Widebody engines can be divided into three broad categories of current, mid-term and older generation types. The issues that determine which suppliers are involved in each market, and the economic factors affecting each are examined.

The widebody engine leasing market

The active widebody fleet totals just under 5,230 aircraft, and is supported by about 12,460 installed engines. This fleet requires 1,500-1,700 spare engines to provide coverage for maintenance of installed engines, and for aircraft lease returns.

The widebody fleet can broadly be sub-divided into three generations. The first is current generation aircraft: the A380, A350, 787 family and 777-200LR/-300ER *(see table, page 8)*. The second generation comprises mid-term types that are still in production and others that have recently ceased production. These include the A330, A340, and 777-200/-200ER/-300 *(see table, page 8)*. The third generation includes widebodies that entered service in the 1980s, including the MD-11, A300-600, A310, 767 family and 747-400 *(see table, page 8)*.

The portion of spare engines that is owned has steadily decreased with the steady growth of engine leasing from the late 1980s. As the volume of leased engines has grown, the number of engine support products available to airlines has also evolved. The products available, however, differ according to the generation of engines being supported.

Market evolution

The number of airlines owning and operating their own engine maintenance and overhaul shops has declined, especially since the early 1990s. Most of the engine original equipment manufacturers (OEMs) had a limited involvement in aftermarket engine support, either in terms of providing maintenance or spare engines, up until the early 1990s. The exception to this was Rolls-Royce (RR), which provided maintenance for a relatively high percentage of its engines in service.

The leasing of engines was originally provided by a limited number of specialists, including Willis Lease Finance Corporation (WLFC) and Engine Lease Finance (ELF). These broadly provided two main products of short- and long-term leasing. Short-term leases, of a few months, provided temporary power for aircraft while an engine was undergoing shop visit (SV) maintenance. Monthly lease rentals or the lease rate factor, expressed as a percentage of the engine's value, are relatively high. Long-term leasing evolved to provide airlines with an alternative to owning their own spare engines. Lease rate factors are lower than for short-term leases.

Both types of traditional engine leases involve the payment of lease rentals and maintenance reserves by the airline lessee, which is responsible for the maintenance of the engine. Payment for the SV has to be reimbursed to the lessee from the paid reserves.

Leasing allows airlines to divest their spare engine inventories by selling them to lessors and then leasing them back under a sale and leaseback (SLB) transaction. This gives engine lessors an easy entry into the market. Engine lessors were able to acquire new-build engines of older generations from the OEMs relatively easily.

The presence of many airline and independent engine maintenance and parts shops allowed a large number of engine lessors and traders to enter the market with relative ease. The only barriers to market entry were capital and technical expertise.

Market development

The traditional engine support market started to change in the early 1990s with engine OEMs General Electric (GE), Pratt & Whitney (PW), and RR increasing their presence through the acquisition of a large number of independent and airline-owned engine shops. All three OEMs now have a global network of engine shops to provide maintenance and technical support coverage for most of their engine types in operation.

The OEMs also increased their leasing activity to provide their airline customers with spare engine support. Ancillary services for issues such as aircraft-on-ground (AOG) situations, provisioning of inventories of line replaceable units (LRUs), and engineering management mean that OEMs provide all levels of service an airline requires.

There are now five broad categories of engine maintenance contracts: time-and-material, fixed-price, and not-to-exceed (NTE) contracts, all of which are relatively simple, and relate to how the engine SV is charged for; and also power-by-the-hour (PBH), and integrated services.

PBH-style contracts evolved in the early 1990s, and provide operators with a predictable cost per engine flight hour (EFH) or engine flight cycle (EFC) for the cost of an SV or several SVs over one or a series of predicted removal intervals. It is estimated that 25% of the global engine fleet is maintained under PBH-style contracts. They are offered by airline-owned, independent and OEM shops.

PBH contracts provide a predictable cost per EFH or EFC for the operator. An inherent disadvantage is that the airline ultimately pays more per EFH or EFC compared to the cost of a time-and-material SV amortised over the removal interval. Other difficulties are that lessors and maintenance providers both want maintenance reserves paid to them in the case of a leased engine. The operator then needs a mechanism for clawing back one of the set of reserves that has been paid.

