

The A320's success continues to accelerate and its customer base is widening. The oldest aircraft in the fleet have reached maturity. The aircraft has a well-earned reputation for low maintenance requirements, although its schedule still requires operators to compromise.

# A320 maintenance cost analysis

**W**ith the oldest A320s completing their first nine-year structural checks, A320 family aircraft being operated by the majority of the world's major carriers, and aircraft having been involved in used aircraft transactions, an analysis of the A320 family's maintenance costs is essential.

All elements of the A320's maintenance, apart from engine-related items, are examined here. The A320 is the oldest member of the family. Detail of man-hours (MH) and material costs can now be given with some accuracy. There is less experience of A319 and A321 maintenance. The major differences between family members arises, however, with structural items, such as door numbers and cabin work. Most other maintenance items have similar requirements. This analysis relates to the A320, to which estimates of differences for the A319 and A321 can be applied.

The A320 family has proved to be an efficient operator for several reasons. Many airlines are achieving annual utilisations of 3,100 flight hours (FH) and 1,670 flight cycles (FC). This results in an average FH:FC ratio of 1.86FH. This analysis of A320 maintenance costs is based on such a typical operation. Annual utilisation will influence the utilisation of FH and FC intervals between calendar limited checks and thus the economics of the A320's maintenance costs.

Some European carriers, however, achieve lower rates of utilisation and have shorter average flight cycles and so are unable to achieve the same levels of maintenance efficiency.

## Maintenance breakdown

The A320 appears to have a relatively simple maintenance schedule. Unlike in older types, the corrosion

prevention and control programme (CPCP) is an integral part of its airframe checks. So far, there have not been any ageing aircraft service bulletins (SBs) or Airworthiness Directives (ADs).

Apart from airframe checks operators only have to consider line maintenance and the usual removal of heavy components, line replaceable unit (LRU) components and interior work.

The A320 differs to older types of similar size, such as the 737 and MD-80, in its use of fly-by-wire (FBW) flight controls and design. "This reduces the amount of work required for accessing, removing and working on components during heavier checks," explains Ray Kazmierczak, head of engineering and planning at Shannon Aerospace. "The aircraft also has easier and quicker access. For example, it takes about half a day to remove a lavatory from an A320 compared to one and a half days in a 737. It is also easier to take off and put back flight controls such as flaps."

Many maintenance providers are also finding the A320 generally has a lower defect ratio than the 737. "This is explained by a lower incidence of corrosion, it being easier to deal with corrosion and the ability to unbolt old parts of the aircraft's structure and replace them with new ones," says Kazmierczak.

## Maintenance schedule

The A320's schedule is comprised of a simple system of three line checks, a three-multiple A check system, a four-multiple C check and two structural checks.

One negative factor is the large number of out-of-phase items that have to be performed early to avoid excessive downtime.

Line maintenance is broken into pre-flight, daily and weekly checks. The original interval for these checks, as laid

out in the aircraft's maintenance planning document (MPD), are at each FC, every 24 hours and every seven days. The intervals for the daily and weekly checks have been extended by some operators to between 36 and 48 hours and eight days. These three checks can all be performed on the ramp and incur minimal downtime.

Work included in the transit or pre-flight check includes a review of the aircraft's technical log, inspection of landing gear doors, a walk-round inspection of the aircraft and the checking of oil and hydraulic fluids. For V.2500-powered aircraft an inspection of the acoustic panels between the engine fan blades and inlet guide vanes is also added.

The terminal or daily check requires the checking and deeper inspection of battery power and several of the electrical systems, including fire detection and external lights. Checking cargo compartments, draining water from fuel tanks and checking brake wear indicators are also included.

The weekly check includes completion of a terminal check. All flightdeck screens are cleaned, emergency systems are tested, doors and emergency exits and oxygen bottles are tested and landing gear bays are inspected for integrity and safety of downlocking pins. Other items include the replenishing of engine oil reservoirs.

