The global jetliner fleet is forecast to increase by 40% over the next 10 years. Despite time lags for first removals, this fleet growth will result in an almost proportionate rise in the volume of heavy component repair and overhaul.

Future global demand for heavy component maintenance

Heavy components comprise a large portion of total aircraft maintenance costs. Many airlines sub-contract the repair of landing gears, wheels and brakes, thrust reversers and auxiliary power units (APUs) because of the large infrastructure required. This makes the market for heavy component repairs important for third party repair providers and original equipment manufacturers (OEMs).

The global fleet of jetliners larger than the Fokker 100/BAE Avro RJ is expected to grow by about 40% over the next 10 years. Despite this, component repair providers cannot expect a proportionate increase in the size of the heavy component repair market because of improved reliability and repair intervals. How can the heavy component repair market be expected to develop?

Fleet development

The current fleet of jetliners larger than the Fokker 100/Avro RJ totals about 13,300 units (see table, page 36). This comprises about 5,200 older generation aircraft and 8,150 younger or current generation aircraft. Older generation aircraft therefore account for about 40% of the fleet.

The older generation fleet is split between about 4,460 narrowbodies and 740 widebodies. The narrowbody fleet includes about 200 four-engined 707s and DC-8s, which are ageing and being phased out at a high rate by remaining operators. These are predicted to halve by 2013, with a few niche carriers remaining. About 640 three-engined 727-100/-200s are also in operation, and are also being phased out by most operators. Forecasts are that about 380 will still be in operation in 2013.

The DC-9, 737-100/-200, 737-300/-400/-500, MD-80 and MD-90 account for the majority of narrowbodies, and total about 3,600 units in the current fleet. The majority are expected to be operational in 2013. Only 737-100/-200s and DC-9s are expected to have been phased out of operation in large numbers by 2013, while the majority of 737-300/-400/-500s and MD-80/-90s are expected to still be flying. Overall, about 3,100 older generation narrowbodies are forecast to be in operation by 2013, along with most of the older generation widebody fleet. The number of A300B2/B4s, operating as freighters, may have halved. While most DC-10s and L-1011s will have been retired by this point, the number of MD-11s will have changed little since the aircraft is popular as a freighter.

The number of 747-100/-200/-300s currently totals about 350, and 275 of these are expected to remain in service by 2013. The majority of these will be as freighters, although a small number will still be in passenger configuration.

The younger and new generation fleet is expected to see a net increase of 6,100 aircraft, from about 8,150 units to 14,250 in 2013. This represents an average annual addition of about 600 aircraft. While this delivery rate is high, growth in the fleet and demand for capacity will keep the majority of older generation aircraft in operation.

The main difference between the older and younger generation fleets is that most aircraft in the latter are twin-engined. The narrowbody fleet comprises 717s, 737NGs, 757s and A320 family types, and totals about 5,100 aircraft. The 757 will only increase by a few units up to 2006 while the last few on order are built, and will account for just over 1,000 of the fleet. The 737NG and A320 will form the majority of narrowbodies, with the 717 accounting for a minority of aircraft. The number of young and current generation narrowbodies is forecast to rise by about 4,300 to a total of 9,400 by 2013, with annual deliveries adding to the fleet at a rate of about 400 per year. The A320 family and 737NG fleets will account for virtually all of this increase, except for a few 717s.

The young and new generation widebody fleet totals about 3,060 aircraft, with a split between twin-engined and four-engined aircraft.

The twin-engined fleet includes the 767, 777, 7E7, A300-600, A310 and A330, and totals about 2,160 units. The A300-600 and A310 are included in this group since they remain in production. The A300-600 fleet will actually continue to grow because freighters remain on order. The 767 fleet will experience a small decline over the next 10 years, as the last few aircraft are built and the oldest ones are retired. The 777, 7E7 and A330 will account for the growth in the widebody twin-engined fleet, which is forecast to reach about 3,300 units by 2013: an overall increase of 1,100 aircraft. The first 7E7 deliveries will be in 2008, and so the fleet will only have grown to about 160 by 2013. The 777 and A330 will therefore account for the majority of twin-engined widebody fleet expansion.

The 4-engined widebody fleet is forecast to grow by about 650 aircraft from the current fleet of 900 to 1,550. This will be an average annual delivery of 65 units, the majority of which will be accounted for by the A340 and A380. The 747 and its derivatives will also account for a minority of the increase.