WIDEBODY FLEET & INSTALLED ENGINE BASE

Aircraft type	Active fleet	Engine type(s)	Installed fleet
A350	140	Trent XWB	280
A380	220	Trent 900, GP7200	880
787	363	Trent 1000, GEnx-1B	726
747-8F/-8I	124	Trent 1000, GEnx-2B	496
777-200LR/-300ER	787	GE90-110/-115	1,574
A330-200/-300	1,163	CF6-80E1, PW4000-100, Trent 700	2,326
A340-300/-500/-600	233	CFM56-5C, Trent 500	932
777-200/-200ER/-300	503	GE90-76/-85/-90, PW4000-112, Trent 800	1,006
747-400	423	CF6-80C2, PW4000-94, RB211-524	1,692
767 family	967	CF6-80C2, PW4000-94, RB211-524	1,934
A300-600/A310	236	CF6-80C2, PW4000-94	472
MD-11	133	CF6-80C2, PW4000-94	399
Total	**5,292**		**12,557**

OEMs have introduced integrated engine support services following their acquisition of engine shops and hi-tech repair facilities, and the entry into the engine leasing market. In addition to SV maintenance, they provide ancillary services such as engine health monitoring (EHM), engineering management, LRU provisioning, AOG and on-wing support, and spare engine provisioning. Integrated services therefore provide all major elements of engine management. An example of an OEM's product is GE's On Point service. Airlines can thereby rid themselves of most of their infrastructure.

Such contracts encourage airlines to be fully supported for their engine technical support for the first 12-15 years of operation. Problems arise, however, with the variation in engine maintenance status and remaining life limited part (LLP) lives when the contracts expire. The aircraft may be transferred to a new operator at this stage, or the airline may continue to operate the fleet and source a new engine support contract.

"While integrated services provide a one-stop and comprehensive service, most airlines view them as too expensive," says Graeme Crickett, senior vice president & head of technical at Sumisho Aero Engine Lease. "Most airlines taking delivery of new aircraft fleets choose PBH-style maintenance contracts, and then organise alternatives for all related ancillary services, including leasing spare engines.

"PBH-style and integrated engine maintenance and support contracts for current generation engines are increasing in length," continues Crickett. "They were typically at about 10 years, but have been increased to 12-15 years, so they cover the period for two main SVs."

Another factor contributing to the OEMs' market dominance is their tight control of providing licences to engine shops, and providing the intellectual property in relation to SV manuals, and hi-tech repair practices and licences for high-value engine airfoils. Unlike previous generation engines, OEMs have granted licences to operate an engine maintenance shop to only a limited number of facilities. These can be shops with which the OEM has a strategic partnership or a joint venture, or which are part- or fully-owned by the OEM.

Lease support

As described, the widebody engine fleet comprises 12,460 installed units and another 1,500-1,700 spare units that support an active fleet of about 5,230 aircraft *(see table, this page)*.

The portion of widebodies that is owned or financed through mechanisms other than straightforward operating leasing is 50-51%, so just less than 50% are acquired through operating leases.

Crickett estimates that about 90% of spare engines are now leased, and just 10% are owned. The main vehicle for leasing engines is for airlines to conduct SLBs at aircraft and fleet delivery with engine lessors, which immediately allows the airlines to release equity.

Spare engines are divided into three broad categories. Current generation Trent 900, 1000 and XWB, GE90-110/-115 and GEnx engines power the A380, A350, 787 and 747-8. Mid-term generation Trent 700 and 800, GE90 Standard, CF6-80E1, PW4000-110 and PW4000-112 power the A330-200/-300; and 777-200, -200ER and -300. Only the Trent 700, CF6-80E1 and PW4000-100 remain in production for the A330.

Older generation engines are the CF6-80C2, PW4000-94 and RB211524G/H for the 767 family, 747-400, A300-600, A310 and MD-11.

