Few operators have accumulated enough experience to be completely aware of the A340's full maintenance costs. No aircraft have yet had a 10-year check performed, but indications are that C and heavy D checks consume less than similar sized older generation widebodies.

Technology provides A340 with partial gain in maintenance cost

The A340-200/-300 has been in operation for nearly 10 years. The oldest aircraft in the fleet have yet to have their 10-year structural checks. Airline maintenance organisations' experience of airframe checks and the real cost of repairing many of the aircraft's rotable components is limited. This means it is only possible to estimate the A340's full airframe and component-related maintenance costs.

The A340 is operated by major airlines on every continent on long-haul sectors. Average flight cycles (FC) are in the region of 9 flight hours (FH) but, in a few cases, the A340 is used on regional sectors in the region of 2-3FH. Annual utilisations for most operators are 4,400-4,700FH and 500-550FC per year.

This analysis considers all elements of the A340's maintenance, with the exception of its CFM56-3C engines. Each item of line, component and airframe maintenance is examined with respect to its periodicity, man-hour (MH) and material inputs and resulting cost per FH. This considers operations of most airlines, typical maintenance schedules and conservative estimates of inputs for each item. The end result is a guide to total requirements and costs of airframe and component maintenance.

Based on an annual utilisation of 4,500FH and 500FC per year, and a utilisation of about 85% of A, C and heavy check intervals, total airframe and maintenance costs per FH have been calculated *(see table, page 34)*.

Maintenance elements

Line maintenance falls into the three categories of pre-flight, daily and weekly checks. Airframe checks include A, C, 5-year and 10-year checks.

Most job card items in the A340's maintenance programme fall into one of these checks, but there are other job cards that do not have intervals matching a specific check. Airlines' engineering departments plan to add these 'out-of-phase' items to one of the regular checks, or they can perform these separately.

Airframe checks will also include modifications covered by service bulletins (SBs) and airworthiness directives (ADs).

Components are classified by air transport association (ATA) chapter, and can be divided into several categories. The first group includes expendables and consumables. These are used in all line and airframe checks. Consumable and repairable items are low-cost parts.

The second group comprises heavy components of wheels, brakes, landing gear, thrust reversers and the auxiliary power unit (APU). These are all removed for maintenance at their own interval.

The third group includes line replaceable units (LRUs), which are items that can be tested and easily removed and replaced during line checks.

The fourth group consists of rotable and repairable components, including flight controls, hydraulics, pneumatics and electrics. In older aircraft types these units were referred to as heavy check-related, since they were all scheduled for removal during heavy checks. Components in the third and fourth groups are often in the same ATA Chapters. Some can be removed during line checks, while others require deeper access and longer downtime. Many airlines also group this third and fourth category together for the purposes of accounting for their cost.

The maintenance programme for the A340, and several other modern aircraft types, allows components in this fourth group to be removed either on an 'on-condition' basis, so as to extend removal intervals, or at specific 'hard time' intervals. Some of the components have to be scrapped and replaced at these hard time intervals, while others can be repaired.

Maintenance of components on an 'on-condition' basis means they can be inspected, usually during a heavy check, which provides sufficient downtime and access. "Inspection and 'on-condition' maintenance means many have functional tests so they can remain on the aircraft. This is different to removing components at fixed maintenance intervals on older aircraft types," explains Regis Boniau, A340 maintenance manager at Air France Industries. This 'on-condition' philosophy contributes to low maintenance costs, compared to older technology aircraft, because components are allowed to achieve longer times on the aircraft.

Maintenance schedule

The A340's line maintenance programme has pre-flight, transit, daily and weekly checks.

The pre-flight check is one that most airlines have performed by the flight crew, and involves a walkround and visual inspection. The transit check is performed by line mechanics, and is similar to the work required by the pre-flight check. The daily check has to be performed every 24 hours. Taking the A340's operation into consideration, most aircraft perform two or, on average, just less than two flights per day. Most airlines therefore perform the daily check at their home base prior to departure for a return trip. The transit check is thus usually performed at the outstation.

Weekly checks are performed every seven days, although some airlines have approval for a one day addition.

The aircraft's airframe check

Operator experience with the A340 is relatively low, and no airline has yet performed a 10-year check. Experience of intervals and costs for all LRU and rotable components is also limited.

programme has the four basic elements of A, C, 5-year and 10-year checks.