## A checks

The A320's A check cycle consists of three A check multiples. The 1A multiple job cards package has an interval of 50 days and 500FH. There are also the 2A and 4A multiples with intervals of 100 days and 1,000FH and 200 days and 2,000FH.

The A320's A checks can be organised by an operator in two ways.



The first is to perform the multiples separately. This results in A1, A2, A3 and A4 checks being performed every 50 days. These four are performed in a continuous cycle. The A1 would be performed first, including just the 1A, at 50 days. The A2 would then be done at 100 days and would include the 1A and 2A packages.

The A3, at 150 days, would include just the 1A package again, while at 200 days the A4 would comprise the 1A, 2A and 4A items.

"The A1 is basically a line check," explains Simon Ferguson, senior technical planner at FLS Aerospace. "Most operators can perform this on the line, although Scandinavian Airlines have to do this in the hangar because of weather conditions.

"The A4 includes engine borescopes in the case of V.2500-powered aircraft and also undercarriage and wing lubrications," says Ferguson. "To make planning easier and downtime more even between A2 and A4 checks, the 4A items which relate to the left side of the aircraft are sometimes put into the A2 checks. These are items, however, which are FH-related and concerned with the V.2500. In the case of CFM56 engines, the same tasks are FC-related and so, depending on the operator's FH:FC ratio, may have to be performed as items which are out of phase with the A and C checks," he continues.

These checks are performed in a constant cycle until the C check is reached.

The other method of organising A checks is by an equalised system. This puts 1A tasks into every check and splits 2A items in half and 4A items into

quarters to derive an equalised A check of four equal packages. "Job cards can again be split between left and right items so as to spread the workload," says Ferguson.

There are different types of engine and auxiliary power unit (APU) used on the aircraft. The A320 family uses two Allied Signal APUs and the Sundstrand/APIC APS 3200 series. The different number of line tasks on these APUs causes small differences in MH content on A checks.

"The CFM56-powered aircraft tend to be better because the engine does not require a borescope every A4 check, unlike the V.2500," explains Ferguson. "The CFM56 has a longer borescope interval, plus the V.2500 also has a lot of inspections at the moment because it requires an ultrasound scan every A4 or C check because of cracks found in the dovetail joints of the fan blades."

## C checks

The C check has four multiples: the 1C, 2C, 4C and 8C. The basic 1C tasks have an interval of 15 months and 4,000FH. However, that figure is rarely achieved because of most operators' annual utilisation.

On the basis of 3,100FH per year used in this analysis, 3,875FH will be generated between C checks if performed every 15 months. Swissair, for example, is working to have its C check interval escalated to 18 months, which will increase FH between the checks. In fact, many operators find it more convenient to schedule C checks annually.

*The A320's maintenance schedule still has awkward intervals for A-check and C-check multiples, structural checks and out of phase items which force operators to compromise maintenance planning.*

Operators will aim to complete two A check cycles and perform a C check with the second A4 check at 400 days, or every 12–13 months. The A320's maintenance schedule is awkward in this respect, since two complete A check cycles have to be completed in 400 days, 50 days short of the C check interval.

Operators may be forced to align the C check with another A check, if performed every 450 days. This is likely to be an A1 or A2. An alternative is to perform the C check early, usually at a convenient 12-month interval. This reduces FH between C checks, reducing efficiency. When the C check interval is extended to at least 18 months it will become economically feasible to align the C check at the end of the third A check cycle.

The basic 1C package has an interval of 15 months, while the 2C is 30 months. The C1 check is therefore just 1C items, while the C2 check is 2C job cards. The C3 check is the same as the C1 and the C4 comprises 1C, 2C and 4C items.

This cycle is basically repeated, with the C8 check also having 8C job cards. The C8 check has an interval of 120 months, or 10 years.

"Operators and lessors have to be careful when terminating leases," says Ferguson. "Aircraft have to be cleared of major maintenance tasks for 15 months for a new lease. Therefore, the next C check due has to be performed. All out-of-phase items and major component changes have to be done as well. Many lease contracts also require the aircraft to be returned to the lessor with the original engines. This can all require a lot of early maintenance for the aircraft."