CURRENT FLEET & FORECAST FLEET DEVELOPMENT: 2004 TO 2013

Year	2004	2008	2013
Older generation aircraft			
DC-9, 737-100/-200, 737-300/-400/-500, MD-80/MD-90	3,620	3,585	3,122
727-100/-200	640	554	386
707/DC-8	203	136	90
Total narrowbodies	4,463	4,275	3,598
A300B2/B4	105	77	60
DC-10/MD-11	277	268	232
747-100/-200/-300	352	331	274
Total widebodies	734	676	566
Total older generation	5,197	4,951	4,164
Young/new generation aircraft			
717, 737NG, 757 & A320 family	5,087	6,756	9,403
767, 777, 7E7, A300-600, A310, A330	2,162	2,627	3,272
747-400, A340, A380	896	1,160	1,551
Total young/new generation	8,145	10,543	14,226
Total fleet	**13,342**	**15,494**	**18,390**

Fleet implications

The younger and current generation aircraft will thus account for about 77% of the total fleet in 2013. The significance of this is that the fleet will have a higher proportion of aircraft with components that have longer removal and repair intervals. This is especially true of wheels, brakes, thrust reversers and APUs. The repair intervals for landing gears are similar for younger and older generation aircraft.

Another significant point is the reduction in the number of three-engined aircraft, mainly in exchange for twin-engined types. The current fleet has a total of about 920 three-engined and 1,450 four-engined aircraft, while twin-engined types make up the remaining 10,970 of the fleet. By 2013, tri-jets are forecast to have reduced in numbers to about 620, and four-engined aircraft will have actually increased to about 1,900 units. Twin-engined aircraft will account for the remaining 15,780 units. Overall, twin-engined jets will account for a similar percentage of the total fleet as they do currently. The forecast demand for large aircraft means that tri-jets are, however, expected to make way for four-engined aircraft. This would result in an increase in the number of installed engines of about 36%, similar to the predicted growth in fleet numbers. This has a direct implication for the volume of thrust reverser repairs.

Thrust reversers

Thrust reversers are maintained on an on-condition basis. The intervals for repair are flight cycle (FC) related, and are longer for younger and modern generation aircraft compared to older generation aircraft. The proportionate rise in numbers of installed engines to fleet growth means the growing popularity of twin-engined aircraft will not offset the effects on longer repair intervals.

Removal intervals for older narrowbodies such as the 737-200, DC-8 and MD-80 are in the region of 6,000FC. Given that their rate of utilisation is about 2,000-2,500FC per year, each thrust reverser is removed every 30-36 months. These aircraft total about 1,750, so have 3,500 installed reversers, therefore generating about 1,200-1,400 thrust reverser shipset removals per year. About 10% additional repairs will be required for unscheduled maintenance.

Thrust reversers on the 727 will have similar intervals of 30-36 months, and the three engines mean the fleet has about 1,900 installed engines. This generates in the region of 650-750 thrust reverser shipset repairs per year.

The 707/DC-8 fleets have about 800 installed engines and removal intervals of three to four years, thereby generating 200-300 shipset removals each year.

The reverser on the CFM56-3, powering the 737-300/-400/-500, has achieved longer intervals of up to 12,000FC. Similar rates of utilisation mean each reverser is removed about once every four or five years. The current fleet of 1,900 aircraft and 3,800 installed engines means that about 800 shipsets are removed each year.

The small A300B2/B4 fleet, with 200 installed engines, has a low rate of utilisation, and so will produce only about 30-40 shipset removals per year.

The DC-10 and MD-11 fleet have about 800 installed engines in total. These aircraft accumulate only 800-1,200FC per year, while thrust reverser removal intervals are in the region of 6,000-8,000FC. They are slightly higher for the CF6-80 engines than for the CF6-50s. Removal intervals are therefore longer than for other types, at six to 10 years, generating in the region of about 100 reverser shipset repairs each year.

The 747-100/-200/-300 fleet has about 1,400 installed engines. Annual aircraft utilisation is in the region of 800FC, while the reverser repair interval is about 5,000-6,000FC (a six to seven year period). The fleet will thus only generate about 200 shipset repairs each year.

In total, the older generation fleet might be expected to result in 3,200-3,600 ship repairs each year. This number will fluctuate, but will be relatively stable considering all aircraft types are in mature fleets. This does not take into consideration, however, that it is possible for many airlines to acquire time-continued reverser shipsets on the aftermarket at rates lower than the cost of a reverser shipset shop visit. While this can save money for a period it only defers maintenance since the supply of used reversers will diminish.

The issue with the younger and current generation fleet is more complex, because many aircraft are young, and there is a time lag of up to eight years before reversers are first removed. Mature aircraft are the 757, 767, 747-400, A320, A300-600, A310, A330 and A340. These types also have young aircraft, however, which have yet to have, or about to have, their first reverser removals. The youngest 777s, now about seven years old, will be having their first removals. The same is true for the 737NG.