Traditionally engine leasing has been divided between two simple products: short- and long-term contracts. Short-term leasing is prevalent among engines for narrowbody aircraft, since the aircraft types are operated in large numbers. The logistics of shipping spare engines, and the strong certainty of finding several airlines with a requirement for an engine, or several airlines in succession with the same requirement to avoid minimal downtime between leases, mean that there is little financial risk in the activity.

Short-term leasing is more common with older and mid-term generation widebody engines, but virtually absent among new generation powerplants. The high capital cost of these engines, of up to $36 million in the case of a high-rated GE90-115, the expense of shipping engines between airlines, and the risk of significant zero lease revenue downtime between leases means engine lessors have little appetite to put engines such as the GE90-110/-115, GEnx, Trent XWB, Trent 900, and Trent 1000 out on short-term leases.

Long-term leases will be available to all three generations of widebody engines.

The increased presence of OEMs in the market, and the evolution of engine support products has meant that a variety of products are now available to airlines in addition to the traditional short- and long-term leases. The development of these products has been determined by the availability of engines for purchase by lessors, the access that lessors have to capital, and their access to maintenance and technical support services. These factors vary between generations of engines.

Current generation engines

Current generation aircraft include all those in production in recent years: the A350, which has been in production since late 2014, with 140 built to date; the A380 with about 220 built to date; the 787 with more than 360 built to date; the 747-8 with 124 built to date; and the 777-200LR and -300ER with 787 built to date. The total number of these five main types is 1,634 aircraft, and are powered by about 3,956 installed engines.

This installed fleet of engines will require spare engine support equal to about 10% of the fleet, or 400 engines. The portion of spare engines is expected to drop to 7-8% over the long term as reliability stabilises.

All of these types remain in production, however, and the installed base of engines will clearly grow. The supply of spare and used engines will remain tight. There is no prospect of any used engines coming available on the aftermarket for several years.

The oldest type among the current

generation of engines is the GE90-110/-115 powering the 777-200LR and -300ER. These have been in production since 2004. All other types started production more recently: the Trent 900 entered service on the A380 in 2007; while the Trent XWB is the most recent type, with production starting in 2014.

The GE and RR engines in this group are operated by a relatively small number of airlines. These are mostly flag carriers, operating the latest equipment on the world's prime intercontinental routes.

The installed engines on the operational fleet will either be under PBH or integrated service contracts for maintenance and technical support.

PBH contracts will only provide maintenance, and the operator will have to source all other levels of technical support from other providers.

Integrated services will include full maintenance and technical support services, and spare engine provisioning. The main providers of these services will be GE's On Point service for the GE90-110 and -115, and RR's Total Care package for the Trent 900, 1000 and XWB models.

Integrated services for the GE90-110/-115 are also provided by MTU Maintenance, MTU Maintenance Lease Services.

The global supply of maintenance capacity for these engine types is carefully monitored and limited by the OEMs. There will be few airline or independent engine shops that can offer maintenance capability independently of the OEMs.

It is hard for independent lessors to acquire new and current generation engines. Since not all airlines acquire their fleets on operating lease, however, some fleets are owned or acquired through other financing vehicles. Their spare engine inventories are therefore available for potential purchase by lessors interested in SLB transactions.

Despite the ability to enter the market for the GE90-110/-115 and GEnx, independent lessors can only provide the provisioning of spare engines for long-term lease support. Airlines opting for this service will then have to acquire all the remaining maintenance and technical support services from GE and its associated shops, or the small number of alternatives. One is MTU Maintenance, which has capability for overhaul and repair, and engineering support, on the GE90-110/-115 at its Hannover facility.

"MTU Maintenance offers an entire range of support options for the GE90-110/-115," says Alistair Dibisceglia, vice president and head of global leasing, at MTU Maintenance Lease Services. "These range from short- and long-term leasing, SLB transactions, and various maintenance and technical support products. Besides SV maintenance, these include provisioning of modules, and AOG services."