## Structural checks

Like all other Airbus aircraft, the A320 family has two structural checks, the first performed at five years and the second at nine years. Operators will attempt to terminate A and C check cycles at these checks, although the nine-year check will have to be scheduled with the C7, leaving the C8 to be done on its own 15 months later. Most operators actually aim to schedule the nine-year check with the C8, completing the C check cycle a year early.

"The five-year and nine-year checks run independently from the C checks," explains Ferguson. "The five-year and

nine-year checks are basically similar to D checks on other aircraft types.”

The five-year and nine-year checks can also involve a structural sampling programme. “Each operator has to nominate the oldest fifth of its fleet as those to be included in the sampling programme,” says Kazmierczak. “That is, if an operator has five aircraft, the oldest one will go in the sampling programme. If the airline has between six and 10 then two will have to be put into the sampling programme.”

“An operator is not permitted to have aircraft in the sampling programme across different models. That is, A319s, A320 and A321s have to be considered separately in their own sub-fleets,” says Kazmierczak. “If aircraft not in an operator’s sampling programme are sold to another airline and are the oldest it operates, they must be put into the sampling programme.”

The objective of the sampling programme is to test for structural integrity as defined by Airbus in the aircraft’s MPD. All the same tests are done on all aircraft in the sampling programme. “Once one aircraft has accumulated 40,000FC then all the aircraft in your fleet have to be put into the sampling programme,” says Kazmierczak. At the nine-year check an aircraft with average levels of utilisation will have achieved 15,030FC and so about 30,000FC by the second nine-year check. All aircraft will therefore have to start the sampling programme at their third nine-year check. Many operators with short FCs that achieve at least 2,200FC per year will have to start the sampling programme at the second nine-year check.

“The content of five-year and nine-year structural checks is extensive,” explains Kazmierczak. “First, C4 and C7/C8 checks and corresponding A checks will be included. The routine work will also include functional tests and structural and system checks. These will also throw up non-routine items or defects. The routine and non-routine work and supervision required to carry it out will incur a substantial number of MHs.

“The additional items, as required by each operator, can include interior refurbishment, stripping and painting, incorporation of SBs and ADs, repair of rotables and out-of-phase tasks,” says Kazmierczak. “The 20% sampling programme adds about 2,500MH to aircraft when it is included in their schedule. The findings of the sampling programme may then require more aircraft going into the programme at an operator’s discretion. One effect of this could also be to increase the number of MH required in the check.”

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## Additional items

Besides regular A and C checks, the A320 family has several maintenance tasks that are out of phase with A and C check intervals.

“There are items that have intervals that lie in various stages between A and C checks,” explains Ferguson. “The actual timing of these depends on the aircraft utilisation. For example, an item

with a 500FH interval falls between an A and C check. If the operator does 10FH per day, however, then this item will fall conveniently into the A check. Most airlines, with a lower rate of utilisation, will not achieve 500FH in 50 days and the task will have to be brought forward into the A check and done early.”

In addition to weekly and A checks, some operators also have supplemental



The A320 has earned a reputation for easy access and low defect ratio. This keeps man-hours low.

checks that are performed every 28 days, about halfway between A checks.

C checks also have out-of-phase tasks incorporated into them, escalating MH consumption.

Out-of-phase items that raise the MHs required include heavy component changes and engine and APU borescopes.

## MH consumption

MHs consumed can usually be estimated in many aircraft types by taking MPD estimates and escalating them by a labour efficiency factor to derive MH expenditure on routine work. A defect ratio will then derive additional MH required, as will a factor applied to calculate handling and administration.

“The A320 MPD does not have MH estimates,” says Ferguson. “It is also more difficult to derive a multiplication factor to get from MPD MH to routine MH, as well as estimating the defect ratio.”

