The global engine fleet has evolved, with new technology powerplants fast superseding older technology engines. The engine fleet has grown fast and will continue to grow at a fast rate. Global engine maintenance demand and capacity is reviewed here.

Global engine shop activity survey

Despite the economic downturn, many of the world's engine shops are actually expanding their engine capabilities and capacity.

This is a trend that seems to have changed little over the past decade *(see Engine shop visit demand & capacity, Aircraft Commerce, August/September 2001, page 25)*, with many of the engine shops' capacities exceeding demand by about a third. While some currently operate to their maximum capacity, others will have excess to cover variations in demand, as well as to prepare for any new engine types.

Some facilities, such as Aveos Fleet Performance Inc., have a much larger capacity compared to their actual annual throughput, but maintain staffing levels at a lower level, meaning that their realistic capacity is much smaller, unless additional labour can be employed. This is one way that engine shops have of dealing with the economic downturn, as well as having the additional capacity (such as when spikes in demand occur) through overtime or additional staff. Facilities that are close to, or have reached, their maximum capacity continue to grow, despite the poor state of the global financial market, since engines still need to be overhauled at the start and end of their leases even when operators are trying to reduce the size of their fleets. Such facilities are Ameco Beijing, Lufthansa A.E.R.O. Alzey GmbH, MTU Maintenance Zhuhai, and Singapore Aero Engine Services Pte Ltd (SAESL), as well as the new Pratt & Whitney (PW) Engine Centers in Turkey and Shanghai. It can be no coincidence that many of these facilities are in the Asia Pacific region and, in particular, China, where the recent steady growth of the aviation industry is showing no signs of abating.

The following survey is looking at the current engine-overhaul activity of most, if not all, of the global engine shops. We are looking at engines of at least the size that power regional jets (RJs), and that are readily available around the world. Therefore, engines that power turboprops, business jets or general aviation have not been considered, nor have military engines (both on transporters or fast jets) and those from the former Soviet Union.

Engine-overhaul market

At the start of this century, the engine repair and overhaul market was dominated by the original equipment manufacturers (OEMs) and a few major airlines. This is still the case today, but not necessarily in quite the same way. Major airlines such as Lufthansa and Delta have a large share in the market place, the former by having subsidiary and joint venture (JV) facilities all over the world. Not all the OEMs are involved in maintenance, but the main ones are General Electric (GE), PW and Rolls Royce (RR).

As fleets have developed over the past two decades, the variety of aircraft, and therefore engine models, has increased. The reliability of the engines has also improved. A much more recent development has been for airlines to use smaller RJs, as well as the traditional short-haul aircraft, on feeder routes.

While the increased variety of aircraft and their engines in the market may seem to suggest that these will prompt a growth in engine shop requirements, this is dampened by the reliability and longer maintenance intervals of modern engines. The newer developed engines on modern and next-generation aircraft have longer shop visit intervals compared to those in regular operation 10 or more years ago. For example, the engines on older 737s, such as the CFM56-3, had first removals of 7,000 to 18,000 engine flight cycles (EFCs), with subsequent removals of 5,000-10,000EFC, depending on the thrust rating *(see CFM56-3 maintenance analysis & budget, Aircraft Commerce, April/May 2006, page 18)*. Newer 737s, equipped with CFM56-7B engines, have first removal intervals of 11,000-20,000EFC, with subsequent intervals of 8,000-20,000EFC. Again, this depends on the thrust rating. On first viewing, the removal intervals do not seem that much improved, but the minimum recommendations are much longer in each interval on the newer engines. These also have much higher thrust ratings than seen on the older engine model and slightly longer engine flight hour (EFH) to EFC ratios *(see CFM56-7B maintenance analysis & budget, Aircraft Commerce, June/July 2008, page 18)*.

There are a lot more new aircraft in operators' fleets compared to 10 years ago, and this has had an effect on the engines being repaired or overhauled. There is also an increasing demand for engine sale and leasebacks. This means that, although engines are considered more reliable and removal intervals are seen to be increasing, there are more engines in the system than a decade or two ago.

While there is a massive increase in new-generation engines now going through the engine shops, there is still a demand, for the time being, for the repair and overhaul of older engines such as the JT8D, which generally have shorter shop-visit intervals than more modern engines.

As the new-generation engines have come on line, OEMs have increased their presence in the maintenance repair and overhaul (MRO) market. Those that undertake MRO services have done so in a big way, with engine shops all over the world. It is fair to say that at least 30% of the global engine shops are a joint venture in some way with engine

SUMMARY OF ESTIMATED GLOBAL ACTIVE ENGINE FLEET

Engine OEM	Engine type	Installed engines (June 2009)	No. of annual shop visits in 2008 (by OEM)
CFMI	CFM56-2	2,136 *	2,438
	CFM56-3	3,298	
	CFM56-5A/-5B	4,314	
	CFM56-5C	952	
	CFM56-7B	5,660	
General Electric	CF34	5,400	2,138
	CF6-6	195	
	CF6-50	739	
	CF6-80A/-80C2	3,251	
	CF6-80E1	348	
	GE90	774	
Pratt & Whitney	JT3D	476	2,105
	JT8D	3,872	
	JT9D	574	
	PW2000	792	
	PW4000-94	1,841	
	PW4000-100	320	
	PW4000-112	328	
	PW6000	30	
Rolls Royce	AE3007	2,524	1,725
	RB211-22	24	
	RB211-524	726	
	RB211-535	1,100	
	Conway	60	
	Spey	176	
	Tay 600	523	
	Trent 500	456	
	Trent 700	526	
	Trent 800	440	
	Trent 900	48	
	BR700	1,728	
Other (inc. IAE, Honeywell, Superjet & Engine Alliance	V2500	3,326	1,076
	ALF502	578	
	LF507	636	
	SaM146	4	
	GP7200	20	
Total		**48,200**	**9,482**

*** Includes 1,860 military engines**

manufacturers.