"There are five groups of A check packages," says Rainer Schwarz, section manager of aircraft maintenance planning at Lufthansa Technik. "Our interval for the 1A package is 550FH, while there are 2A, 3A, 4A and 8A items with corresponding multiple intervals. The 2A items have an interval of 1,100FH, the 3A tasks at 1,650FH and so on."

These could be equalised to generate an equal sized A check. Lufthansa, which has the world's largest A340 fleet of 32 aircraft, has opted to perform these tasks as they come due. The consequence is for A checks to vary in the number of tasks, downtime for completion and MH inputs. That is, the first A check, the A1, will be performed at 550FH and have just the 1A items. The A2 check at 1,100FH will comprise 1A and 2A tasks, and the A3 check 1A and 3A tasks. The 8A items complete the A check cycle, which is independent of the C check cycle, at the A8 check after 4,400FH, which has 1A, 2A, 4A and 8A tasks.

Iberia, which has 15 aircraft, has an A check interval of 500FH, equal to the maintenance planning document (MPD) interval. "We have four A check packages, and so the A4 checks have an interval of 2,000FH," explains Rufino Velasco, A340 maintenance manager line maintenance at Iberia. "We do not equalise the A check packages, and so have different sized A checks. The A check cycle is thus completed every four A checks at 2,000FH. We will combine an A and C check when they come close together."

Air France has been able to extend its 1A and 2A intervals to 700FH and 1,400FH, and hopes to do the same for its 4A and 8A packages. These would have intervals of 2,800FH and 5,600FH.

C checks

The A340's 1C package has a calendar interval. The MPD interval is 15 months. Lufthansa has an extended interval of 18 months; equal to about 7,100FH under its operation. "There are 1C and 2C job cards," says Schwarz. "We do not equalise C checks, and so have different sized C checks."

The 1C and 2C tasks are light. There are also 4C and 8C items, which are heavier. The C check cycle is therefore completed after eight C checks. The basic interval of 15 months means the C4 check, the first with heavy tasks, has an interval of 60 months. The C8 completes the cycle at 120 months.

Most operators aim to combine the C4 and C8 checks respectively with the 5-year and 10-year checks: the structural inspections. This avoids repetition of deep access in the aircraft and so minimises downtime.

There are therefore C1 to C8 checks, with the C1, C2, C3, C5, C6 and C7 checks being light.

The C4 check has 4C items, while the C8 check has 4C and 8C items. They will also be combined with 1C and 2C tasks if the light C checks have the same intervals as the 5-year and 10-year checks, with which the C4 and C8 checks are respectively combined. The C4 and C8 checks are thus heavier than the six other C checks.

The MPD intervals for the 5-year and 10-year checks match those of the C4 and C8 checks. The 5-year and 10-year checks are often referred to as 'IL' and 'D' checks. Many A340 operators will have two cycles of three light C checks (C1, C2 and C3) followed by a heavy C4/IL check. This is then followed by another cycle of a further three light C checks (the C5, C6 and C7, which have the same tasks as the C1, C2 and C3 checks) and the C8/D check.

Because the MPD interval for the C8/10-year check is twice that of the C4/5-year check, the C8/D check will include the C4/IL. Heavy checks thus alternate between a 4C/IL check and a combined 4C/IL and 8C/D check.

The IL and D checks include structural inspections and provide an opportunity for modifications to be incorporated, the interior to be refurbished and aircraft to be stripped and re-painted. Because the A340's maintenance programme has been conceived under a maintenance steering group 3 (MSG3) philosophy, structural sampling and the corrosion prevention and the control programme (CPCP) have been incorporated into the C, 5-year and 10-year checks as routine job cards.

Because of the age of the A340 fleet, the first aircraft, belonging to Air France, is due for its 10-year check in 2003. Air France will actually do this first check in late 2002 for scheduling purposes. Major operators so far only have experience of IL checks. "So far we only have experience of the A340 up to the C4 and IL check with our oldest aircraft," explains Miguel Cano, planning and control manager at Iberia. "The downtime for the combined checks is about four weeks."

The A340's IL check occurs at an interval about 5,000FH less than the 747's D check.