MH consumptions quoted here assume that two A check cycles are completed prior to each C check with the second A4 done together with a C check. The C4 and C7 checks are then assumed to be combined with the five-year and nine-year checks. This leaves the C1, C2,

C3, C5, C6 and C8 checks to be performed individually.

Typical MH consumption for line checks are one for each pre-flight check, three for the daily, about 10 for weekly checks and about six for the supplemental checks (*see table, page 46*).

Using the un-equalised A check system, the A1 and A3 checks have a typical consumption of 45MH for routine tasks. The A2 check consumes about 160MH and the A4 about 175MH. The A320 A checks typically experience a defect ratio of about 50% and so defect MH arise accordingly. The defect ratio starts at about 40% for new aircraft and is expected to climb by about 5% a year before maturing after about 20 years.

About another 10MH should be added for interior cleaning and up to 50MH per check for out-of-phase tasks and the incorporation of SBs. This takes consumption to about 130MH for A1 and A3 checks, 300MH for A2 checks and 325MH for A4 checks. This takes MH consumption for an average A check to about 200 (*see table, page 46*).

The C checks have additional elements in them which escalate MH over those required for routine work and any defects arising. The C1, C3 and C5

checks each require about 680MH, while the C2 and C6 consume about 1,050MH for routine work. The C8, performed separately, requires about 1,320MH for routine tasks.

As in the A checks, defect ratio increases with age, but also varies with depth of the inspection. The C1 check, therefore, generally has a lower defect ratio compared to the C8. Defect ratio for all C checks, except the C8, vary between 0.65 and 0.85. The C8 has a defect ratio which is at least a factor of 1.0 because of the deeper level of inspection of the check.

This takes the sub-total of MH for routine and consequent defects to between 1,100 and 1,800MH for all checks, except the C8 which uses about 3,050MH. A 15% factor to cover administration and supervision should then be added.

Most operators will have to budget for additional MH to keep their aircraft in a good maintenance condition. Interior cleaning will add about another 100MH for all C checks, except for the C8 which will use about 150MH. Up to another 700 can be added for SBs, ADs, out-of-phase items and customer-specific requirements. This large number of additional MH is required because deeper inspections and consequent defects can also result in cleaning and corrosion treatment.

This will take MH totals for all C checks, except the C8, to between 2,000 and 2,700. The average for the C1, C2, C3, C5 and C6 checks is about 2,400MH. The C8 check will consume up to 4,200MH (*see table, page 46*).

The five-year and nine-year checks are used by most operators to perform stripping and painting, interior work and repair of rotables because of the long downtime and the depth of checks. The five-year check also comprises the C4 check and so accrues a large number of MH. About 4,200MH are used for routine work on an A320 at typical labour efficiencies. The A321 will consume about 200 MH more than this. Early five-year checks will experience a defect ratio of 0.55, although this will rise with age. This ratio will result in a further 2,300MH for defects, taking total MH to about 6,500 for the A320 and 6,750 MH for the A321.

Interior work will be heavier for the nine-year check, but the five-year check



will still involve the repair and repainting of panels. The actual workscope will, however, be customer-specific. A budget of about 1,300MH for an A320 and 2,100MH for an A321 would be typical for an operator wanting to keep a clean aircraft with a pleasing appearance.

Incorporation of SBs and out-of-phase work and other customer-specific items will add about a further 1,800MH to the check. These can include fairly major modifications, such as installation of traffic collision avoidance systems (TCASs) on the aircraft. This modification is appropriate for the earliest delivered aircraft which did not have TCAS originally installed. Major modifications to most aircraft will also be required on an on-going basis, as well as deferred and casualty items.

Stripping the aircraft and repainting may only be done during the nine-year check, but most carriers may elect to apply a new paint job at the five-year check. This would add another 1,500MH. Operators should finally budget about 300MH for component changes.

This takes the total for the A320 to about 11,400MH (see table, page 46) and for the A321 to about 12,500MH.

