There are more than 6,000 CFM56-3s and -5A/Bs in operation. Despite several teething problems, their durability has contributed to efficient operating economics of modern narrowbodies. Re-rating to lower thrust is allowing many operators to achieve the lowest possible shop visit and life limited part replacement costs.

CFM56-3 & -5A/B maintenance costs

The CFM56-3 and -5A/B families have made significant contributions to improving the economic efficiency of narrowbody aircraft. The family concept and several thrust ratings have allowed re-rating to lower thrusts, which has, in turn, extended on-wing times. The engine's basic design also makes it durable, contributing to long on-wing times.

The economics of maintaining the CFM56-3 and -5A/B families is determined by several factors. On-wing times between removals will be the biggest influence on resulting cost per flight hour (FH). On-wing times will also in turn influence the shop visit workscope and its cost. Although long on-wing times generally reduce cost per FH, they also raise subsequent workscope costs.

The main determinant of on-wing time is degradation of exhaust gas temperature (EGT) margin. The higher the thrust rating for a particular variant the faster the rate of EGT margin deterioration and shorter on-wing time.

The second factor will be the engine's management with respect to life limited parts (LLPs). These are fixed in flight cycles (FC).

Because LLPs are expensive, the most economic maintenance management possible will be achieved so that the on-wing times of one, two or three runs equals the lives of LLPs. Re-rating to lower thrust is one way to aid this.

LLP lives throughout the engine vary, but are close *(see table, this page and page 32)*. This complicates on-wing management and operators have to decide how to deal with the variations.

CFM56-3 FAMILY CHARACTERISTICS

CFM56-3 variants	-3B1	-3B2	-3C1
Thrust ratings (lbs)	18,000 20,000	20,000 22,000	18,500 20,000 23,500
Aircraft applications	737-500 737-300	737-300 737-400	737-500 737-400
EGT margin	101	57	140/75/50
LLP lives FC:			
Fan & booster spool	30,000	25,000/30,000	20,000/30,000
HP shaft	20,000/25,000	16,000/20,000	16,000/20,000
LP turbine spool	25,000/30,000	25,000/30,000	19,000/30,000

The CFM56-3 family

The CFM56-3, which powers the 737-300/-400/-500 series, evolved in the mid-1980s. It was the first CFM56 variant to develop as a family for a family of aircraft.

The CFM56-3 first entered service as the -3B1, rated at 20,000lbs for the 737-300. It was subsequently de-rated to 18,000lbs for the 737-500.

-3B1

The -3B1 has an EGT margin of 101 degrees centigrade. EGT margin deterioration erodes at a rate of about three per 1,000FC. On-wing times for new engines are therefore likely to be up to the 20,000FC LLP life limit.

Shop visit workscopes then restore most of this EGT margin. The rate of deterioration of EGT margin increases on subsequent runs and so on-wing times are shorter. This also has to be borne in mind with respect to matching with LLP lives.

-3B2

The development of the 737-400 led to the -3B2 variant, rated at 22,000lbs. This could also be de-rated to 20,000lbs for the 737-300. The -3B2 therefore became the more popular engine, before the more flexible -3C1 was launched.

The -3B2 has an EGT margin of about 57 degrees when new. This deteriorates at a rate of about five degrees per 1,000FC at the 22,000lbs rating. Operators can therefore expect an on-wing time of about 10,000FC before removal is required. An average FC time of 1.2EFH will then result in a first run of about 12,000EFH.

Air France operates 61 -3C1s rated at 18,500lbs. Because the engine has a manufactured EGT margin of 140 degrees centigrade, the airline says the engine could remain on-wing for up to 45,000FCs. It is only because of the need to replace LLPs in the core that it is expected to remain on-wing for up to 20,000FC or 26,000EFH. Because EGT margin will still be about 75 degrees, the shop visit workscope is expected to be light.