IL & D check treatment

Iberia's schedule has a basic C check interval of 15 months. "This is equal to about 5,800FH in our operation," explains Cano. "In our case the C4 check comes due at 60 months; the same time as the IL check. This is after about 23,500FH for the first one and then every 23,500FH for subsequent heavy checks."

Lufthansa has an 18 month C check interval, which means its C4 check has the same 72 month interval as its first IL check. Lufthansa's C8/D check interval is 120 months, meaning that it will fall between the C6 and C7 checks. This means the C8/D check will have to be

The A340's maintenance schedule is complicated by light and heavy C checks. It is more convenient to schedule heavy C checks with 5- and 10-year checks because of the deep access required. C and heavy check intervals do not necessarily have convenient multiples for efficient timing, however.

performed separately from the C4/IL check.

Lufthansa's utilisation of about 4,600FH per year means C checks occur about once every 7,100FH. The first IL check will come due after about 27,600FH and then every 46,000FH or 10 years thereafter, alternating with the combined IL/D check. Only two D checks are likely to be completed in an aircraft's lifetime.

Air France has an 18 month C check interval. This is equal to about 7,500FH, since Air France achieves about 5,000FH per year with its A340s. The C4/IL check first comes due after about 72 months and 30,000FH, and then every 60,000FH thereafter.

The current D check has an interval of 120 months, and so will come due at about 60,000FH. Air France's original C check interval was 15months, but was escalated to 18 months. The C7 check for some of the first aircraft therefore came due at 114 months, and the following C8 check, with just C1 and C2 items, came due at 132 months. The 8C items and D check interval thus fell between these two checks. Because of escalation, the actual interval for each C check was different for each aircraft.

"We have been able to escalate the C4 and IL check items to six years," explains Boniau, "and will try to escalate the C8 and D check items from 10 years once we have performed the first check and the findings of the inspections have been made." If Air France can escalate its D check to occur 18 months after the C7 check, it will have an interval of 144 months or 12 years, which will combine conveniently with the C8 check. This will allow an equal interval of 18 months to be maintained between each C check.

A340 in operation

In most cases the A340 achieves 4,500-5,000FH per year. Average FC times are 9FH, and so 500-550FC are operated annually. This is equal to about 1.4FC and 12-13FH per day. Despite operating long-haul routes and having a turn time of about three hours, airlines find it hard to schedule more flights and achieve higher rates of utilisation because of time zone differences, flight times, airport curfews, the need to schedule attractive departure and arrival times, and scheduling with other long-haul flights. This will leave 8-9 hours per day for daily and weekly checks. Schwarz explains that daily and weekly checks each require about three hours' downtime. These checks are therefore unlikely to reduce the number of days an aircraft has available for operations.

An A check requires up to about half a day, but if scheduled well will not interfere with the aircraft's operation. C and heavy checks will require several days a year for maintenance downtime.

Cano explains C checks require up to five days downtime. Because of the interval, the equivalent of three or four days a year will be required for C checks. Cano says the C4/IL check takes about four weeks. Amortised over its five year interval, it is equal to about six days per year downtime.

The average annual days per year available for operation will therefore be in the region of 355.

Besides downtime, the actual utilisation of the available interval between checks will also determine the timing of checks and resulting cost of maintenance per FH. In many cases airlines use 85-90% of the available interval between A, C and heavy checks.

In Air France's case the A check interval is as long as 700FH, and so this cycle will be completed in 5,600FH, or 5,000FH if 90% of the interval is utilised. The basic A check interval is as short as 500FH in Iberia's case, and for many other operators with small fleets of young aircraft which have been unable to extend their check intervals beyond the MPD.

This analysis assumes an A check interval of 550FH, and a utilisation of 475FH between A checks. For an aircraft with an annual utilisation of 4,500FH, nine A checks will be completed each year.

This analysis further assumes an operator has a C check interval of 15 months and combines the C4 with the IL check and the C8 with the D check. It is also assumed the C4/IL is will be combined with the C8/D check. An interval utilisation of 90% means that C checks are performed about once every 14 months, or 5,250FH. This would be as high as 6,650FH for an airline with an 18 month interval and annual utilisation of 5,000FH.

The first IL check is therefore completed after about 21,000FH and the first D check at 42,000FH. A heavy check therefore follows about every 21,000FH.