Only a few maintenance facilities now have experience of nine-year checks. Although the first aircraft consumed more than 20,000MH, some maintenance centres believe that aircraft not in the sampling programme should consume about 17,000–18,000MH once they have been through the learning curve of dealing with the aircraft.

The nine-year check requires about 7,000MH for routine items. The defect ratio in the first aircraft to be put

through nine-year checks was about 0.7, but as mechanics become familiar with the aircraft this is coming down to about 0.6. This adds about another 4,000MH. The sampling programme will add about another 2,500MH, taking totals for routine elements to 11,000MH for aircraft not in the sampling programme, and to about 13,500MH for aircraft in the sampling programme.

Operators will elect to perform interior refurbishment on the aircraft during this check. This will involve the complete removal and cleaning of the toilets and galleys, installation of new seat covers and carpets and refurbishment of sidewall panels and overhead bins.

Customer modifications are likely to require a large number of MHs for the initial batch of production aircraft. This is explained by small design errors requiring modification, which were incorporated on the production line for later-built aircraft. These machines may therefore require fewer MHs for this part of the nine-year check.

Some individual modifications can also require a large number of MHs to rectify. SBs can also be issued several years before a large enough check, such as the nine-year check, comes due for them to be implemented. While some operators may only input about 600MH for additional items, a budget of up to 2,500MH is prudent.

Another 1,500MH should be considered for stripping and painting. The A320 is generally harder to strip than the 737, because the A320 has composites in its structure which cannot be stripped and so have to be sanded. There are also some paint schemes which

*Operators should experience differences of about 1,500 MH consumption between A320 family members for the nine-year checks.*

peel off and leave the primer, while others have to be completely stripped.

Finally, about an additional 500MH should be budgeted for component changes, which may include the landing gear and thrust reversers.

All these elements take the total MH count to about 18,000 for an A320 not in the sampling programme for its first nine-year check. Aircraft in the sampling programme will use about 20,600MH (see table, page 46).

Differences in total MH consumption of about 1,500 MH will arise between the A320 and smaller A319 and larger A321 in their nine-year checks. These will result from differences in MH consumed for interior refurbishment, the cargo compartments and doors.

## Materials and rotables

Materials and consumables are expended in all checks. Aircraft components are maintained on a variety of schedules and each have to be considered.

Components should be broadly divided into 'off-aircraft' components and 'on-aircraft' components. Off-aircraft rotables are those which have maintenance schedules independent of airframe checks or are maintained on an on-condition basis. This group of parts includes landing gears, wheels, brakes, tyres and LRUs. They are considered in the next section.

On-aircraft rotables are those parts which are removed for repair during heavier and deeper airframe checks, when access permits their removal. Their maintenance schedules can either be hard time, that is, in conjunction with airframe checks, or on-condition.

The A320's on-aircraft rotables are maintained on-condition and will be removed for repair during five-year and nine-year checks. They will have a low removal and repair rate for the first of these checks. The amount of rotatable repair will increase from the second five-year and nine-year checks, however.

The last group of materials and parts to budget for are those used for interior refurbishment. In most cases this will include seat covers and carpeting.

Materials and consumables used during line, A and C checks will be used at a rate of about \$15–20 per FH. That

figure is typical for aircraft of this size. This generates material and consumable consumptions as described (*see table, page 46*). Lighter A checks consume about \$2,000 while heavier A2 and A4 checks consume up to \$5,000. This will average about \$3,300 for an A check.

All lighter C checks (C1, C2, C3, C5 and C6) will consume an average of \$34,000 of materials and consumables. This ratio of cost will rise as the aircraft ages and the defect ratio rises. The heavier C8 check, performed independently of the nine-year check, will consume about \$50,000 for well-maintained young aircraft.

The depth of the five-year and nine-year checks means that their material and consumable consumption level will be higher than the lighter A and C checks. The five-year check will use materials and consumables closer to a level of \$20 per MH spent and the nine-year check at a rate of about \$25 per MH. This generates expenditure of \$250,000 and \$450,000 for the two checks (*see table, page 46*).