Lufthansa operates a large fleet of 737-300s and -500s powered by -3B2s and -3B1s. It averages first-run on-wing times of 17,000–19,000EFH with -3B2 engines operated on a 1.0EFH FC time.

"We try to manage our LLPs to maximise their useful life and then replace them. We achieve this with those which have the shortest lives after the first run," explains Walter Heerdt, senior vice president powerplant at Lufthansa Technik. "Other LLPs with some remaining life either have to be sold or scrapped, since keeping them in the engine will cut short the second on-wing time. One method we use is to install them in other engines so that LLP lives can be matched to the performance life of the engine.

"The problem is that most CFM56-3s fly a 1.0EFH cycle and so it is difficult to avoid compromising the second run. LLP lives can be increased if the engines are de-rated," says Heerdt. "So we first use the LLPs in the -3B2 and at the first shop visit put those with remaining lives in a -3B1. We also swap LLPs between different rated engines. Basically we try to build engines so that the remaining EGT life is about equal to LLP lives.

"Ultimately it is impossible to have perfect engine management. LLPs with lives of 20,000FC are the trouble-makers. They last longer than the first run, but do not have remaining lives that could match the second run. They therefore often have to be scrapped. Those with 30,000FC lives are better."

Lufthansa's second-run on-wing time is about 8,500EFH/FC. "After the first removal, on-wing times are consistently about 8,000–10,000FC," says Heerdt.

-3C1

The -3C1 was developed later on to cater for the whole of the 737-300/-400/-500 family. It is rated at 18,500lbs, 20,000lbs and 23,500lbs, respectively.

These configurations allow airlines to operate the -3C1 at the highest rating of 23,500lbs on the 737-400. When EGT margin is eroded, rather than put the engine through a shop visit, it can be re-rated to 20,000lbs and can re-gain some EGT margin. A further on-wing interval is then gained prior to putting the engine through the shop.

The engine can even be re-rated for a second time to 18,500lbs to get a third run. This requires careful management, but is not always possible, since an airline may not require the same number of engines for each thrust rating. It also requires the staggering of removals and engine shop visits, which is not always easy to obtain.

EGT margin degradation is not only affected by thrust rating, but also by style of operation, pilot de-rate, FC time and environment.

A new -3C1's EGT margin is about 50 degrees at the highest rating of 23,500lbs. At 22,000lbs the margin is 75 degrees and at 18,500lbs by about 140 degrees.

The -3C1 can be managed either to perform separate on-wing runs at the same rating, or re-rated after EGT margin erosion to lower ratings.

The -3C1 rated at 23,500lbs has an EGT margin erosion of about six degrees per 1,000FC. Airlines with typical short-haul operations might expect to get a first-run on-wing time of about 8,500FC before EGT margin is eroded. Engines could then be re-rated to a lower thrust, or put through a shop visit.

When an engine is re-rated it is prudent to perform a borescope to check for interior damage to areas such as the nozzle guide vanes, combustors and cracks to tips of turbine blades.

If a problem is discovered at this stage then a core restoration shop visit could be performed. This would restore some EGT margin and the engine would be rated at 23,500lbs and used again on a 737-400.

Re-rating to a lower thrust of 20,000lbs would restore an EGT margin of about 44 degrees. This would deteriorate at a slower rate of about four degrees per 1,000FC, compared to a new engine which would see EGT margin reduce at about three degrees per 1,000FC.

A second on-wing run then could be about 11,000FC. The two runs together would provide enough on-wing time for the full life of the shortest LLPs to be utilised.

The shortest lives of LLPs is about 16,000FC, which limits the combined first and second on-wing run both for re-rated and non re-rated engines. At this stage LLPs would have to be replaced and an overhaul would be required.

Only about 20 -3C1 engines globally have completed a third on-wing run. As Heerdt comments about on-wing times reducing considerably after the first run, the third run has averaged about 6,500FC for the -3C1 rated at 22,000lbs. The number of annual shop visits for the -3 series is about 900, but this is expected to climb to about 1,200–1,300 as the engine reaches maturity in 2003.