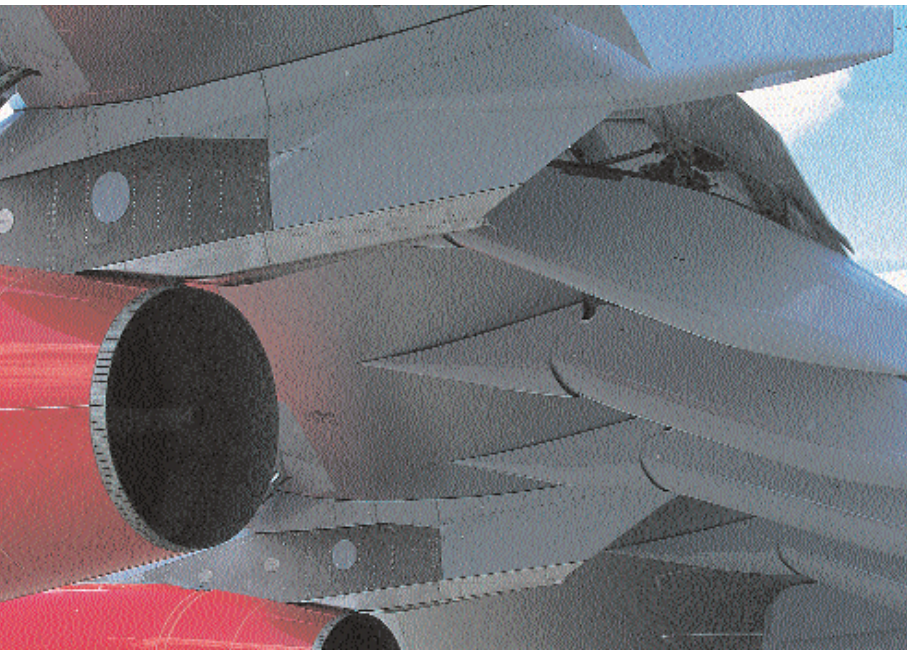
Line maintenance inputs

Under a typical pattern of operation, the A340 will require six daily checks per week plus a weekly check for 50 weeks a year. The aircraft will also require about 250 transit checks during the year.

Velasco estimates a MH consumption of about two hours for a transit check, thus generating a total of about 500MH per year. This work will typically be sub-contracted at the outstation. A labour rate of $65 per MH will incur a cost of $32,500 per year. This labour rate is consistent with that used in the 747-400 airframe and component maintenance cost analysis *(see 747-400 shrugs off heavy maintenance burden of earlier classics, Aircraft Commerce, June/July 2001, page 26)*.

Consumable and expendable materials will cost about $200 per check, and so another $50,000 annually *(see table, page 34)*.

Boniau estimates labour used for daily checks at 15MH, and a range from seven to 20 MH is typical. An average of 12MH per check for 300 checks per year



Many of the A340's rotable components, such as flap screwjacks, have on-condition maintenance rather than fixed intervals. This on-condition maintenance allows longer intervals for component repair, and so contributes to lower maintenance costs compared to older technology aircraft.

will generate about 3,600MH. Consumables and expendables will cost in the region of $500 per check. At a rate of $65 per MH total cost for daily checks will be about $384,000 annually *(see table, page 34)*. This is equal to about $85 per FH for an aircraft operating 4,500FH per year.

Weekly checks consume 15 to 30MH. An average of 20MH per check for 50 checks will generate a requirement for about 1,000MH each year. A labour rate of $65 per MH results in a charge of $65,000. Material consumption for a weekly check is about $1,000, and so total annual cost for weekly checks is about $115,000, equal to $25 per FH.

This is a total of $128 per FH for all line check MH and expendable and consumable inputs *(see table, page 34)*. This compares with $180 per FH for the 747-400 for the same checks.

A check inputs

As described, most operators do not equalise their A check packages and so have A checks varying in the number of tasks and MH inputs.

"The A check workscope includes visual inspections, engine servicing, cabin cleaning and checking of seats and reading or downloading of information from computers, and checking for failures in the avionics," explains Schwarz. Some of the A340's many out-of-phase items are added to A checks, causing even wider variation in MH input.

A checks also provide an opportunity for exchanging LRUs on the aircraft. A4 are heavier than A1/2/3 checks, as are A8 checks.

The A1, A5 and A7 checks have just 1A tasks, while A2 checks are slightly heavier with 2A tasks in addition, and 3A tasks also increase the inputs for A3 and A6 checks.

