in Fort Lauderdale, offers engine overhaul, but is not involved in the component and accessories repair market for this engine.

While the North American region loses out on the overhaul market, it more than makes up for it in component and accessory manufacturing and repair.

Many of the international companies already mentioned with facilities in the Asia Pacific and Europe are headquartered in North America. AAR Component Services has a facility in New York that deals with many of the LRUs and systems of the CF6-80C2.

Other LRU specialists include Chromalloy, Component Repair Technologies, GKN Aerospace Chem-Tronics, JFJ Industries, PAS Technologies, TCI, Twin Manufacturing and Woodward Governor Co. With five separate facilities in North America, Chromalloy has a large LRU capability.

A number of companies in the region specialises only in thrust reversers on this engine: First Wave MRO, Goodrich (with two facilities), Middle River Aircraft System, Nordam's North American repair division, and Triumph Airborne Structures.

South America

There are just two main engine maintenance facilities in South America: GE's own Celma Engine Services and Tampa Cargo's maintenance division in Colombia. Tampa just carries out smaller maintenance, such as hot section inspection, with GE doing full overhauls. Nearly 6% of overhaul contracts are dealt with by GE Celma Engine Services in Brazil.

Component repairs

An engine's components often need specialist repair. While many large shops can deal with most components, a number of specialist facilities concentrate on a small section of an engine, such as the nacelles, seals, LLPs or LRUs.

As the OEM of the CF6-80C2, GE is the main provider of component repairs. Additional facilities with large multiple component capabilities include AA-MRO, AAR Component Services, ADAT, AFI-KLM E&M, AMS, Delta TechOps, EGAT, Finnair, GMF AeroAsia, LHT, MTU, QANTAS, Thai Airways International and Turkish Technic. Many of these facilities are also one-stop shops.

Other specialist repair capabilities include the blades, vanes & stators for the LPC and HPC, and the fuel nozzles and combustion cans of the combustion chamber.

Chromalloy excels in such component overhaul and repair. It has a number of facilities, six of which have direct CF6-80C2 capabilities. Other specialists in these areas include Airfoil Services in Malaysia, Airfoil Technologies Singapore, LHT Shenzhen, PAS Technologies and Twin Manufacturing.

Woodward Governor in the US repairs and manufactures engine fuel delivery systems and combustion control systems including fuel nozzles, igniters and valves. Finnair has a specialist repair of airfoils involving borescope blending.

Coatings

Often, while there are standard repair processes, a company will develop its own high-tech or alternative repair, for example developing or adapting a coating to repair and extend the life of parts. LHT's Intercoat uses an advanced epoxy-coating process on many parts, including those in an engine, with the aim of increasing repairability, reducing scrappage, down time and costs, and improving the part's performance.

GKN Aerospace Chem-Tronic also offers specialist coatings. An example is a repair to a stage one fan blade, involving vibratory finish of the airfoil, repair of fretting, nicks, dents, scratches and midspan shrouds by blending and application of a Cu-Ni-In thermal spray & dry film lubricant coating on root surfaces. Additional repairs include replacing tungsten carbide coatings and dovetail/ platform seals, welding build-up of blade tips, and straightening and repairing leading and trailing edges with insert welding.

AFI offers specialist processes such as high velocity oxygen fuel (HVOF) coating, plasma spraying, electro beam weld repairs, laser welding and drilling, and electric discharge machining (EDM).

Support for the CF6-80C2 is comprehensive on a global level. Airlines and operators have a large number of airline-associated, independent and OEM shops and repair facilities to choose from.

Seals and bearings

Within the LPT, seals are required to retain minimal contact between the airfoils and the turbine case, so that they, rather than the actual airfoil, wear away. Honeycomb seals are the non-rotating component of seals, while knife-edge seals are rotating seals. While many of the large MRO facilities offer this repair, it is considered a specialist service. For example MTU Maintenance says it is able to inspect these seals, but does not carry out repairs in-house. "Delta TechOps manages the overhaul of all seals and bearings. Bearings, rotating seals and stationary seals are cleaned and inspected in-house. PTFE seal surfaces and thermal spray coatings are replaced on site. Bearing repairs, honeycomb seal replacements, and knife-edge seal weld repair are outsourced," says Boldt.