The number of installed engines and thrust reverser shipsets will increase almost in proportion with the fleet. Removal intervals are longer for reversers on modern aircraft than they are for older generation types, but the annual volume should steadily climb as the fleet grows.

The younger generation fleet has about 5,100 twin-engined narrowbodies with 10,200 installed engines, which accumulate 2,000-2,500FC per year. Removal intervals are 10,000-12,000FC, equal to five to six years. A large portion of the 3,900 737NGs and A320s will thus not have generated any reverser removals so far. The fleet will only be producing 600-800 reverser shipset removals per year. The fleet growth of 500-600 aircraft should see this number increase by about 200 reverser removals per year.

The twin-engined widebody fleet has about 4,400 installed engines. Annual utilisations of 600-1,200FC and removal intervals of 6,000-10,000FC means 400-600 shipset removals per year would be expected for a mature fleet, but actual numbers will be less given the young age of some aircraft.

The 900 A340s and 747-400s in operation accumulate only about 500-650FC per year. Reverser removal intervals are 6,000-8,000FC, and so occur for the first time at an age of 10-13 years. This implies that 350-400 reverser shipsets will be removed each year if the fleet were mature. The oldest A340s will therefore have had their first removals while a larger portion of the 747-400 fleet is mature. The number of annual removals will thus only be in the region of 200.

The younger and current generation fleet may then only be expected to generate up to 1,000-1,200 reverser repairs per year. This will increase by about 300 shipsets per year as the fleet matures.

A large jump in the number of reverser repairs will occur as the wave of second removals for older types coincides with the first removals of younger types. In the case of the A320 this will have been about 11-12 years after the first aircraft entered service, which was in about 1999-2000. A further rise will be seen after another 4-5 years as the oldest aircraft have their second or third removals. This coincides with aircraft of five to six years old that are having their first removals.

The 737NG fleet will produce a steady stream of reverser repairs over the next few years as the first aircraft have their removals. The surge of second removals coinciding with the first removals of younger aircraft will occur in the 2008-2010 period. By this time the narrowbody fleet is forecast to have increased to about 7,650 units. Taking into consideration the time lag between aircraft delivery and first removal, the fleet will be generating about 2,000 reverser shipset removals per year. This will have increased to about 2,500 per year in 2013.

The time lag of nine to 10 years between aircraft delivery and first reverser removals on the twin-engined widebody fleet will result in about 500 reverser shipset removals by 2013. The number of removals for four-engined aircraft will total 400-450 given the long interval between aircraft delivery and first reverser repairs.

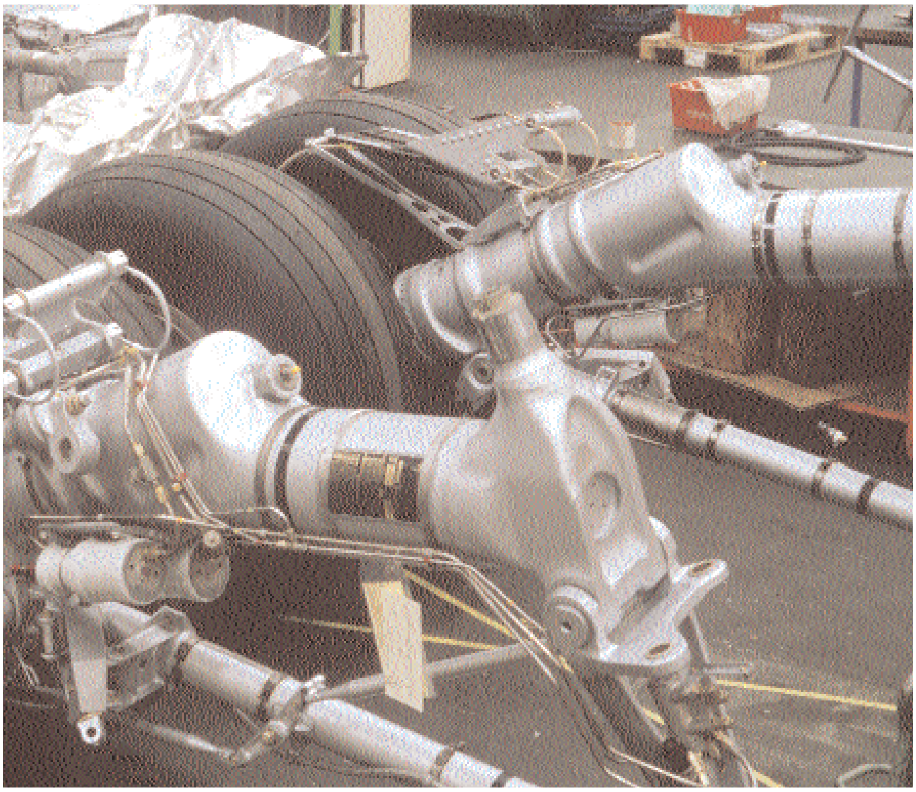
The reduction in the fleet of older aircraft will result in a proportionate decrease in the number of reverser shipset repairs. The interval for the 737-300/-400/-500 is expected to reduce to about 8,000FC as the fleet matures. Twin-engined narrowbodies will be generating about 2,100 reverser repairs annually, while 727s will be producing a maximum of 450. The 707 and DC-8 will be generating a minimal number, as will the A300B2/B4 fleet. The DC-10 and MD-11 fleet will only be producing about 80 shipset repairs annually, while removals from the 747-100/-200/-300 fleet will be less than 200. Older generation aircraft will be needing in the region of 3,000 shipset repairs per year. This small reduction compared to the current annual volume is a result of an expected decreased interval for the 737-300/-400/-500.