Large airlines are the other major influence in the engine shop market, with some of the larger operators having their own engine shops. Not only do some have a main shop at their own base, but a few have also diversified into other continents. Lufthansa, for example, through JVs and wholly owned subsidiaries, has many engine shops in Europe, Asia Pacific and North America.

About 50% of the global engine shops are connected to an airline. About 75% of global engine shops are connected to either an airline or an OEM. Some, such as TAESL and HAESL, are connected to both. This leaves just a quarter of engine shops in independent hands. The largest of these independent companies include MTU Maintenance, ST Aerospace and SR Technics, all of which have invested in facilities on three continents.

Shop-visit demand

The fleet of installed engines was estimated in 2001 to be 38,000 units *(see Engine shop visit demand & capacity, Aircraft Commerce, August/September 2001, page 25)*. Flight's Aircraft Fleet & Analytical System (ACAS) shows that in June 2009 there were 48,200 active engines equipping RJs and larger types.

Spare engines account for 15% of the installed fleet, so about 7,500 spare units would be needed to support this current active fleet. There will be larger quantities of spares for older types once their fleet numbers have imploded following retirements.

The increase in the number of engines is likely to slow down over the coming years as operators defer new aircraft deliveries and older aircraft are parked, as a result of the economic downturn and airline re-structuring. OAG/AeroStrategy's latest commercial aircraft MRO forecast makes a conservative estimate for installed engines in 2013 of 52,361, as well as 57,831 installed units by 2018 (www.OAGaviation.com). The installed fleet is estimated to increase by an average of 981 per year from 2009 to 2013.

The global market for annual engine shop visits was worth $15,327 million in 2008 according to OAG/AeroStrategy, and is likely to rise by 9% by 2013, and by an additional 15% by 2018 according to the same source. This is despite the number of annual engine shop visits only increasing by 1.5% and 11.5% for the same periods. It follows that, for each engine, the fleet of installed and spare engines equated, in 2008, to 0.19 shop visits a year. This is about equal to one shop visit every five years. This compares to 0.26 shop visits per engine in the fleet in 2001, according to *Aircraft Commerce* data.

Using the forecasted data for 2013 and 2018 from OAG/AeroStrategy, an engine's average number of shop visits is likely to fall to 0.18 times a year, showing that the removal intervals and reliability of new-technology engines are indeed increasing. This could plateau, however, in the coming years until additional engine technology is introduced. The results that show a plateau could also be due to the fact that by 2018 many of the new-technology engines will require major engine shop visits, having been on-wing for a number of years.

There are about 28,000 of these new-technology engines, which reflects the trend towards more fuel-efficient, twin-engined aircraft. These new technology powerplants are the CFM56-5A/-5B, CFM56-7B, CF6-80E1, GE90, Trent family, V2500 and GP7200.

There are about 20,000 old-technology engines in operation, but this number is falling each year. The older engines include the CFM56-2, CFM56-3, CF6-6/-50/-80, JT3D, JT8D, JT9D, PW2000, PW4000-94, RB211 and ALF502/LF507.

Intervals between shop visits will differ between engine types, as well as between engine variants depending on the

aircraft they are fitted to, the operations they undertake, and the age of the engine itself. Younger engines have longer intervals than older types (which can have potentially less predictable reliability), and often higher daily & annual utilisation.

Individual types

Nearly 30 different engine types were examined on the ACAS June 2009 data, amounting to 48,200 engines used for RJs and larger types.

Of those, the most prolific engine type by far is the CFM56 with 16,360 active units *(see table, page 54)*. The most popular CFM56 models are the -7B (used on next-generation 737 aircraft) and the -5B (used on the A320 family of aircraft) with 5,660 and 3,336 engines respectively. It follows that the largest market is for the CFM56.

This is followed by the CF34 and CF6 families, with 5,400 and 4,533 active engines respectively *(see table, page 54)*. These figures show a large change in the market share over the past eight years. In 2001, figures suggested that the CF6 had a similar market size to the CFM56, and was one of the largest markets with about 1,800 shop visits annually. The CFM56 was correctly predicted to become the dominant engine in future years *(see Engine shop-visit demand & capacity, Aircraft Commerce, August/September 2001, page 25)*. But, as the article states, the CF6 fleet had already reached maturity in 2001, hence the reduction in its current market share. This is emphasised by the large drop in the popularity of its associated aircraft, the 747-400, 767-300, A300-600 and their predecessors, over the past eight years due to the availability of more efficient replacement aircraft. These include the 777 and A330/340. In addition, the long awaited A380 has now come on line to replace some 747s.

By comparison the CFM56 had 2,438 annual shop visits in 2008, according to AOG/AeroStrategy, compared to about 1,500 in 2001. The 2008 annual shop visit figures are forecast to rise by 18% to 2013, with a further 20% rise to 2018. This is an easy prediction, since there were over 2,000 orders for the CFM56 yet to be delivered in 2001, plus orders after that date. Many of these would now have been delivered, or be nearing major shop visits. In other words, the CFM56 fleet has grown over the past eight years by nearly 200%.