There is a limited number of GE90-110/-115s for lease as spare engines. MTU Maintenance has some in its lease pool. MTU Maintenance set up two joint ventures in 2014 with Sumitomo Corporation. It has a Dublin-based affiliate, SMBC Aviation Capital, which finances aircraft acquisitions and is the world's fourth largest aircraft lessor. One joint venture that it has created is MTU Maintenance Lease Services. Based in Amsterdam, this provides engines on short- and medium-term leases for the GE90 and a variety of narrowbody engines. The services of MTU Maintenance Lease Services are expanded in line with MTU Maintenance's maintenance and repair capabilities each time that a new engine type is added.

The second joint venture is in Sumisho Aero Engine Lease, also based in Amsterdam. This is 90% owned by Sumitomo Corporation and 10% by MTU Aero. Sumisho Aero Engine Lease focuses on long-term lease arrangements and financing solutions for engines.

The OEMs' domination of the market for these current generation engines, means that prospective competitors have limited scope for entering the market.

Barriers to entry include the investment capacity to acquire engines, and the need for market understanding and technical expertise. MTU Maintenance and MTU Maintenance lease Services is one of the few alternatives to GE that has this wide-reaching expertise for the GE90-110/-115.

While MTU Maintenance Lease Services has GE90-110/-115s in its portfolio, its joint venture partner Sumisho Aero Engine Lease has GEnx engines in its portfolio. These are in addition to a variety of narrowbody engines, including current generation types like the LEAP-1A and CF34-10E.

MTU Maintenance, MTU Maintenance Lease Services, and Sumisho Aero Engine Lease are therefore able to offer airlines maintenance and technical support coverage, such as AOG assistance and LRU inventory; engines on short-term leases; and fleet inventory on long-term leases. The range of products offered therefore provides an alternative to those offered by the OEM. As a lessor, Sumisho does not tell its lessees where to maintain the engines. Besides MTU Maintenance, AFI KLM E&M also has GE90-110/-115 shop visit maintenance capability, provides 'hospital' or quick turn shop visits, provides spare engines for scheduled and unscheduled removals, and engineering support.

An independent lessor in the current generation market is WLFC. It has a large portfolio of 850 engines, making it the largest independent engine lessor. The portfolio includes the GE90-115 and GEnx. "We do not have any RR Trent models, and about a quarter of our portfolio comprises widebody engines of all three main generations," says Charles Willis, chairman and chief executive officer at WLFC. "In addition to WLFC for engine leasing, we also have Willis Asset Management in Wales in the United Kingdom, which was previously Total Engine Support (TES). Willis Asset Management provides all engineering and related technical services that are ancillary to engine maintenance, so we can provide all the engine-related services an airline needs except for SV maintenance.

"These include engineering management, or continued airworthiness management organisation (CAMO) functions," continues Willis. "Willis Asset Management also manages lease returns, and engineering management with respect to managing SVs, AOG assistance, and defining SV workscopes for airlines. We acquired TES because of its engine management activities. It has a staff of 60 technical and engineering management people in Wales and another 40 at our facilities in the US; and various other offices in Singapore, Shanghai and Dublin. We are one of the few companies to offer services that are an alternative to the OEMs. The added infrastructure has allowed us to increase the volume of business by a factor of 2.5 since mid-2016."

WLFC acquired GE90-110/-115s and GEnxs from airlines via SLBs, and direct from the OEMs. "These engines are brand new, and have list prices of $27-33 million," says Willis. "At least half the current generation widebodies, and their spare engine portfolios, are owned, so airlines are in a position to sell their spare engines. These engines can be acquired through SLBs. This applies only to GE engines, however, since we do not see any current generation RR Trents coming available on the market. Virtually all are included under RR's Total Care packages."

WLFC is one of the few entities in the market that is able to provide the services and the necessary financing available to compete with the OEMs. "We have access to capital markets. An example is a recent securitisation we conducted which raised $300 million," says Willis. "Also, our second largest shareholder is the Development Bank of Japan."

WLFC also has the volume of engines in its portfolio to compete with the OEMs. For example it has 22 engines

The GE90-110/-115 is the most prominent engine type in the category of current generation types. GE provides integrated services that include engine maintenance, engineering and technical services, and spare engine provisioning. MTU Maintenance and AFI KLM E&M provide similar servicses as alternatives to the OEM.

leased to Southwest Airlines.