The younger fleet will generate a total of about 3,500 shipset repairs in 2013, taking the total volume to 6,700-7,000 for the whole fleet, against the current volume of 4,200-4,800 reverser repairs per year. Considering the time lag between delivery and reverser removal and forecast deliveries of up to 600 aircraft per year, the number of thrust reverser repairs could increase by about 200 per year after 2013.

Brake repairs

Brakes can broadly be divided between steel units used on older generation aircraft and carbon brakes used on younger types, although some aircraft can be fitted with either type. Removal intervals are FC driven, and average intervals vary. Carbon brakes have the advantage of being lighter and having about twice the removal intervals of steel units. Brake repairs are made when disk stacks reduce in width.

Typical removal intervals are 600-1,500FC for steel brakes and 1,600-2,500FC for carbon units. Intervals are influenced by aircraft weight and braking action by pilots at landing. Carbon brakes on the lighter 737-600/-700 might have an average interval of 2,000-



The majority of landing gears are removed about every eight years, and there is therefore a time lag between fleet growth and an increase in number of gear overhauls. The volume of landing gears overhauled in 2013 for younger generation aircraft will have a strong relation to the number of aircraft delivered in 2006.

2,200FC, while being about 1,700FC on the heavier 737-800.

Annual utilisations are 1,800-2,200FC for short-haul aircraft, 700--1,500FC for medium-haul types and 500-700FC for long-haul aircraft. This means there is only a small time lag between aircraft delivery and the first brake removals. The annual volume of brake repairs therefore closely reflects the number of aircraft in operation.

The volume of brake repairs is also determined by the number of brakes on each aircraft. Most narrowbodies have four units, while the 757 has eight. Most widebody twins have eight brakes, although the 777 has 12. The DC-10, MD-11 and A340 have 10 units, the 747 16, and the A380 20.

A 737-100/-200 generating about 2,200FC per year, and with an average brake repair interval of 800FC, will have an average of 11 brake repairs annually. In contrast, an A320 accumulating about 1,800FC per year and with a brake removal interval of about 1,800FC will have an average of four brake repairs per year. Most older narrowbodies will have 10-12 brake repairs each year, although types used in freight operations will have less because of lower aircraft utilisation.

Older widebodies will have nine to 12 brake repairs per year considering all factors, although the MD-11 will have only three or four because of a combination of longer removal intervals and low FC utilisation from long-haul operations.

Young narrowbodies operating on longer average FCs than their older counterparts will have annual utilisations in the order of 1,800FC. Combined with a carbon brake repair interval of 1,800FC, this means the 737NG and A320 will generate about four brake repairs per year, while the 757 will have about twice the number.

Most younger widebody twins with carbon brakes and utilisations of about 750FC will have four to five brake repairs per year, although aircraft with steel brakes will have about 10.

Long-haul four-engined aircraft will have four to seven brake repairs per year, depending on actual brake numbers.

On this basis, the current old generation fleet will generate 47,000-50,000 brake repairs a year. This will reduce to about 38,000 per year in 2013.

The young generation fleet will produce about 40,000 brake repairs per year, which will increase, with a small time lag with fleet growth, to about 66,000 repairs per year. The overall volume for the fleet is thus expected to increase from about 88,000 to 105,000 over 10 years with fleet growth. This is an increase of about 20%, which compares to a forecast increase in fleet size of about 40%. This demonstrates how the longer repair intervals partially offset the increase in fleet size.