The CF6 is, in actual fact, now the third largest engine market. The CF34 has taken second place, with over 5,400 active engines showing in June 2009. This has a lot to do with the increased popularity of Bombardier and Embraer RJs in recent years.

The next engines in the pecking order are the JT8D, with 3,872 active engines, and the V2500, with 3,326 active engines *(see table, page 54)*. These two engines illustrate opposite ends of the technology scale. The JT8D is slowly on its way out, having powered older aircraft such as the 727 and DC-9, while the V2500 is a growth market as it powers many A320 and A319 aircraft. In 2001 there were 1,300 active V2500s (with 330 annual shop visits), meaning an increase of 155% in eight years. There are currently nearly 3,000 JT8D and just 80 V2500 engines parked according to ACAS, which backs up the idea that the JT8D fleet is shrinking fast.

The next two markets are also very different, despite having a similar number of active engines in operation. Both the PW4000 and AE3007 number about 2,500 engines *(see table, page 54)*, but represent extremes in operations. The PW4000, a successor to the JT9D, is an option to power long-haul, wide-bodied aircraft such as the 747-400, 767-300ER, MD-11, A330 and 777, as well the A300-600 and A310. Many of these aircraft are working towards the twilight of their careers, meaning that total numbers could well fall over the coming years, although the 777 and 747-400 fleets are still slowly increasing in size. The AE3007 is a much less powerful engine, which originally equipped many small

As the fleet develops large numbers of older engine types will be phased out. About 18,000 new-generation engines are forecast to enter the fleet over the next nine years, and this will have an impact on the engine overhaul and maintenance market.

executive jets, but is now found mostly powering the ERJ-145 family. The ERJ-145 is an RJ, so its shop-visit intervals and requirements are very different to those of the PW4000.

The BR700, PW2000 and RB211 engines each amount to 1,600-1,850 active engines in operation *(see table, page 54)*. The BR700 commercial aircraft market is likely to disintegrate quickly over the coming years, since it is the engine on the 717, although it also powers the corporate Gulfstream V. The RB211 engine consists of the -22, -524 and -535 variants, and has now been superseded by the RR Trent family. As such, the RB211's numbers are likely to fall, with 376 already parked according to ACAS. The -22 powered the L-1011, and most examples are parked, with just 24 engines being active. The -524 is used on the 747 (both -200 and -400) and 767, while the -535 was produced for the 757 and is more prolific with 1,100 active engines.

According to Total Engine Support (TES), the number of RB211-535E4 shop visits over the next three years is likely to remain stable or decline according to the aircraft fleet size. The RB211-535E4 can be expected to have about 200 shop visits each year. TES also says that there are about 105 spare engines in operation, equating to an additional 9% on top of the current active installed fleet, and it estimates that this number could rise as the relevant aircraft are parked or scrapped. The PW2000 is also used on the 757, and there are about 792 active engines, 400 more than the RB211-535. The PW2000 had about 360 shop visits a year according to 2001 data, but this number is likely to have since fallen. Both the RB211-535 and PW2000 are mature markets that will only decrease and be replaced by markets such as that for the Trent engine family and the GE90.

The Trent family of engines accounts for, in total, 1,470 engines and is divided into the Trent 500, 700, 800 and 900 models. There are about 500 engines for each model, except the newest, the Trent 900, for which there are about 50 *(see table, page 54)*. Each Trent model is treated as a separate engine type, so they are listed separately *(see table, page 54)*. This means that as individual engines they each represent a small market, but as an engine family, they are a considerable market. Whichever way they are considered, they are a growing market, with very few examples parked, and the aircraft they power (A330, A340, A380 and 777) all still popular. In addition, the Trent 1000 and Trent XWB will power the upcoming 787 and A350, again strengthening the Trent market. The vast majority of engine shops with Trent capabilities are, in fact, either wholly owned by RR, or are a joint venture (JV), with RR and another party. Therefore, although the market will grow, its growth will not benefit independent engine shops.

The GE90 accounts for over 770 active engines *(see table, page 54)*. The engine's fleet is roughly split 60/40 between the GE90-110/115 and GE90-7/8/9 with 440 and 334 engines respectively. This is compared to 200 active engines in 2001. It is an option on the 777, along with the PW4000 and Trent 800, although it is the sole engine option on more recent 777 models. This explains the fleet growth over the past eight years, and the likelihood that its numbers will again increase.

The remaining engine markets fall into two camps: new engines that are growing in numbers, and older engines that will very nearly not figure at all. The older engines account for just over 3,000 active engines, and include the ALF502 (BAe146), JT3D (707 and DC-8), JT9D (747-100 and A310), LF507 (Avro RJ), RR Conway (707 and DC-8), RR Spey (BAC1-11 and Fokker 28) and RR Tay 600 (Fokker 70, Fokker 100 and a re-engine of two BAC 1-11s and one 727).

The newer-technology aircraft that should grow in the coming years account for 54 active engines including the GP7200 (A380), PW6000 (A318) and SaM146 (Sukhoi SuperJet 100).

Engine markets that will develop in the coming years, but that do not figure in this survey, are for the GEnx, Trent 1000/XWB and PW1000G. These will power the 787, A350, 747-8 and Bombardier C-Series. These aircraft have already won large orders, with more due over the coming years.

Repair providers

Facilities that offer engine repair and overhaul capacity generally fall into one of three categories: the OEMs, independent companies and/or airline shops. In some cases a facility may fall into more than one category. SAESL, for example, is a JV between an airline and an OEM. HAESL is a JV between an independent MRO facility and an OEM.