With the addition of Willis Asset Management to its portfolio and the technical and engineering management capabilities it provides, WLFC now offers a full lease and support service called Constant Thrust. This is offered because the market is changing from straight leasing. "Constant Thrust makes us more like an operator rather than a finance house that is simply a supplier of engines on short- and long-term leases. A full service is now required that includes a range of technical support products," says Willis.

Long-term lease rate factors for current generation types, such as the GE90-100/-115 and GEnx have declined over the past eight to 10 years from levels higher than 1% per month to 0.7% to 0.95% per month. These low lease rate factors are explained by the low cost of capital and competition in the market. Some engines will have to be leased at competitive rates, since it is desirable for the market as a whole to avoid a surplus of engines.

The current list prices for the GE90-110/-115 are $31-36 million, depending on thrust rating. List prices increase at about 1% per year. Most of these engines will power high gross weight versions of the 777-300ER, and so cost $35-36 million. Monthly market lease rentals should therefore be $245,000-342,000.

The current list price for the GEnx is $22-28 million, again depending on thrust rating. This powers the 787-8, -9 and -10. Monthly lease rentals can be expected to be $154,000-266,000.

Mid-term generation engines

The mid-term fleet of widebodies includes the A330 and A340 families, which commenced production in the early 1990s; and the three earlier series of the 777 which started production in 1997: the 777-200, -200ER and -300. The only type that is still in production is the A330-200 and -300. Production of all A340 models and the first three 777 variants has ceased.

The A340-200 and -300 were the first into production. A total of 246 were built, and 139 remain in service with 107 now phased out of operation. These aircraft were uniquely powered with the CFM56-5C series, so more than 425 installed engines have been released onto the market.

The later A340-500 and -600 had a limited production run of 131, and 94 are still operational. These were uniquely powered by the Trent 500, and are a specialist market.

To date, about 1,400 A330s have been built, and 1,170 are in service. About 230 aircraft, or 16% of those built, have therefore been retired or phased out of operation. These are powered by the PW4000-110 and CF6-80E1 engines, which are not present on any other aircraft types.

Production of the 777-200, -200ER and -300 totalled about 570 aircraft. These were powered by different thrust rating variants of the GE90 Standard, RR Trent 800 and PW4000-112 engines. Most aircraft, 503, are still in active service, with 67 no longer operational. These have therefore placed up to 130 engines on the used market.

Collectively, there are 1,900 of these active mid-term generation widebodies with an installed base of 4,264 engines. Given typical SV removal intervals, this fleet will have to be supported by 430-650 spare engines.

Most mid-term generation engines are a mix of low-, medium- and high-rated variants of the same engine model. This applies to the GE90, PW4000-112 and Trent 800 powering the 777-200, -200ER and -300. It also applies to the CF6-80E1, PW4000-100, and Trent 700 powering the A330-200 and -300.

The CFM56-5C and Trent 500 powering the four variants of the A340 have less significance because of the limited numbers of aircraft in service, the weak demand for them on the aftermarket, and limited interest in the aftermarket from traders and lessors.

The difficulty with the range of thrust ratings among the same main engine models powering the three earlier 777 variants and the A330-200/-300 is that it is either not possible or too expensive to upgrade lower rated variants of these engines to higher rated models. The fleets of each engine type are therefore subdivided by thrust rating.

Lower-rated variants of each type powered the earlier-built aircraft on the production line, so they account for most of the aircraft to have been retired. This means that the supply of their engines on the aftermarket is generally in surplus.

Higher-rated variants of the same engines power the later-built aircraft. Some of these are new, as in the case of the A330-200 and -300. The last 777-200ERs with the highest-rated GE90s and PW4000-112s were built in 2010, with exception of a small number built in 2012.

These engines are young, but some of the oldest examples of high-rated engines will have completed their original PBH or integrated service contracts with the OEMs. Some will now be maintained under fixed-price or NTE-style maintenance contracts with the OEMs, a small number of independent MROs, and airline-owned engine shops.