Landing gear

Landing gear removals are related to FC and calendar intervals. Calendar intervals for all aircraft types do not exceed 10 years, and the average for most aircraft in operation is eight years. Some aircraft operating at high FC rates of utilisation may have shorter intervals of six or seven years. The number of landing gears repaired each year is a reflection of the number of mature aircraft in operation, which is related to the delivery profile of younger generation aircraft.

There are 4,500 older generation narrowbodies in operation. They have removal intervals in the region of seven years, so the fleet will generate about 650 landing gear shipset overhauls annually. Widebodies with lower rates of FC utilisation will have intervals of about eight years, and the current fleet of 930 aircraft will result in about 120 landing gear overhauls per year. Total for the older generation fleet will be 750-800 shipsets per year. The reduction in the older generation fleet will reduce this to about 600 per year in 2013.

The annual volume of landing gear overhauls for the younger generation fleet will be small in relation to fleet size, since only a small portion of 1,640 737NGs in service will have had a landing gear removal. Only about half of the 2,320 A320s in operation are not yet due their first landing gear removal. This leaves only about 1,000 aircraft that have had landing gear overhauls, generating an average volume of 125 per year. The eight-year time lag between delivery and overhaul means there will be a sudden surge in removals as large numbers of A320s and 737NGs have their first landing gears removed. Taking into consideration the forecast fleet size in 2006, the young generation narrowbody fleet could generate in the region of 650 landing gear overhauls per year. This large increase is a reflection of the large numbers of 737NGs and A320s that have been delivered each year, as well as the number that are forecast to be delivered.

In the case of widebody twins, the

mature 767, A300-600 and A310 fleet of 1,200 aircraft generate about 150 overhauls per year. There is currently only a small volume of A330 gear overhauls and the first 777 landing gears are due in the next two years. Taking into account the fleet forecast in 2006, the 777 and A330 fleet will be generating 125 gear overhauls per year in 2013, taking the annual total to 275.

The 747-400 and A340 fleets currently generate about 55 gear overhauls per year. The fleet of four-engined widebodies is forecast to be 1,000 aircraft in 2006, and so will result in about 125 gear overhauls in 2013. The number of annual gear overhauls for the younger generation fleet is thus expected to increase from about 250 per year to 1,000 annually in 2013.

APU shop visits

APU removal intervals are related mainly to APU hours. Most APU types have shop visit intervals of 1,700-3,000 APU hours, while more reliable types will have intervals of 4,000-6,000 APU hours.

APU removal intervals in relation to aircraft utilisation depend on APU operation. Across the fleet, there is an average of 1.5 APU cycles per aircraft FC. Short-haul aircraft have average APU cycle times of about 30 minutes, and so have about 50 minutes per aircraft cycle. Long-haul aircraft have average APU cycle times of 40-50 minutes, and so use about 90 APU minutes per FC.

On this basis, an APU removal interval of 2,500 APU hours for an older generation aircraft will be equal to an aircraft interval of about 3,000FC for a short-haul aircraft. This is equal to about 18 months for most operations. This will be reduced to about 1,700FC for long-haul aircraft, equal to two to three years for most operations.

An APU interval of 3,500 APU hours on a younger generation aircraft will be equal to an aircraft interval of 4,250FC for a short-haul operation, about two years' utilisation. Long-haul aircraft will have APU removal intervals of about 2,300FC, equal to four years' operation.

While these intervals mean there is some time lag between delivery and first APU shop visit, the spread and variation of APU intervals means the number of annual shop visits is closely related to fleet numbers.

The current fleet breakdown means older generation aircraft being used for short-haul operations will generate about 3,300 APU shop visits per year, and the number of old generation long-haul aircraft will result in about another 250 APU shop visits.

Young generation aircraft used in short-haul operations will generate about 3,000 APU shop visits each year, while long-haul aircraft will produce a total of about 500 APU shop visits per year.

The reduction in the older generation aircraft fleet will see the number of APU shop visits from the short-haul fleet decline to about 2,500 per year. Similarly, APU shop visits in the long-haul fleet will reduce to about 200 per year.

Growth in the young generation fleet will see a rise in APU shop visits to about 5,500 per year in 2013 for the short-haul fleet, and an increase to about 750 per year for the long-haul fleet.

Overall, the current fleet generates about 7,000 APU shop visits per year, being split about 50-50 for old and young generation aircraft. The development of the fleet is forecast to result in an increase in total APU shop visits to about 9,000. This increase is less than the growth in the total fleet size; improved APU reliability is partially offsetting the increase in aircraft numbers. About two-thirds of the total volume will be accounted for by young generation aircraft. AC