The engine shops assessed are those that offer a full engine-overhaul service. Many smaller MRO facilities and airlines will have facilities to undertake minor repairs, but it is the facilities that can perform module disassemblies and full shop visits that are being considered.

Although there are at least eight engine OEMs, just four of them offer major engine repair and overhaul shops. These are GE Engine Services, Pratt & Whitney Engine Services, Rolls Royce Aero Repair & Overhaul, and Snecma Services. As mentioned above, they hold a significant share of the engine shop-visit market and often have the capability to overhaul competitors' engines.

The number of independent engine repair shops has declined in recent years, often because they have been acquired by

MAJOR ENGINE SHOPS - ASIA PACIFIC

Engine Shop	Engines covered	Module disassembly/ reassembly	Module disassembly to piece part	Location	Annual capacity	Actual annual throughput	New engine types	Specialist part repairs
Aerothrust - Christchurch	CFM56-7B			Christchurch New Zealand				
All Nippon Airways	CF6-80 CFM56-5A1F, PW4000	Yes	CF6-80 CFM56	Haneda Airport, Japan	200	190	CFM56-7B24 Trent 1000	
Ameco Beijing	PW4000-94 RB211-535E4 CFM56-3	Yes	Yes	Beijing, China	65	65 (50:50 PW& RR)		
China Airlines	JT9D-7R4G2 PW4000 CF6-80C2 CFM56-5C/-7B	Yes	Yes	Taiwan	100	75	CF6-80E1	HPC/HPT Case, grinding, HMU overhaul
Eagle Services Asia Pte.Ltd.	PW4000(94"&100") JT9D-7Q,-7R4 GE90-115B	Yes	Yes	Singapore	300	190 (185xPW4000, 5xJT9D) Preciously did 240		P&W EcoPower engine washing
GE Engine Services -Malaysia	CFM56-3/5B	Yes	Yes	Selangor, Malaysia	N/A	N/A		
GMF AeroAsia	CFM56-3 Spey555 CF6-50C	Yes	Spey CFM56	Jakarta, Indonesia				
HAESL	RB211-524C2/D4/ RB211-524G/H/G-T/H-T Trent 500/700/800	Yes	Yes	Hong Kong	250	210		
IHI Corporation	V2500-A1/A5/D5 CF34-3/-8/-10	Yes	Yes	Mizuho-machi, Tokyo, Japan	120xV2500 60xCF34	90xV2500 50xCF34	TBD	V2500 rubber panel crack repair, fan blade Cu-Ni-In coating repair, HPC blade/vane tip repair, fan blade L/E patch repair
LTQ Maintenance	CF6-80E1/C2 CFM56-3/-7	Yes	Yes	Melbourne, Australia	100			
MTU Maintenance -Zhuhai	CFM56-3/5/7	Yes	Yes	Zhuhai, China	200	160 & growing		
P&W Christchurch Engine Center	JT8D V2500	Yes	Yes	Christchurch, New Zealand	150			
P&W Shanghai Engine Center	CFM56				Up to 300		Open 2009	
PIA	CF6-50C2/E2 CFM56-3B	Yes	Yes	Karachi, Pakistan	15-20 for each engine line	15 for each engine		Robotic plasma flame spray, vacuum heat treatment
QANTAS	RB211-524G-T/H-T	Yes	Yes	Sydney, Australia	100	40-45	Trent 900 Spare Engine Management (not overhaul)	Plasma spray, machining, welding, heat treatment, sheet metal, composite, painting, shot peen, NDT, chemical clean
SAESL	Trent family	Yes	Yes	Singapore	250	233 for '09 & 250 '10	Trent XWB & poss Trent1000	Compressor blade repair, plasma spray, fan blade repair
Sichuan SNECMA Aero Engine SVS	CFM56-3/-5B/-7B	Yes	Yes	Chengdu, China		500 shop visits for Snecma globally		
ST Aerospace Engines	CFM56-3/5B/7B JT8D-std/-200 series plus smaller engines	Yes	Yes	Singapore & a new shop in Xiamen, China in 2010	400+	300+	Genx on-wing support	High speed grinding, Robotic plasma spray, High-velocity oxy-fuel flame spray, vacuum furnace heat treatment, wet glass bead peening, eddy current inspection, 6-axis auto welding
Thai Airways International	CF6-50/80 Trent 800 PW4158	CF6-50/80		Bangkok, Thailand	60	50		