The shops available for the GE90-90/-94 powering the three older 777 variants are GE Aviation in Wales, UK; GE Evergreen Engine Services; and Air

There has been a constant supply of CF6-80C2 and PW4000-94 engines coming on to the market over the past five to 10 years following the retirement of large numbers of MD-11s and 747-400s. This has depressed engine values, and consequently limited the number of engines that airlines have been putting through shop visits.

France Industries KLM Engineering & Maintenance (AFI KLM E&M).

The shops available for the PW4000-112 powering the same 777 variants are PW's Eagle Services Asia shop in Singapore, and Air India Engineering Services shop in New Delhi. The Air India shop only performs about 10 SVs per year, however. PW's shops account for most of PW4000-112 SVs.

The same shops provide maintenance capability for the PW4000-100 powering the A330. In addition, SR Technics has SV capability for the PW4000-100 at its Zurich facility.

Maintenance capability for the CF6-80E1 is offered by GE's Caledonian shop at Prestwick in Scotland, United Kingdom; GE Celma, in Brazil; and AFI KLM E&M.

There is also a small number of non-owned and non-JV shops for the Trent 700 and 800. These include TS&S in Abu Dhabi, Delta Tech Ops, and N3 in Germany.

These shops make it easier for airlines to continue operating older A330s and 777s, while using time-and-material, fixed-price, or NTE engine maintenance contracts. This avoids the cost of adhering to PBH and integrated service contracts for an extended term. Airlines can also avoid paying reserves for LLPs and other expensive overhauls and part replacements while engines have sufficient maintenance status to continue in service for a remaining period that only requires lighter SV workscopes. This is possible for a high percentage of engines because they are owned, and so free of the difficulties experienced with engines owned by lessors.

Older and lower-rated engines can also be broken for parts when demand for complete engines declines as more older aircraft are retired and phased out. Despite several differences in configuration and thrust rating, there is still extensive parts commonality with the higher rated variants. Older engines therefore provide an economic source of material and parts for the higher rated engines that are being maintained on an independent basis.

Mid-term generation engines are available for lease from the OEMs; several major lessors that include WLFC and ELF; and a growing number of traders and lessors that include Apollo, AerSale, GA Telesis, and Castlelake.

The mid-term generation market is one where WLFC's Constant Thrust product provides an alternative source of comprehensive services to the OEMs.

"We have changed from just being a traditional engine lessor," says Willis. "First, we buy aircraft, and strip and repair the old engines. We then re-deliver the aircraft with improved engines. This aircraft will be put out on lease again, but it will not have the usual lease stringent return conditions that many aircraft have. It is now becoming easier to buy Trent 700s and 800s from older A330s and 777s."

As with WLFC evolving its combined engine lease and technical support products, MK Aviation has also introduced some innovative products into the market. The lessor has a range of mid-term and older generation engines in its portfolio that include the PW4168 for the A330-200/-300; as well as several variants of the older generation of PW4000-94. "In addition to the PW4168, we are evaluating the PW4090 for the 777-200ER," says Ran Ackerman, vice president of marketing and sales for EMEA and Asia at MK Aviation. "Our principle is that instead of the traditional lease where we supply the engine and the airline lessee is responsible for the maintenance and the engine's maintenance condition, we take responsibility for the engine's maintenance and all technical issues. We have introduced this because it is unreasonable for an airline to have to pay for an SV if one is needed when an engine is on a short-term lease. An airline also has to get the cost of an SV reimbursed from the reserves it has paid over the long term.

"We therefore pay for the cost of maintenance and SVs out of the reserves we have collected from the airline lessee," continues Ackerman. "We have engines on lease for three to five years and have adapted this concept of what we call a mechanical lease. We may have to pay for an SV if one is required during the lease term, and this has to come out of the reserves we have collected. The engine gets handed back to us, and after inspection we may decide to break it down for parts and used serviceable material (USM), depending on the extent of its failure. On balance this type of structure works financially for us, but we do not always win. We do get some engines that fail early, and are too expensive to repair compared to the reserves that have been collected."

There are also independents such as MTU Maintenance Lease Services that have these engines available; as well as a few airlines that include AFI KLM E&M, and Lufthansa Technik.