Estimates of total MH inputs for 1A tasks are in the region of 160MH. Velasco explains that actual MH inputs required for A and C checks depend on the aircraft's age. "This affects both routine and non-routine inputs. A young aircraft will use about 80MH for routine and 20MH for non-routine work in a 1A check. This will rise to a total of about 220MH for older aircraft," explains Velasco. "As the checks get heavier the MH inputs rise, as they also do as the aircraft ages. The A2 check consumes 180-280MH, while the A3 will be less because of the absence of 2A tasks."

The MH inputs for the lighter A1/2/3 and A5/6/7 checks vary between 180 and 270MH. Estimates of material inputs for lighter A checks are in the region of $7,500. An average labour consumption of 250MH for these six lighter A checks charged at $60 per MH will generate a total cost of $22,500.

Heavier A checks, A4 and A8, consume 320-350 MH and material consumption is higher at about $15,000. This puts total cost per check in the region of $37,000.

The pattern of A checks means that three light checks precede a heavy one, and so the cost for a cycle of four A checks will be about $105,000. This will be incurred over the A check cycle time of about 1,900FH, resulting in a cost of $55 per FH *(see table, page 34)*.

C & heavy check inputs

While a few lead operators have 18 month C check intervals, most will be confined to 15 month intervals. As stated, with typical interval and annual aircraft utilisations, this will be equal to about 5,250FH.

Three light C checks will first be followed by the C4/IL check at about 21,000FH, about 7,000FH less than a 747-400's D check.

Light C checks, the C1, C2, C3, C5, C6 and C7; have just 1C and 2C tasks. Because most operators do not equalise these they vary in MH and materials input. "The C1 check has a downtime of about 36 hours," says Schwarz "and requires an total input of about 1,200MH. The additional 2C items add about another 350MH for the alternating heavier checks." Lufthansa Technik says average material inputs for light C checks is in the region of $90,000.

Boniau has similar estimates of MH inputs for the light C checks. Gerritt Van Humbeeck, interiors engineering manager at Sabena Technics, estimates that MH inputs for C2 and C6 checks (light C checks with 2C items) will consume about double those with just 1C items: about 2,300MH.

Some estimates of material costs for lighter C checks are in the region of $55,000.

Iberia reports heavier MH inputs for its light C checks. Cano says that routine MH inputs for the 1C items are about 1,000MH. "Another 900-1,200MH should be added for non-routine, taking the total to 2,000-2,200MH. Then a further 300MH can be used for cabin cleaning and modifications to cover for service bulletins (SBs), and airworthiness directives (ADs) can use another 500-900MH. This takes the total for a C1/C3 check up to about 3,400MH." Cano estimates the C2 inputs at 1,600MH for routine, 1,300 for non-routine, 700-1,000 for cabin work and 500-1,300 for modifications, putting the total at 5,200MH. "MH for modifications can be high because there is a programme to update all A340s to the same specification," explains Cano.

Heavier C4/IL and C8/D checks can also include 1C and 2C items when scheduled together. To date few C4/IL checks have been performed, and no 8C/D checks have been completed.

Iberia's first aircraft had its first 4C/IL check in January 2001. "Inputs for this were 7,000MH for routine, 5,800 for non-routine, 4,000MH for cabin work

Air France will be the first airline to perform a 10-year check. Man-hour estimates for this check are anticipated to be 44,000-47,000. Experience and findings may allow leading operators to extend their intervals to 12 years.

and about 5,000MH for modifications. This took the total to about 22,000MH," says Cano. "The 5,000MH was for the FSIP, which incorporates a large number of SBs. Consumable and expendable consumption was about $325,000. This includes materials required by the SBs."

Matthias Baschant, account manager aircraft overhaul & modification at Lufthansa Technik puts MH inputs for the 4C/IL check at 12,000-13,000 for the routine element, 11,000-13,000MH for the non-routine element and 6,000-8,300MH for modifications. This would take the total to 29,000-34,500MH. "Material costs are about $250,000 for the routine inputs and $250,000-500,000 for the non-routine work," says Baschant. Lufthansa's inputs for the C4/IL check are therefore heavier than Iberia's, while Iberia's lighter C checks are heavier than Lufthansa's.