Rotable repairs are sub-contracted by many maintenance facilities and only the largest can justify the cost of their own in-house shops. Total third-party rotable repair costs are about \$50,000 each for the first five-year and nine-year checks. These could rise to as much as \$200,000 for the second series of heavy checks.

Materials for interior refurbishment will amount to about \$100,000 for the nine-year check and about \$40,000 for the five-year check for the A320. The cost of materials and MH required for this part of airframe maintenance is one of the major areas of difference between members of the A320 family.

## Components

The components covered so far are the rotables repaired during major airframe checks. The others to be considered are the APU, landing gear, wheels, brakes, tyres and LRUs.

The A320 family's landing gear has a removal interval of eight years and 20,000FC. Considering typical rates of utilisation the FC limit is not likely to be reached in eight years and operators will not be able to utilise the 20,000FC. In this analysis and rate of utilisation assumed for the aircraft only 13,360FC will be achieved every eight years. This is equal to almost 25,000FH.

The removal interval for landing gear will probably get extended to 10 years and so allow 16,700FC between removals. The current eight-year interval will be exploited to its maximum and so gear removal will first occur at the C6 check, after 23,250FH and at the same

FH interval thereafter.

Most operators now opt to have their landing gears repaired and replaced with exchange systems. This involves removing the landing gear and having a freshly overhauled one supplied by an agency. Rather than incur the cost of having its own landing gear shop and paying for repairs, the operator pays an exchange fee to cover the cost of ownership and inventory for the gear and

another element for the repair.

Exchange fees should typically be about 5% of the capital cost. A new set of landing gears has a new cost of about \$1.7 million and so an exchange fee of \$85,000 would be expected. Overhaul can incur a further \$215,000. Competition in the market, however, has forced down exchange fees and a market of between \$130,000 and \$160,000, with an average of \$145,000, can be

## A320 FLIGHT HOUR (FH) AIRFRAME AND COMPONENT MAINTENANCE COSTS

Maintenance Item	Interval	MH consumed	MH cost (\$)	Materials used (\$)	Rotables/Interior (\$)	Total cost (\$)	Cost per flight hour (\$)
Pre-flight check	Per cycle/1.9FH	1	50	14		64	34
Daily check	36 hours/13FH	3	147	41		188	15
Weekly check	8 days/68FH	10	489	137		626	9
Supplemental check	28 days/238FH	6	300	84		384	2
Average A check	50 days/425FH	220	11,000	3,300		14,300	33
C1/2/3/5/6 check	15 months/3,875FH	2,400	119,000	34,000		153,000	33
C8 check	120 months/31,000FH	4,190	210,000	50,000		260,000	8
Five-year check	60 months/15,500FH	11,400	570,000	250,000	90,000	910,000	59
Nine-year check	105 months/27,125FH	18,000	903,000	450,000	150,000	1,503,000	55
Nine-year check with sampling programme	105 months/27,125FH	20,600	1,028,000	450,000	150,000	1,628,000	60
Landing gear	8 years/23,250FH					145,000	6
APU repair (GTCP 36-280/APS 3200)	7,000FH					125,000	17
Wheel inspection	1,500FH-6					5,900	4
Wheel repair	2,800FH-3					12,800	2
Wheel replace	9,000FH					37,400	4
Tyre remould (3)/replace	300FC/900FC					17,200	12
Brake repair/replace	1,000FC/15,000FC					297,000	11
LRU PBH rate							205
<b>Total cost per Flight Hour (sampling programme not included)</b>							<b>509</b>

*This table is based on an annual aircraft utilisation of 3,100FH and 1,670FC and an average flight time of 1 hour and 52 minutes*

expected for the A319 and A320. The A321's heavier gear would be expected to have a fee in the order of \$170,000. This results in a cost of \$6.25 per FH for the A319 and A320 and \$7.30 per FH for the A321.