Older generation engines

Older generation engines are dominated by the CF6-80C2 and PW4000-94 families. These two power all five main types of 1980s generation widebodies: the 747-400, 767 family, A300-600, A310, and MD-11. These two engine types have an almost 50% equal share of airline selections.

The Rolls-Royce RB211-525G/H was chosen for several 747-400 fleets, the largest being that of British Airways (BA), which totalled about 60 aircraft at one

time. The same engine was also selected for BA's 767-300ER fleet, as well as a small number of aircraft for China Yunnan. The RB211-524G/H is absent on the A300-600, A310 and MD-11.

The CF6-80C2 and PW4000 families powered more than 2,000 widebodies when the collective fleets were at their peak operational numbers.

The fleets of 1980s generation widebodies have been declining for several years. The MD-11 now has 133 active aircraft out of 200 built. All operational aircraft are in freighter configuration, and the fleet will continue to steadily decline. The A310 and A300-600 totalled 560 aircraft built, but there are now only 236 left in operation. Most of these are in freighter configuration.

The 747-400 fleet peaked at about 650 units in 2005. The flag carriers that operated most 747-400s have replaced them with the 777-300ER and A380 in most cases. Only 240 747-400s are left in passenger configuration, and another 180 are in service as freighters. While most of the freighter fleet will persist, the passenger-configured fleet is in terminal decline. BA's fleet of 36 aircraft will be one the last to be phased out.

The 767 family is the most successful of the 1980s generation widebodies, with a total of about 1,100 aircraft having been built. There are still 967 aircraft in operation, testament to the fact that the 767 is an economic small widebody to operate, and that it is in a class of its own, even though there are now more than 360 787s and 140 A350s in active service. These two aircraft were both late going into service, and this delay has prolonged the operation of many 767s. Continued international traffic growth and intercontinental airline route development has kept large numbers of 767s in service.

The active fleet of older generation widebodies totals about 1,759 aircraft and an installed engine base of 4,497. This fleet will need a spare engine base of up to 15% of installed engines, so equal to 675-700 engine units on a normal operating basis. The supply of large numbers of engines from retired aircraft will now make the number of spares required to support the fleet less relevant.

Overall, of about 2,555 aircraft built, 790 have been retired, parked or scrapped. This is 31% of the fleet. These aircraft have therefore released up to 2,125 engines onto the used market.

Many of these engines will have been broken up and dismantled for parts and USM. This can be used to lower the cost of maintaining engines that have remained in service. Besides the fleet of RB211-524Hs that power BA's fleet of 36 747-400s and the small number of other aircraft still in operation, about 4,300 of the installed engines in operation will be CF6-80C2s and PW4000-94s.

There are a larger number of airline-owned and independent engine shops left to provide maintenance. These include airline-owned shops of American Airlines, Delta Tech Ops, Lufthansa Technik, AFI KLM E&M, Iberia and Ameco Beijing. There are also several independents that include MTU Maintenance and SR Technics.

The availability of used or green-time engines and USM will reduce the continued cost of operating these engines. There is still a large number of 767s in operation, as well as substantial fleets of A300-600/A310 and 747-400 freighters. These total 1,400-1,450 units and the fleet will decline less slowly than the 747-400s and MD-11s that have already been phased out.

CF6-80C2s and PW4000-94s are available from major engine lessors WLFC and ELF for short-term leases of the typical three- to five-month terms. They are also available from traders and lessors such as Apollo, GA Telesis, AerSale, AG Walter, MK Aviation and Magellan Aviation.

Ackerman makes the point that the

key for MK Aviation's mechanical lease product is to find engines that have an attractive value in relation to their maintenance condition. "We can acquire engines very quickly, and make a decision in 10-20 days," says Ackerman. "The maintenance portion of the monthly payments can include an element for shop visits and LLPs. Reserves do not necessarily have to be paid for LLPs, however, and we can do a deal where the lessee pays a rental for the engine and reserves just for the SV. This will be appropriate for engines with sufficient LLP life to last for the remaining years before they are retired or broken for parts and material that is still serviceable."