An input of 25,000-35,000MH for a heavy check performed at about 21,000FH compares to an input of about 55,000-60,000MH for a 747-400 at 25,000-28,000FH *(see 747-400 shrugs off heavy maintenance burden of earlier classics, Aircraft Commerce, June/July 2001, page 26)*.

While an 8C/D check has yet to be performed on the A340, Baschant says Lufthansa estimates inputs will be 17,000-19,000MH for routine items, 19,000-21,000 for non-routine, plus 4,000-7,000MH for modifications. This will take the total to the region of 40,000-47,000MH. "We expect expendable and consumable inputs to be $400,000 for routine and $550,000 for non-routine," adds Baschant.

Boniau says Air France expects an input of about 40,000MH for the 8C/D check, while Cano says Iberia anticipates a similar input.

Inputs for light and heavy C/structural checks vary, but the total MH input for a cycle of three light C checks followed by the C4/IL check is close between Iberia's, Air France's and Lufthansa's inputs, totalling in the region of 29,000-36,000MH. Taking Lufthansa's light C check, C4/IL and 8C/D check inputs, MH consumption over the three light C check and C4/IL check cycle will be about 35,000MH over an interval of 21,000FH. Labour charged at $55 per MH will cost about $1.95 million. Added to this will be material costs of an average of $60,000 per light C check plus a conservative estimate of $700,000 for the C4/IL check. This will take total MH and material costs to $2.8 million.

The second cycle will have similar inputs for the light C checks, but the heavier input for the 8C/D check based on Lufthansa's inputs will take total inputs to 44,000-47,000MH plus $1.1 million for materials. The total cost will be $3.7 million over the 21,000FH following the first 4C/IL check.

The total input for the complete C, IL and D check cycle will therefore be $6.5 million over 42,000FH. This is equal to $155 per FH *(see table, page 34)*.

Heavy components

Like most other aircraft types, the landing gear, wheels and brakes, thrust reverser and APU can be treated separately.

While the landing gear has a similar fixed removal interval to older generation aircraft, the other components are maintained on an 'on-condition' basis and generally have better reliability and maintain condition better than the same components on older types.

The A340's landing gear has four legs, with two main ones each supporting a four-wheel bogie and a centre main leg with a two-wheel bogie. The landing gear has a fixed overhaul interval of 10 years, although Boniau explains that gears have already been exchanged earlier than this because of a retrofit programme to upgrade landing gears.

Most operators now opt for an exchange programme with an overhaul shop. This avoids the need to operate a landing gear repair facility and hold inventories of spare gears.

Typical exchange programmes consist of three cost elements. These are an exchange fee to cover the capital cost of the gear, a fixed overhaul fee and variable extra costs for additional repairs for failed parts that have to be replaced. The typical total cost will be in the region of $860,000 for the A340. This is high, since the A340 is still relatively young for landing gear repair. Rates may become more competitive as the aircraft matures.

At an annual utilisation of 5,250FH between C checks and a removal at the 8C/D check, this cost will be amortised over 42,000FH. This will generate a reserve of $20 per FH *(see table, page 34)*.

The A340 uses carbon brakes, which have longer removal intervals between repairs but higher repair costs. Carbon brake removal intervals are in the 1,700-2,200FC range. At the assumed rate of aircraft utilisation this is equal to 15,000-20,000FH, or once every three to four years. The A340 has 10 brake units, so at an average repair cost per unit of $30,000, brake repairs for the shipset will cost about $300,000 once every 15,000-20,000FH, equal to a cost of $15-20 per FH *(see table, page 34)*. New brake units are rarely required, but the cost of a new unit is about $65,000.

Wheels and tyres are affected by the costs of tyre remoulds and replacements and wheel inspections. Wheels are removed when tyre treads have worn, and the average interval is about 300FC or 2,700FH. Tyre retreads cost about $375 and an average of four retreads are made before replacement at the fifth removal, at 1,500FC or 13,500FH. New tyres cost in the region of $1,000. The cost of retreads and tyre replacement