MAJOR ENGINE SHOPS - EUROPE

Engine Shop	Engines covered	Module disassembly/ reassembly	Module disassembly to piece part	Location	Annual capacity	Actual annual throughput	New engine types	Specialist part repairs
Air France Industries	CFM56 CF6, GE90			France	275+	275 (60% CFM56, 30% CF6, 10% GE90)	GE90 is growing	
Alitalia Maintenance Systems	CFM56-5B CF6			Italy	62+	34 x CFM56 28xCF6		Majority of SV are LHT off load engines.
Finnair	CF6-80C2 CFM56-5B, PW2000			Finland			High speed grinding machine, engine condition monitoring	
GE Caledonian Ltd	CF6 family(all)	Yes	Yes	Prestwick, Scotland, UK	N/A	N/A	GEnx	
GE Engine Services - Wales	GE90, GP7200 CFM56-3/-5/-7	Yes	Yes	Cardiff, Wales, UK	N/A	N/A		
Iberia	RB211-535E4/535C37 CFM56-5A/5B/5C/7B JT8D-200, CF34-3A/3B	Yes	Yes	Madrid, Spain	240	180 in 2009 200 in 2010	TBC	
JatTehnika	CFM56, JT8D-STD		Yes	Belgrade, Serbia	60xCFM56 10xJT8D	20xCFM56 10xJT8D	CFM56-7	Machining, welding, thermal spray,
KLM Engineering & Maintenance	CF6-80C2/-50/-80E CFM56-7B			The Netherlands		160 (100 CF6-80C2, 40 CFM56-7B)		
Lufthansa A.E.R.O. Alzey GmbH	CF34-1/-3/-8 + smaller engines	Yes	Yes	Alzey, Germany & Tulsa, OK, USA	465 engines p.a.	450 in 2008 Increase to 800 p.a.	CF34-10E	
Lufthansa Airmotive Ireland	CFM56 family(all) JT9D family (all) V2500-A5	Yes	Yes Ireland	Rathcoole, Dublin,	130-140	100-110	V2500-A5 has only just been added	
Lufthansa Technik	CFM56-3/-5/-7B CF6-80C2 V2500, PW4000-94	Yes	Yes	Hamburg, Germany & shops+parts repair globally	No comment	Lufthansa Technik =1000+ events globally	CF34-10	
MTU Maintenance - Berlin	CF34-1/3/8/10E + other smaller engines	Yes	Yes	Berlin-Brandenburg, Ludwigsfelde, Germany	500 small engines	340-380 shop visits		
MTU Maintenance - Hannover	CFM56-7 CF6-50/-80C2 V2500-A1/A5/D5 PW2000, PW6000	Yes	Yes	Hannover, Germany	680	320-400		
MyTechnic	CF6 series	Yes		Istanbul, Turkey			JT8D-200 series	NDT
N3 Engine O/H svcs	Trent 500, 700	Yes	Yes	Arnstadt, Germany	200	80	Trent 900	Many specialist
P&W Norway Engine Center	CFM56-3,-5B/P,-7B	Yes	Yes	Stavanger, Norway	100+	79?		
P&W Turkish Engine Center	CFM56 V2500-A5				Up to 200		Open 2009	
Rolls-Royce Aero Repair & O/H	Trent 500/700/800 RB211-535/-524			Derby, UK	150+	150+ engine & 700+ modules		Component repair expertise
Rolls-Royce Deutschland	BR700	Yes		Germany				Technical & spares support, Non-destructive testing
Rolls-Royce East Kilbride	V2500, AE3007 Spey & Tay			Scotland, UK	400+	400+ engines & 800+ modules		Component repair specialist
SNECMA Services Brussels	CFM56-2/-3/-7B	Yes	Yes	Brussels, Belgium		500 shop visits for Snecma globally		Combustion chamber repair
SR Technics	CFM56-5 & -7B PW4000-94"/100" Tay 650, Trent 700 V2500, CF-80	CFM56 PW4000	CFM56 PW4000	Zurich Airport, Switzerland	320 engines	253 full shop visits for 2008	TBC	
TAP Maintenance & Engineering - Portugal	CFM56-3/-5C/7B RB211-524B4/D4 JT8D-STD, JT3D	Yes	CF6-80C2A2	Lisboa, Portugal	120	110		Machining, plating, spray, arc spray, coating applications dabber TIG welding, high temperature vacuum brazing
Turkish Technic	CFM56-3C/-5C2F/-5C4 CF6-80A3/-80C2 V2500, LF507-1F	Yes		Istanbul, Turkey	75+	75 for 2009		Cleaning, surface treatment, balancing, inspection

MAJOR ENGINE SHOPS - NORTH AMERICA

Engine Shop	Engines covered	Module disassembly/ reassembly	Module disassembly to piece part	Location	Annual capacity	Actual annual throughput	New engine types	Specialist part repairs
Aerothrust -Miami	JT8D CFM56-3			Miami, USA				
APECS Engine center	JT8D - series	Yes	JT8D Baby JT8D-200	Kendall, Florida, USA	25	25	CFM56	
Aveos Fleet Performance Inc.	CF34-2/-3/-5 CF34-8C/E CF34-7/-10 -growing cap. JT9D-7 series	Yes	Yes	Dorval, Quebec, Canada	200 x CFM56 100 x CF34 30 x JT9D	125 x CFM56 50 x CF34 20 x JT9D	Growing cap. CF34-7/-10	Combustion Liners & Casings for all engine models listed
Aviation Engine Services	JT3D JT8D	Yes	Yes	Miami, USA				
Bizjet International	Spey 511-8 Tay 611-8 plus smaller engines	Yes	Yes	Tulsa, OK, USA	50	30-50		
Dallas Airmotive	Tay 600 series	Yes	Yes	Dallas, Texas	NA	NA	NA	Component & Accessory repair
Delta TechOps	JT8D-219 PW2000 PW4000-94 CF34-3A/3B CFM56-3/5B/7 CF6-80A/-80C	Yes	Yes	Atlanta, Georgia, USA	1000	650+	CF34-8C	Full overhaul, restoration & hospital visits, internal repair capability
FJ Turbine Power Inc.	JT8D			Florida, USA				
GE Engine Services -Strother	CF34-3/8/10 CFM56-2/3/5/7 CT7 T700	Yes	Yes	Strother, Arkansas City, Kansas, USA	N/A	N/A		
Honeywell -Phoenix	ALF502/ALF507			Phoenix, USA				
MTU Maintenance - Canada Ltd	CFM56-3 CF6-50	Yes	Yes	Vancouver, Canada	70	40-50 shop visits		
P&W Cheshire Engine Center	JT9D (all except -7Q) PW2000 PW4000 (all models)	Yes	Yes		200			
P&W Columbus Engine Center	V2500			Columbus, USA	300			
Rolls-Royce - Canada Ltd	BR700 RB211-535 Tay, AE3007							Blade cell casing specialist repairs
TAESL	RB211-535E4 Trent 800	Yes	Yes	Fort Worth, USA	300	200		Component repair, Piece part repair, Accessories
TIMCO Engine Center	JT8D-7/-17/-200	Yes	Yes	Oscoda, USA	300	about 200		
United Services	CFM56-3 PW2000 PW4000			San Francisco, USA				

the OEMs. An engine shop that has remained independent and, in particular, has a global coverage, is MTU with at least four engine shops on three continents. The other main independents are SR Technics in Europe, ST Aerospace in Asia Pacific and Timco in North America.