SUMMARY OF CFM56-3B2/-3C1 MAINTENANCE CHARGES

Engine variant	-3B2	-3C1	-3C1
First run			
Thrust rating	22,000	23,500/ 18,500	18,500
EGT margin	57	50/65	140
EGT margin erosion (deg C/1,000FC)	5	6/4	3
Actual on-wing FC	17,000	11,500/ 8,500	20,000
Shortest LLP lives	17,000	20,000	20,000
First shop visit			
Man-hours	3,000	3,100	3,100
Materials & sub-contract $	500,000	600,000	600,000
New LLPs $	1,130,00	1,130,000	1,130,000
Sales used LLPs	200,000	150,000	180,000
Net cost LLPs	930,000	980,000	950,000
Second run			
Engine thrust	22,000	23,500 18,500/	18,500
EGT margin	40	45/55	110
EGT margin erosion (deg C/1,000FC)	5	6/4	4
Actual on-wing FC	8,500	8,500 11,500/	20,000
Shortest LLP lives	17,000	20,000	20,000
Second shop visit			
Man-hours	3,800	3,400	3,400
Materials & sub-contract $	600,000	700,000	700,000
New LLPs $	0	1,130,000	1,130,000
Sales used LLPs	0	150,000	180,000
Net Cost LLPs	0	980,000	950,000

Norwegian carrier Braathens also operates the -3C1. It uses all three thrust ratings of 23,500lbs, 20,000lbs and 18,000lbs for its 737-400s and -500s. Cycle times vary between 46 and 55 minutes, or an average of 0.8EFH.

"The first engine run is always long because we re-rate it from 23,500lbs for the -400 down to 20,000lbs for the -500," explains Bert Veenstra, director of marketing & sales at Braathens Technical division. "We manage our engines so that the first run achieves a 99% utilisation of LLPs with the shortest lives.

"The -3C1's manufactured guarantee EGT margin is 40–45 degrees, but is often 55 degrees," says Veenstra. "EGT margin erodes at six or seven degrees per 1,000FC. We re-rate down for the 737-500 just less than halfway through because of zero EGT margin. After re-rating we regain about 64 degrees of EGT margin. First-run on-wing times are then about 16,000EFH/20,000FC. Without re-rating, on-wing runs would only be about 10,000FC.

"The resulting workscope is a full performance restoration and replacement of all LLPs. This is so that the subsequent on-wing run is not compromised by stub lives of LLPs with long lives," explains Veenstra.

LLPs with lives remaining are sold. "It is only possible to sell parts, however, which have at least 5,000FC remaining," says Veenstra.

"Following the overhaul and performance restoration we can retrieve this 55 degree margin". Braathens' fleet is only seven to 10 years old and none of its -3C1 engines have yet got to their second removal triggered by EGT margin erosion or a need to replace LLPs. The depth of workscope on the first shop visit means that Braathens expects to get a second run of another 20,000FC.

The second shop visit would be heavier than the first, since many parts cannot be repaired more than once or twice, so a higher rate of replacement would result.

Air France is another operator that can achieve such long on-wing times with the -3C1 that first removals are triggered by the need to replace LLPs. The airline operates 61 engines, which it has had since 1991. These are used on its 737-500 fleet and are rated at 18,500lbs thrust. "We operate them on a 1.3FH cycle and are very happy with them," says Jean-Marc Gabriel, CFM products manager at Air France Industries. "A manufactured engine has an EGT margin of about 140 degrees, which is of course much more than the same engine rated at 23,500lbs. EGT margin deterioration is at a rate of about three degrees per 1,000FC and so we can expect an on-wing run of 18,000–20,000FC (23,400–26,000EFH) after about 10 years of operation, up to the point when the LLPs with the shortest lives have to be replaced.