PASSENGER A340-200/-300 FLIGHT HOUR (FH) AIRFRAME AND COMPONENT MAINTENANCE COSTS

Maintenance Item	Maintenance interval	MH used	MH cost ($)	Materials & rotables ($)	Total cost ($)	Cost per FH ($) 9.0FC
Pre-flight	Every FC	2	130	200		
Daily	24 hours	12	780	500		
Weekly	7/8 days	20	1,300	1,000		
Total annual MH		5,100	331,500	250,000		129
Light A check (x3 performed)	475FH	250	15,000	7,500	22,500	
Heavy A check (4th in cycle)	1,900FH	365	22,000	15,000	37,000	
Total A check cycle	1,900FH	1,115	67,000	37,500	105,000	55
Light C check (x3 performed)	5,250FH	1,450	77,000	60,000	137,000	
4C/IL check (4th in cycle)	21,000FH	31,000	1,700,000	700,000	2,400,000	
Total 1st cycle	21,000FH	35,000	1,950,000	880,000	2,830,000	
Light C check (x3 performed)	5,250FH	1,450	77,000	60,000	137,000	
8C/D check (4th in cycle)	21,000FH	42,650	2,350,000	920,000	3,220,000	
Total 2nd cycle	21,000FH	47,000	2,600,000	1,100,000	3,700,000	
Total C, IL & D check cycle	42,000FH	82,000	4,500,000	2,000,000	6,500,000	155
Heavy components						
Landing gear exchange & repair	C8/D check 42,000FH				860,000	20
Brake repair & overhaul	1,700-2,200FC/ 15,000-20,000FH				300,000	15-20
Tyre remould (x4 performed)	300FC/2,700FH				4,500	
Tyre replace (5th in cycle)	1,500FC/13,500FH				12,000	
Total tyre remould & replace	13,500FH				30,000	2
Wheel rim inspection	1,500FC/13,500FH				9,000	1
Thrust reverser repair	6,000FC/54,000FH				800,000	15
APU shop visit	22,000FH				275,000	13
LRUs/Rotables						
Lease rate						60
Fixed FH repair cost						415
Tot al cost per FH						**885**

every 1,500FC is $2,500 per tyre and $30,000 for the complete shipset. This cost is equal to $20 per FC, or $2 per FH for an average cycle length of 9FH *(see table, this page)*.

Wheel rim inspections are done about every five wheel removals, which will occur about once every 1,500FC or 13,500FH. The inspection cost per wheel is in the region of $750, and so $9,000 for the full shipset. This is equal to about $6 per FC or $1 per FH *(see table, this page)*.

Thrust reversers for the A340 are maintained on an on-condition basis, compared to the fixed intervals of older aircraft types. Estimates for removal intervals are in the region of 6,000FC, equal to about 54,000FH or 12 years of operation. This implies that airlines will only have to consider one repair for each thrust reverser during the life of the aircraft.

Third party repair costs are expected to be in the region of $170,000-220,000 per unit, or about $800,000 per shipset. This is equal to about $135 per FC, or $15 per FH *(see table, this page)*.

The A340's APU is the GTCP331-350, and is the same model used by the A330. The GTCP331-350 is more reliable than APUs on older aircraft types, and also has no fixed removal intervals for the replacement of life limited parts.

The most important aspect of APU maintenance is the mean time between removals, which in the case of the GTCP 331-350 is expected to be about 3,300 APU hours. The A340 operates two APU cycles per flight. The one during taxi will be relatively short, but the second prior to departure will be more than one hour in some cases. An average APU cycle time of 40 minutes and flight cycle of nine hours means an APU utilisation of about nine minutes per FH.

APU removals will therefore take place about once every 22,000FH. An average shop visit cost of $275,000 is expected, which will be equal to an APU maintenance cost of $13 per FH *(see table, this page)*.

LRUs and rotables

These components are those described in the third and fourth groups (see page 27). These components include air conditioning (ATA Chapter 21), autoflight (ATA 22), communications (ATA 23), electrical (ATA 24), fire protection (ATA 26), flight controls (ATA 27), fuel system (ATA 28), hydraulic power (ATA 29), pneumatics (ATA 36) and engine and fuel control (ATA 73).

The A340 benefits from lower A, C and heavy check man-hour inputs compared to older generation aircraft. Line inputs are similar to other large widebodies, irrespective of actual size. LRU and rotable repair costs are also close to other widebodies. The A340 thus gains some benefit from modern technology compared to older generation counterparts.

The repair philosophy for these components is that some are on-condition, some have hard lives for repair, and others hard lives for replacement. Some airlines have established 'soft' intervals for parts with on-condition maintenance.