GE has extended its share of the market over the past 10 years by buying, or entering into JVs with, the engine shops of airlines (such as British Airways and Malaysian Airlines), or independent companies (such as Aviall). This has resulted in at least five large engine shops on four continents, in addition to at least five other smaller shops. This has also enabled GE to gain expertise in engines other than their own, when the shop has additional capabilities, to cover all of an airline's fleet.

Pratt & Whitney (PW) and Snecma have also followed a similar path. PW now has at least six large engine shops on three continents, with two of those engine shops opening this year as JVs with airlines. Snecma has also formed a JV with airlines, meaning that they now operate at least four large engine shops on three continents.

The last engine-shop type, the airline shop, has been fluctuating a great deal. Many of the major North American and

MAJOR ENGINE SHOPS - SOUTH AMERICA, AFRICA & THE MIDDLE EAST

Engine Shop	Engines covered	Module disassembly/ reassembly	Module disassembly to piece part	Location	Annual capacity	Actual annual throughput	New engine types	Specialist part repairs
GE Celma Engine Services	CF6-50/80C2 CFM56-3/5/7	Yes	Yes	Rio de Janeiro, Brazil	N/A	N/A		
ITR	JT8D-std JT8D-200			Mexico				
Rolls-Royce Brazil	AE3007 Tay 600 Spey807 Trent family			Sao Paulo, Brazil				
Snecma America Engine Services	CFM56-5B/-7B			Mexico		500 shop visits for Snecma globally		
TAP Maintenance & Engineering, Brazil	PW118/A/B PW120/A PW121 PW125B T56	Yes	Yes	Porto Alegre, Brazil	60	38	PW127 (end '09)	Machining, plating, plasma spray, arc spray, coating applications, dabber TIG welding
EgyptAir Maintenance& Engineering	V2500-A1/A5 CFM56-5C/3C PW4090/4158 Trent 772B	CFM56-3C PW4090/4158 Trent 772B	V2500 A1/A2 CFM56-5C	Cairo, Egypt	70	30	CFM56-5B CFM56-7B	Minor repairs, at present
SNECMA Morocco Engine Services	CFM56-3/-7B			Casablanca, Morocco		500 shop visits for Snecma globally		
South African Technical	JT9D JT8D RB211 V2500 CFM56-3/-5C/-7B			Johannesburg, South Africa				
Bedek Aviation (Divn of IAI)	JT3D-3B/-7 JT8D-7A thru 17R JT8D-200 series JT9D series CFM56-2/3/5/7	Yes	Yes	Ben Gurion Intl. Airport, Lod, Israel	500	400	V2500 CF34 CF6-80	High pressure turbine blades
Jordan Airmotive	JT3D JT8D - std RB211-524 series CF6-80C2 (partial cap) CFM56-5A (partial cap)	Yes	Yes	Amman, Jordon	45	36	Full cap on CF6-80C2 & CFM56-3	Machining, Heat treatment, NDT, welding, plating, shot peening, balancing & testing
ADAT - Abu Dhabi Aircraft Technologies	CFM56-5A/-5C CF6-80C2/-50 Trent 700	Yes	Yes	Abu Dhabi, United Arab Emirates				Machining, plasma spray, heat treatment, plating, welding, balancing

European airlines have had, and still operate, engine shops. But, many have sold off their engine operation, formed JVs with OEMs or closed down their shop and contracted the work out. Therefore, those airlines that do still offer this service have grown to offer a large third-party capability (within their specialised engines), such as with Delta TechOps, Lufthansa Technic (LHT), Aveos Fleet Performance, Iberia, Qantas and TAP Maintenance and Engineering (TAP). TAP, and LHT in particular, are airline maintenance departments that have also gone into ventures in other continents, to expand their capabilities, capacity and market share.

Asia Pacific

There are a number of engine shops covering a fair amount of the Asia Pacific region. The main ones are in Australia, China, Indonesia, Japan, Malaysia, New Zealand, Pakistan and Thailand. There are other facilities in the region that offer engine component capabilities, but the main shops are those that offer full engine overhaul facilities for relevant large engines *(see table, page 60)*. There is a fair mix of OEMs or airline-connected engine shops in the area, as well as a few independent shops.

For those facilities that have given their maximum annual shop capacity, the region's maximum capacity for 2009 stands at over 2,500. This figure includes PW Shanghai Engine Center which is due to open this year. The actual throughput of the region's engine shops is nearer to 1,500 shop visits for the past year.

The maximum capacity available shows that the region could, in theory, accommodate more than a quarter of all global engine shop visits. As well as the PW facility in Shanghai, MTU's facility at Zhuhai is expecting growth, while Ameco Beijing has reached its capacity and Singapore Aero Engine Services Ltd. (SAESL) is expecting to reach its capacity in 2010.