WLFC has a large number of PW4000-94s and CF6-80C2s in its portfolio. It uses its Willis Aero facility in California to disassemble these engines, and various narrowbody powerplants, to source parts. This is part of its engine and aircraft leasing activity. Aircraft can be acquired and returned on lease with engines in a higher maintenance condition.

"There is a large number of CF6-80C2s on the market, and in fact too many due to a large number of 747-400 retirements," says Willis. "The prices of engines are generally holding up well, however. The price depends on maintenance condition, and there has been a lot of attrition. The lease rates for a PW4060, for example, to power a high-rated 767-300ER are about $60,000 per month plus whatever maintenance reserves are required. The rates are affected by airline lessee creditworthiness, the age of the engines, and length of the lease."

Ackerman points out that demand for serviceable CF6-80C2s and PW4000-94s fluctuates, and has been strong recently. "Only small configuration changes are required to them to swap them between aircraft types," says Ackerman. "Many airlines are not putting engines through shops and replacing the LLPs. Instead airlines are looking for good quality green-time engines, and this is holding up values. The reluctance to put engines through SVs has resulted in some shortages. An example is a shortage of used serviceable T1 and T2 high pressure turbine blades for the PW4000-94. This has not been helped by Amazon and Atlas Air acquiring a large number of 767-300ERs for freight conversion."

Bill Polyi, president and chief executive officer at Magellan Aviation comments that there has been a constant supply of 747-400, 767 and MD-11 retirements that has led to this reluctance among remaining CF6-80C2 and PW4000-94 operators to put them through shop visits. "The consumption of 'green time' or time-continued engines is constant, and when combined with a reluctance to put engines through the shop, it has inevitably resulted in the supply of mid-life engines getting reduced," says Polyi. "The demand is mainly coming from 767F, 747-400F and MD-11F operators. These will take a different approach to managing their engines compared to first-tier 747-400 and 767-300ER operators.

"The values and market for the CF6-80C2 and PW4000-94 are virtually identical, the two engine types originally winning about 50% market share each," continues Polyi. "It is now possible to buy run-out engines for $250,000-500,000. These are purchased for the value and use of three main types of used serviceable material (USM). These are the high pressure turbine (HPT) blades, the low pressure compressor (LPC) spool, and high pressure compressor spool (HPC). If these can be taken in relatively good maintenance condition they can produce worthwhile savings in an engine shop visit. There are no other parts that are worth salvaging from engines, such as fan blades and cases, since all other components have long lives and a slow turnover rate. There is consequently a surplus of these on the market."

Polyi puts the market value of engines with a half-life maintenance condition at $750,000-1.5 million. "The actual value will depend on the engine's exhaust gas temperature (EGT) margin and its remaining LLP lives, and consequently its probable remaining on-wing life," says Polyi. "Values at this level explain why airlines are interested in green time engines, and not putting engines through shop visits."

The market value of engines in a high maintenance condition are $3.0-3.5 million. "This compares to a core value of about $0.5 million and a shop visit cost of about $2.5 million," says Polyi.

Ackerman agrees on the value of zero-time engines, but expects good quality engines to achieve higher values. "An engine for part-out and breakage for USM has a value of $0.5 million; whereas an overhauled engine, with LLPs that have more than half their life remaining, has a value of $4.0-4.5 million. An engine with LLP lives that allow just one more SV removal interval of four to five years will have a value of $3.5 million."

Polyi comments that while supply of engines is high and values are low there will be little shop visit activity, but Magellan sees that the surplus of green time engines is diminishing, and expects this to stimulate demand for shop visits in the future.

In the meantime, airlines have changed their approach to leasing these types of engines. "Operators are either paying a fixed monthly fee for the engine plus a maintenance reserve, or paying a fixed rate per EFH, with varying rates of utilisation," says Polyi.

Ackerman puts lease rentals of CF6-80C2s and PW4000-94s at $35,000-60,000 per month, depending on the maintenance status. Polyi says that with a maintenance reserve included, the rate will be $50,000-75,000 per month. The reserve is only for shop visit maintenance, and does not include LLPs. The engines are often leased until they become unserviceable, and then retired without maintenance being performed. - *CHW* AC