Components with on-condition lives and that can be easily removed and replaced during line maintenance are grouped as LRUs. An inventory of these is required at the main base, while access to the parts not classified as 'no-go' items is required at outstations. It is estimated that a fleet of 15 A340s will require an inventory of about 800 different line items and a total of about 2,200 different parts *(see The economics of acquiring & maintaining LRU inventories, Aircraft Commerce, February/March 2001, page 32)*. The investment for this will be in the region of $20 million. To illustrate the equivalent cost for this, the inventory can be leased and the repair and management can be paid for on a power-by-the-hour (PBH) basis. A lease rate factor of 1.2% per month will result in a lease of $240,000 per month for 15 aircraft. This is equal to about $60 per FH per aircraft in the fleet *(see table, page 34)*. The PBH rate for repair and management will be in the region of $300 per FH.

Many of the other components are deep in the aircraft and so require the deep access for removal provided during a heavy check. This is despite some being on-condition, and theoretically being capable of a removal interval that requires removal between heavy checks. Lufthansa Technik puts a cost for the repair and overhaul of these components at a rate equivalent to about $115 per FH *(see table, page 34)*.

The total cost for LRU and rotable components is therefore $475 per FH.

The problem for most A340 operators is there is still relatively little experience with components and their realistic maintenance costs. Third party contracted costs are therefore likely to be high. Once more experience is gained, rates charged will probably reduce. An internal airline cost for the repair and overhaul of all LRUs and rotables is in the region of $200 per FH. This is considerable lower than the fixed PBH rate for LRUs and additional separate cost for rotables.

Summary

Based on the assumptions of utilisation and check intervals, the cost per FH for airframe and component maintenance is $885 *(see table, page 34)*. This compares to $1,040 per FH for the same elements for the 747-400. The A340 has consistently lower costs per FH for line and all airframe checks. In particular, the A340's combined cost for C and heavy checks is $155 per FH against the 747-400's $235 per FH. The 747's costs, however, include an element for rotables, assumed to be repaired during the D check. The costs for these are accounted for separately in the A340's case, at $115 per FH.

Taking repair and maintenance costs for all LRUs and rotables at $200 per FH, the A340's total maintenance costs will be in the region of $750 per FH, $135 per FH lower than with LRU components supplied and repaired on a third party basis.

On account of modern technology, the A340 has a lower MH consumption per FH for C and heavy checks compared to the 747-400. The 747-400 consumes about 75,000MH for cycle of three C checks followed by a D check. This is equal to about 2.7MH per FH. Over the full C check cycle to 8C/D check, the A340 consumes about 82,000MH over an interval of 42,000FH, equal to about 2MH per FH. The difference is almost zero once the seat numbers of the two aircraft is taken into account.

As for most aircraft types the cost of LRU inventory for the A340 is high relative to total airframe and component maintenance costs. At $60 per FH for leasing the material and a further $300 per FH for repair and management, LRU components account for about 40% of total airframe and component cost. The cost for this element is similar to that for the 747-400, and so the A340 loses some of the advantage gained in lower line and A check costs per FH. Despite being lower than the 747-400's cost, line check inputs are disproportionately higher for all smaller aircraft.

The A340-300 is configured by many carriers with about 275 seats, compared to 380 in the 747-400. The A340-300 therefore has an airframe and component maintenance cost per seat about 20% higher than the 747-400's. This is due to the A340's disproportionately higher line inputs and LRU component costs.

The 747-400 is one aircraft the A340-300 can be compared to. The 747-400 is based on a design originally conceived in the 1960s, with 1980s technology incorporated. The DC-10-30 provides another comparison for the A340-300. This is also an aircraft conceived in the 1960s, but with few improvements the 747-400 has. Passenger configured DC-10-30s have airframe and component maintenance costs of about $1,020 per FH *(see Maintenance cost budget for DC-10s, Aircraft Commerce, January/February 2000, page 22)*. This is for an aircraft operated under a MSG2 maintenance schedule. The DC-10's line check inputs are similar to the A340's, but the DC-10 has a higher A check cost of about $10 per FH. The DC-10's combined C and D check cost is about $80 per FH higher than the A340's. The DC-10-30 is typically configured with 245 seats, and so has a maintenance cost per seat about 30% higher than the A340-300. The final difference is largely influenced by actual LRU and rotable repair costs.