The growth in the Asia Pacific region is clear to see, not only in the capacity increases, but also with the additional new engine capabilities that are being offered for the near future. SAESL plans to add the Trent XWB to its capabilities, and possibly the similar Trent 1000. All Nippon Airways is to add the Trent 1000 and CFM56-7B in response to its fleet growth, and ST Aerospace is to offer on-wing support for the GEnx that could develop into full overhaul capability.

Many facilities, such as IHI Corporation, are also in the process of deciding on new engine types.

There are more than 10 different large engine types that are overhauled in the major Asia Pacific shops, but it is often only one or two different shops that do each type. The most popular engine type is understandably the CFM56, which is overhauled by at least half of the shops, followed by the CF6, which is overhauled by a quarter of the shops.

The largest shops in the region are Eagle Services Asia, Hong Kong Aero Engine Services Ltd (HAESL), PW Shanghai Engine Center, SAESL and ST Aerospace Engines, each of which has the capacity to overhaul at least 250 engines each year.

Europe

Europe possesses the majority of global engine shops with at least 24 main shops, not including some of the smaller subsidiaries or airline shops *(see table, page 61)*. Exactly half the engine shops are connected to airlines and just over a third are directly run by, or are connected to, an OEM. Just four engine shops are completely independent. The main shops are located in Belgium, Finland, France, Germany, Ireland, Italy, The Netherlands, Norway, Portugal, Serbia, Spain, Switzerland, Turkey and the United Kingdom.

Europe's annual shop-visit capacity is at least 3,900. This figure includes the capacity of PW's Turkish Engine Center, which opens this year, but it excludes the additional increase in capacity that Lufthansa A.E.R.O. Alzey is planning for the next few years, or Lufthansa Technik's and Snecma's annual capacity, which is shown as a global figure (although most of Lufthansa Technik's shop visits are in Europe). Europe's engine shops probably complete 4,500-5,000 shop visits per year, accounting for up to 50% of the global market.

Of those European shops that have given *Aircraft Commerce* their actual throughput, the total comes to just over 3,000 shop visits, not including module repair. While a few of the smaller engine shops are close to reaching their current maximum capacity, there are a number of shops that still have a lot of capacity available to fill. This includes Iberia, Lufthansa A.E.R.O. Alzey, MTU Maintenance Berlin, MTU Maintenance Hannover, N3 Engine Overhaul Services and SR Technics. Air France Industries expects its GE90 capacity to increase.

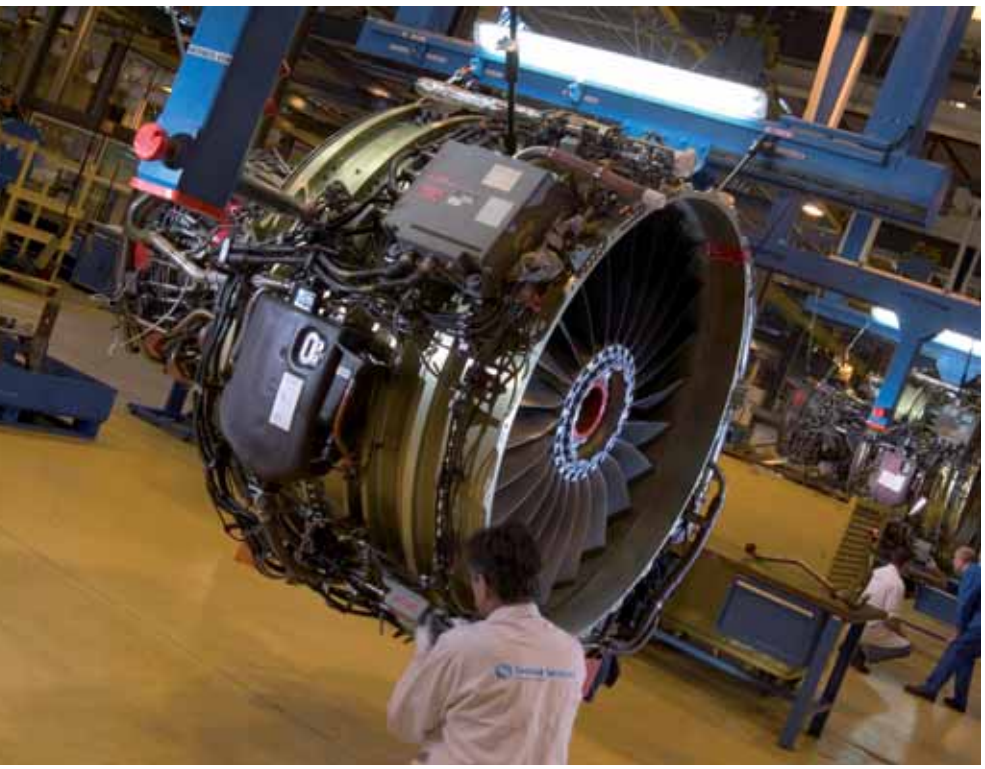
Both Iberia and Lufthansa A.E.R.O Alzey plan to increase their maximum annual capacity over the next few years, and many of the European shops are introducing new engine types into their list of capabilities. GE Caledonian plans to introduce the GEnx when it comes on line, and N3 Engine Overhaul Services will introduce the Trent 900 in 2010. Other shops intend to increase the number of models of an engine that they can overhaul. For example, two of Lufthansa Technik's maintenance facilities will do so in order to reflect the increased use of E-Jets in its short-haul fleet.