"Even when the engine is removed it can still have an EGT margin of about 75 degrees. If it was not for the LLPs we could keep the engine on-wing for up to 45,000FC; equivalent to 20 years flying!," explains Gabriel. "Because we have to replace LLPs in the HPC and LPT we will be obliged to do a restoration of the HPC, combustor and the HPT when the first engines come off. The workscope is going to be light, however, and we have still not decided how much EGT margin is going to be worth restoring."

At this stage the remaining LLPs have up to 10,000FC life remaining. "We have also not yet decided what policy to have with the remaining LLPs, which will be key to the engine's management," explains Gabriel. "It is probable we will scrap LLPs with median life cycles, or even all LLPs. This is because we try to build engines with close remaining LLP lives. Also, because we will probably regain 60–70% of the lost EGT margin we can get another on-wing time of 20,000FC. Of course, we still have to be prudent about other causes of removals, such as HPT blades or the mechanical engine control."

-3 shop visits

In the case of the -3B2s and -3B1s operated by Lufthansa, LLP replacement is the main driver of the first shop visit. Following a run of about 17,000FC a heavy performance restoration is required. "The workscope on the LPT depends on its condition and the remaining lives of its LLPs," explains Heerdt. "Because on-wing times are now so long, a hot section inspection is rarely

CFM56-5A/B FAMILY CHARACTERISTICS

CFM56-5A family	-5A4	-5A5	-5A1	-5A3
Thrust ratings (lbs)	22,000	23,500	25,000	26,500
Aircraft	A319	A319	A320	A320
EGT margin	135	110	85	80
LLP lives FC:				
Fan & booster spool	25,000/ 30,000	25,000/ 30,000	25,000/ 30,000	16,500/ 25,000
HP shaft	20,000	20,000	20,000	15,000/ 20,000
LP turbine spool	25,000	25,000	25,000	20,000/ 25,000

CFM56-5B family	-5B5	-5B6	-5B4/7	-5B1	-5B2	-5B3
Thrust ratings (lbs)	22,000	23,500	27,000	30,000	31,000	33,000
Aircraft	A319	A319	A319 A320	A321	A321	A321
EGT margin	165	145	115	95	82	50
LLP lives FC:						
Fan & booster spool	19,000-30,000 (all variants)					
HP shaft	14,000-20,000 (all variants)					
LP turbine spool	20,000-25,000 (all variants)					

seen.

"The level of parts exchange is affected by lives of LLPs. This shop visit consumes 3,200–3,800 manhours (MH) and about $400,000 of material and another $80,000 in sub-contract work."

In addition, LLPs will have to be replaced. In Lufthansa's case some with median lives are scrapped, while others with long lives can be kept for the second run. All LLPs except those with lives of 25,000–30,000 have to be replaced at this visit. The cost of these is about $560,000.

The second shop visit that Lufthansa Technik performs on its -3B2/1s is a whole core and low pressure system refurbishment. MH consumption is higher at about 3,800 and materials and sub-contract work total about $600,000.

The remaining LLPs are scrapped here, and these cost about $580,000 to replace. The cost of those replaced at the first visit has to be amortised on a pro-rate basis during the second run.

High thrust rated -3C1s requiring a core restoration after a first on-wing run of 8,500FC would have a core restoration workscope. This would involve EGT margin restoration and work on the HPC, HPT and combustors. HPC blades usually have tips extended and the HPC undergoes a performance restoration.

First-stage turbine guide vanes and blades are repaired or overhauled, or have their tips extended and be re-coated. Sulphidation can result in blades being scrapped at the first shop visit.

A de-rated engine and kept on-wing for up to 16,000FC would have a slightly heavier workscope. The booster would require attention, and the low-pressure turbine (LPT) would be inspected.

MH inputs are typically 2,800–3,400, while material and sub-contract charges are $500,000–700,000. Inputs after a second run would not be much higher.