PAS is a major repairer of honeycomb seals for most engines, while Twin Manufacturing repairs knife-edge seals. There are also simple seals and bearings within engines.

GE, as the OEM, is an obvious repairer of bearings, as are the major engine shops, such as LHT. Twin Manufacturing deals with bearings, as does MRC Bearings in New York, part of the SKF Group. GE's ATI in Singapore refurbishes HPC stator retainer seals, while GE Aviation, Services-McAllen, Texas repairs stationary seals. These capabilities are also offered at both the Celma and Caledonian shops.

Cases and frames

Cases and frames have no moving parts, so they are some of the simplest parts to deal with. Component Repair Technologies, Twin Manufacturing and Chromalloy will often deal with an operator's repair needs on these parts.

Chromalloy specifically provides repairs for compressor cases and frames, the LPT rearframe and shrouds. The compressor rear frame repair is also a capability of China Airlines. Again, many of the large engine shops will deal with cases and frames, such as AFI, Delta TechOps, Finnair (who undertake a specialist top-case repair), MTU Maintenance and LHT.

The capabilities vary for Delta TechOps because some work is outsourced, depending on the part and the repair. Fan booster stator cases, for example, are repaired in-house, while maintenance of LPT cases requires piece-part repairs and is outsourced.

Unsurprisingly, GE has capability in this area at a number of its facilities.

Accessories & LRUs

Engine accessories and components, mounted on the outside of the engine, can be divided into accessories and quick engine change (QEC) components. Accessory repair capabilities are shown *(see tables, pages 44 and 46)*.

Companies that otherwise do not get involved with aeronautical turbine engines, are likely to be the ones that deal with accessories such as electrical and fuel systems. QEC capabilities are offered by most large engine shops, but may also be offered by those maintenance facilities that do not have full engine overhaul capabilities, such as China Airlines, Emirates, GMF AeroAsia and other airline-related maintenance divisions. Goodrich repairs nacelles, which are parts of the QEC in which it specialises.

In August 2011 it became part of MTU Maintenance, and is also known MTU Maintenance Dallas. It undertakes QEC build-up of the CF6-80C2, borescope work, replacement of LRUs and fan blade changes, as well as offering a mobile unit to operators.

Specific QEC components within MTU Maintenance Hannover's capabilities include fuel pumps, actuators, valves, coolers and alternators. Delta TechOps cleans, inspects and repairs many QEC components on-site. There are, however, some component repairs that Delta TechOps chooses to outsource.

Nacelles & thrust reversers

Nacelles are the coverings of an engine, and are related to the cowls and thrust reversers. Goodrich manufactures nacelles and thrust reversers for many production engines, and has a number of facilities with CF6-80C2 capabilities; the major ones being in Europe and North America. Particular specialist repairs are to the inlet, fan and core cowls, thrust reversers, nozzle and engine build-up (EBU), and include autoclave composite bond repairs and new technology composite bonding repairs.

Goodrich is also involved in the pylons of the engine on the MD-11.

Thrust reverser repair facilities are numerous, with facilities in all regions except Africa *(see table, page 46)*. LHT, Nordam (two facilities) and Triumph Airborne Structures are also significant providers of repairs to these components.

AMES in the Middle East has capabilities for nacelle components that include the thrust reverser and inlet and fan cowls. "This work is based on time and material agreements, with some fixed prices per workscope," says Frédérique Thomas, communications director at Aircelle. Additional support from the parent group, AFI, means that AMES can also perform autoclave repairs. While MTU Maintenance has full capacity with regard to cases and frames, it has limited nacelle repair capabilities and none for thrust reversers.