North America

The engine shops of North America are in both Canada and the United States, although the vast majority are located in the southern states of the US. Again there are many facilities in North America that offer capability on engine components as well as on-wing maintenance, but the main shops are those that offer full overhaul *(see table, page 62)*. Again there is an even mix of OEM, airline and independent engine shops with all the OEMs represented except Snecma.

The maximum annual engine-shop capacity for the region (as supplied by shops for this survey), is over 2,500 shop visits. This figure could well be a lot higher, since one of GE's largest shops is located in Strother, Kansas and its capacity was not available. The actual throughput for the region, not including GE Engine Services Strother, is at least 1,370. This shows that North America is more than capable of overhauling a quarter of the global engine fleet, when looking at maximum capacity. While a few engine shops (such as APECS Engine Center) have reached their current capacity, others (such as Delta TechOps, TAESL and TIMCO Engine Center) have a lot of excess capacity.

Both APECS Engine Center and Aveos Fleet Performance intend to increase their CFM56 capabilities in the near future, while Aveos and Delta TechOps will be increasing their CF34 capabilities. This capability growth echoes the fleet changes that operators globally, and in particular North America, are undertaking. More airlines are parking their older aircraft and updating their fleets. A recent move has been towards the use of larger RJs on



The population of civil variants of the CFM56 is more than 14,000 engines, making it the most dominant type in the fleet. Its numbers will continue to increase as outstanding A320 family and 737NG orders are fulfilled.

many short-haul routes previously operated by 737 Classics and turboprops *(see Large regional Jets: the C Series, MRJ, Superjet 100 & E-Jet families, Aircraft Commerce, April/May 2009, page 24)*.

While the North American market is full of new engine technology, it also has a lot of older engines. This is reflected in the range of engines that are overhauled in the North American region, which amounts to about 20 engine types. At least half of these would be considered old, having been launched at least 20 years ago. About 35% of the engine shops offer JT8D capability, which is the same percentage that offer capabilities on the CFM56. These two engines are two of the most well served in terms of the number of shops that offer capability, with the CF34, Tay 600, PW2000 and PW4000 following. The JT8D fleet is likely to contract over the next five to six years as large numbers of 727Fs are retired. The larger JT8D-200 powering the MD-80 will remain an important engine.

The largest engine shop in the region is by far Delta TechOps, which has the capacity to overhaul up to 1,000 engines annually. Other large shops include Aveos Fleet Performance, PW Columbus Engine Center, Texas Aero Engine Services Ltd (TAESL) and TIMCO Engine Center, which each have the capacity to overhaul at least 300 engines annually.

Rest of the world

South America, Africa and the Middle East have much smaller engine markets than North America, the Asia Pacific or Europe. This emphasises their much smaller fleets and the fact that, traditionally, much of their maintenance has been completed at the big engine shops in Europe and North America.

Within the South American region there are only about six engine shops, but this number does include GE, RR and Snecma. The majority of shops are found in Brazil, with Snecma locating its shop in Mexico, and Aerolineas Argentinas in Argentina. The engine shops in this area seem to concentrate predominantly on those engine types operated on smaller aircraft, or that are older technology. Having said that, the engine shops of GE, RR and Snecma do also have capability for some of the newer variants of older engines.

There are three main engine shops in Africa, and all of them are connected to an airline. Northern Africa has EgyptAir Maintenance & Engineering and SNECMA Morocco Engine Services (connected to Royal Air Maroc), while southern Africa has South African Technical. At least seven types of engine are overhauled, the most common being the CFM56 which is overhauled by all three engine shops. South African Technical has a fairly even split between older and newer technology, while EgyptAir Maintenance & Engineering seems to concentrate on relatively newer engines, reflecting EgyptAir's modern fleet.

The Middle East has just three main engine shops, all of which are unconnected to OEMs. These are located in Israel, Jordan and United Arab Emirates. Bedek Aviation alone can accommodate 500 engines a year, and currently operates at 80% capacity.

All three shops overhaul the CFM56, while at least two have capability on the JT3D, JT8D and CF6-80. All of these facilities offer a vast range of repairs including airframe, line and base maintenance within their own facility (Bedek and Abu Dhabi Aircraft Technology), or by being connected to an MRO facility (Jordan Airmotive through JorAMCo). The Middle East has seen some incredibly large growth in the commercial aviation market and the engine shops will be no exception to this. Jordan Airmotive intends to upgrade its capabilities on both the CF6 and CFM56, while Bedek intends to add three new engine types to its capabilities. It will add the CF6-80, like the other two shops, and also the V2500 and CF34 engines.

Looking forward

The profile of the engine fleet will change between now and 2018. A large number of older generation types will be retired. These include the CFM56-2, CF6-6, CF6-50, JT3D, JT8D Baby, CF6-50, RB211-22B, RB211-524, Conway, Spey and ALF 502. Their current numbers total 9,556 engines, accounting for 20% of the fleet.

While not all of these will be retired, airlines operating most of the aircraft they power have plans to retire them. Moreover, most of these aircraft/engine types have poor operating economics with high fuel prices. Most CFM56-2s power military RC-135s, and many CF6-6s will remain in service with FedEx's MD-10s. Many of these other engines will retire, however.

Over the same period, the engine fleet will grow to about 57,800 engines. We can therefore expect to see the number of new-generation engines in the fleet increase by about 18,000 units. Many of these will be CFM56-5s/-7s, V2500s, CF34s, Sam146, GE90s, GEnxs, Trent variants, and PW1000Gs. All will have longer shop-visit intervals, and many will be sold under total support packages. This change in the fleet profile could also see a consolidation in engine shops and the engine maintenance market. AC