Re-rated engines will incur higher shop visit costs, but would be amortised over a longer on-wing interval. Re-rated engines therefore achieve lower overall costs per FC.

All LLPs with short and medium lives are replaced after about 17,000FC at a cost of about $560,000. The remainder with the longest lives would be kept and would have to be replaced at the third shop visit.

Braathens estimates 2,400–3,400MH and about $600,000 in materials and sub-contract would be consumed at this shop visit. All LLPs are replaced. These would be expected to have a residual value of about $180,000 for those that can be sold.

Veenstra expects the second shop visit after a similar time on-wing to consume about 3,400MH and $700,000 worth of materials and subcontract charges. Higher costs are accrued due to greater parts replacement and more repairs. The costs and economics of LLP replacement is similar to the first shop visit.

-3 maintenance costs

Maintenance costs per EFH or FC hinge on the LLP management during the first two on-wing runs. A system operated by Braathens, where all LLPs are scrapped after a long on-wing run, simplifies engine management.

An operator that achieves an initial on-wing run that is a fraction of the shortest life LLPs faces the dilemma of whether to scrap half-life LLPs or to compromise second on-wing time by keeping the remaining LLPs.

The table *(see page 30)* shows a -3B2 that is kept on-wing until its shortest and medium LLPs have to be replaced and the longest sold. The MH and materials used are shown, plus a net LLP cost of about $930,000. The cost of this shop visit amortised over the preceding on-wing time is about $93 per FC.

The -3B2 then starts the second run with all-new LLPs *(see table, page 30)*. The second run, which is expected to be shorter than the first, will partially use LLP lives, avoiding any replacement cost at the second shop visit. The third shop visit will then occur when the shortest LLP lives are reached, after a similar on-wing time to the third of about 8,500FC. All LLPs are then removed. The ones with lives remaining, are sold for about $200,000 as in the first shop visit.

The engine will thus have reached maturity with respect to maintenance costs per FC. The amortised LLP cost per FC for the second and third runs will be about the same as the first. The labour and material costs, however, will be more than twice the cost per FC than on the first run. This is the because the second and third shop visits will have slightly higher labour and material costs, but about half the on-wing time to amortise them over. This will raise costs per FC to about $150.

The -3C1 engine re-rated after complete EGT margin erosion from 23,500lbs to a lower thrust rating

The EGT margins for members of the -5A and -5B families are so varied that there is a similar difference in on-wing times. Like the lower thrust fated -3C1, the -5B5 with an EGT margin of 165 degrees is expected to remain on-wing until LLPs have to be replaced.

halfway through the shortest LLP lives can achieve the lowest possible costs. The same is true with the engine initially rated at 18,500lbs. Moreover, the engine can always achieve similar on-wing times when it has reached maturity and so experience a much slower rise in maintenance costs.

A few LLPs could be sold for about $150,000. Net cost for LLPs will be about $950,000. Manhours and material costs will be about $750,000. The shop visit costs amortised over the first run are about $87 per FC.

CFM56-5A/B family

The CFM56-5A was developed as the first engine for the A320. The first variant, the -5A1, is rated at 25,000lbs. The engine has a relatively high EGT margin of 85 degrees when new.

The powerplant had some growth potential to the -5A3 with a thrust rating of 26,500lbs for higher gross weight A320s. This engine has a slightly lower EGT margin of 80 degrees.

Development of the A321 and the later A319 saw the need for higher and lower thrust engines, while retaining commonality in an engine family.

The -5A lacked the growth potential for the A321, but could be de-rated for the A319. The -5A4 and -5A5 are rated at 22,000lbs and 23,500lbs and have EGT margins of 135 and 110 degrees.

To provide airlines with a common engine for the whole A320 family, the -5B series was launched. This has a range of thrust ratings, starting with the -5B5 at 22,000lbs and up to the -5B3 at 33,000lbs *(see table, page 32)*. The EGT margin of these engines starts at 165 degrees and declines to 50 degrees for the highest thrust rating.

-5A

Lufthansa is one operator that selected the -5A for its A320s. Because the airline later selected the V.2500 for its A321s, it also ordered the -5A for its A319s.

"We operate an average FC time of about 1.1FH. The on-wing run to the first shop visit is about 12,000–15,000 EFH/11,000–13,500FC. This compares to a global fleet average of 9,400 EFH/8,000FC," says Heerdt. "There has been service bulletin (SB) 72541, which forced removals early at 9,000FC because of an issue to do with the forward rotating airseal."

Like the -3 series, on-wing times for the -5A depend on engine management with respect to LLPs, subsequent shop visit build quality and resulting engine performance. "The first workscope is affected by the target for second on-wing time. A first run of 17,000EFH will cause a heavier shop visit.

Air France has the largest -5A1 fleet in the world, with an operating inventory of 145 engines. It also has a small number of -5A3s and -5A4s. Air France and Air Inter started -5A operation in 1988 as the A320 launch customers. "We had teething problems with the HPT nozzle, which has caused two or three removals and shop visits. This has since been resolved with a new HPT design," says Gabriel. "EGT margin deterioration in the -5A1 is five to six degrees per 1,000FC and we operate 0.93–1.30FH per FC. Without the HPT nozzle problem the latest design engines could achieve an on-wing time of 15,000FC. This is because they are being forced off-wing by the forward rotating air seal which is limited at 15,000FC. At this stage they still have 10–20 degrees EGT margin remaining.

"Our LLP policy at the first removal is to scrap all parts with remaining lives of up to 6,000FC. We are finding the same phenomenon at the first shop visit as with the -3C1. That is we have to replace LLPs but require only a light performance restoration. The condition of parts in the fan and booster is very good at this stage," says Gabriel. "We sometimes have to do some work on the LPT because of technical problems. This shop visit restores 45–50 degrees EGT margin."

Because this shop visit will only replace LLPs in the HPC and HPT, the second on-wing life is limited to about 10,000FC.

"If they are available we will put 10,000FC life LLPs into the HPC and HPT, and so we will replace LLPs throughout the whole engine after a total time since new of 25,000FC at the second shop visit," says Gabriel.

-5B

Swissair is one airline which selected the -5B along with every member of the A320 family. Swissair selected the -5B with the double annular combustor (DAC).

SR Technics maintains Swissair's Austrian's and Sabena's later engines. Swissair has an average FC time of 1.3FH. It has not been able to realise maximum possible on-wing times because of cracks in the rear frame, a problem related to the DAC. This has caused removals after an average time of about 5,000EFH.

SUMMARY OF CFM56-5A1/-5B6/-5B1 MAINTENANCE CHARGES

Engine variant	-5A1	-5B6	-5B1
First run			
Thrust rating	25,000	22,000	30,000
EGT margin	85	165	95
EGT margin erosion (deg C/1,000FC)	5	5	5
Actual on-wing FC	15,000	20,000	15,000
Shortest LLP lives	15,000	20,000	15,000
First shop visit			
Man-hours	3,700	3,700	3,700
Materials & sub-contract $	730,000	730,000	730,000
New LLPs $	358,000	1,270,000	620,000
Sales used LLPs	0	70,000	0
Net Cost LLPs	358,000	1,200,000	620,000
Second run			
Actual on-wing FC	10,000	20,000	10,000
Shortest LLP lives	10,000	20,000	10,000
Second shop visit			
Man-hours	3,400	4,000	4,000
Materials & sub-contract $	750,000	770,000	770,000
New LLPs $	1,210,000	1,270,000	650,000
Sales used LLPs	0	70,000	0
Net Cost LLPs	1,210,000	1,200,000	650,000

"The estimated on-wing times of the three variants powering the A319/20/21 vary considerably because of large differences in EGT margin," explains Peter Singer, product manager CFM56 powerplant maintenance, at SR Technics.

"On the first run we expect the highly de-rated -5B6 on the A319 to be about 17,000EFH/13,000FC; the -5B4/7 on the A320 to be about 12,000EFH/9,200FC, and the -5B2/3 on the A321 to be about 9,600EFH/7,400FC," says Singer. "The thrust rating for the A320 is more or less the design limit of the engine, which is why on-wing times for the A321 suffer."

Subsequent runs are expected to be about 20% shorter. These are: 14,000EFH/10,800FC for the -5B6; 10,000EFH/7,700FC for the -5B4/7, and 8,000EFH/6,100FC for the -5B2/3.

SR Technics operates a classic alternating partial overhaul or performance restoration and full overhaul shop visit pattern. On-wing times are about 10% longer after a full overhaul.

Like Swissair, Air France has had on-wing times with the -5B series compromised by technical problems. "An inspection of a C clip in the HPT rotor has to be made at 7,000FC," says Gabriel. "We then have to schedule a shop visit to disassemble the HPT. The EGT margin retention, however, is similar to the -5A1 and we would expect an on-wing time of about 15,000FC with the -5B1 rated at 30,000lbs because of the need to replace LLPs. The -5B3 will probably get removed earlier than this because of EGT margin erosion. We are planning, however, to re-rate our -5B3s to -5B5s for use on the A319s, which will allow us to use LLP lives to the full."

-5 shop visits

The performance restoration for the -5A after about 12,000FC on-wing consumes 3,400–4,000MH, $630,000 in materials and about $100,000 in sub-contract charges.

The second shop visit is heavier due to a higher level of parts repairs and replacement.

SR Technics performs a performance restoration at the first shop visit. "This restores about 60% of the engine's original EGT margin. The workscope could be heavier if we wanted more restored margin," says Singer. "The workscope restores the core and inspects the fan blades. This includes work in the HPC and repairing blade tips, combustor area, HPT and replacing airseals. The workscope works on almost everything in the engine except the LPC, LPT, fan frame, turbine rearframe and gearboxes. These items just get a visual inspection."

-5A/B maintenance costs

A -5A1 rated at 25,000lbs and managed so that short-life LLPs are replaced at the first shop visit and those with long lives left untouched, could achieve reasonable economics. The engine would have short-life LLPs replaced. The resulting costs amortised over the first on-wing run would be about $85 per FC.

Leaving the longest life LLPs in the engine would force a second shop visit at life limits, when a complete new set of LLPs would be replaced. The second shop visit and short second on-wing run would raise the costs per FC to over $200.

Over the two on-wing runs, the cost per FC averages at $136 per FC. The -5A1 should be able to maintain a similar on-wing and shop visit pattern after reaching maturity.

A -5B6 operated in a similar way to the -3C1 at 18,500lbs will be able to reach the shortest LLP lives on its first on-wing run. Most LLPs only have lives of up to 20,000FC. This means it would be prudent to replace all LLPs at this shop visit. LLPs with long lives are likely to be scrapped and sold. The net cost for LLPs in this case would be in the region of $1.2 million and total shop visit costs will be about $106 per FC. This will be about $110 on the second run because of higher shop visit costs.

A -5B1 rated at 30,000lbs will have equal LLP lives to the -5B6. First on-wing time is cut short by the forward rotating airseal. A shop visit at this stage means some LLPs will have to be replaced, but the second on-wing run can then be about 10,000FC because of the limit of long life LLPs. All LLPs will have to be replaced at this stage.

The net LLP cost at the first shop visit will then be about $380,000. The resulting shop visit cost per FC will be $103.

The cost of a new set of LLPs at the second shop visit and labour and materials will take the amortised rate over the second on-wing run to $162 per FC. The total cost for the two shop visits will be $126 per FC.

Without the problem of the forward rotating airseal, the -5B1 might possibly be managed so that all LLPs were replaced at the first shop visit and those with longer lives sold. The overall cost per FC would then be lower. AC