The A320 family is powered by two Allied Signal APUs and the Sundstrand/APIC APS 3200. The original Allied Signal APU was the GTCP 36-280, but has short on-aircraft times for some airlines. "We had an on-aircraft time of about 4,000 operational hours for the 36-280," says Ugo Cucciniello, head of purchasing, logistics and marketing at Alitalia. "We are now retrofitting our A321 fleet with the GTCP 131-9A. We expect an on-aircraft operational time of 7,000 hours for this APU, which will lower maintenance costs. We also expect the APU to have more reliable LRUs."

The APS 3200 also has a reputation with some airlines for not being as reliable as the 131-9A. The APS 3200 has a similar on-aircraft operational time between removals of about 4,000 hours.

The APS 3200 and GTCP 36-280 both only have heavy shop visits and do not have hot-section inspections. These shop visits have a typical third-party cost of \$100,000-150,000. The number of APU operational hours is sometimes difficult to convert to aircraft FC or FH.

The APU is usually required during turn time of about 45 minutes in most operations and for 10 minutes during engine start and taxi out and five minutes during taxi in.

This ratio of one APU operational hours to 1FC means that an APU operational time of 4,000 hours is equal to about 7,400FH. The 131-9A is expected to have an on-aircraft operational time of 7,000 hours or 13,000FH with a similar overhaul cost.

The FH cost for the GTCP 36-280 and APS 3200 is therefore about \$16.80, while the higher reliability of the 131-9A reduces this cost to about \$9.60 per FH.

Wheels, brakes and tyres are more difficult to budget for because of their on-condition maintenance status. Some operators do, however, closely monitor average rates of removal and repair of these components.

"Wheels are inspected by pilots during the pre-flight check," say Joachim Hemming, manager of reliability at SR Technics. "We remove wheels for a non-destructive testing (NDT) inspection about every 800FC and after about another 700FC for overhaul."

Although wheels do not have an ultimate life limit it becomes more economical to replace them after several repairs. This analysis assumes that three

repairs and six NDT inspections, three with repairs, are performed before the wheels are scrapped and replaced with new ones every 5,000FC.

"The average cost of inspecting a set of four A319 and A320 main wheels is \$3,500. When performed six times over 5,000FC, the corresponding number of FH generates a cost of about \$2.30 per FH. A set of four A321 wheels costs about \$4,200 to test and so has a higher FH cost of \$2.70.

Nose wheel inspections cost about \$2,400 per set and so have a FH cost of about \$1.50.

Overhaul of main wheel sets costs about \$2,900 for the A320 family and results in an FH cost of \$1.0. Nose wheel repairs also cost about \$2,900, or \$0.90 per FH.

A complete set of new main wheels costs about \$37,000 and so has an FH cost of \$4.00. Altogether, the cost of inspecting, repairing and buying new wheel rims costs about \$9.60 per FH for the whole A320 family.

"Wheels are also removed for other reasons," explains Hemming. "Besides wheel rim inspections, tyres also have to be removed for remoulding. We remove tyres for remoulding about once every 300FC." Tyres can legally be remoulded three times before having to be replaced.



A new set will therefore be required about once every 900FC, or every 1,700FH on an average FC of 1.86FH.

Remoulding a set of A320 tyres costs about \$3,400, or \$600 per main tyre and \$500 per nose tyre. This is performed twice every 900FC. A new set costs about \$6,800. Altogether, remoulding and replacing tyres at this rate of utilisation will cost about \$8.20 per FH.

Like wheels, brakes are also highly variable in the rate at which they require removal for inspection and repair and ultimate replacement. "We remove brake units for inspection and repair about once every 1,000FC," says Hemming. "It costs about \$2,300 on average to repair each brake unit, making the total repair cost for the four main wheel brakes \$9,200". Brakes are not life limited and could be repaired an indefinite number of times. A brake unit has an average life of 15,000 FC and so will be repaired 14 times and replaced on the 15th removal. The cost for a main wheel brake is about \$42,000. The cost of repair is therefore about \$5 per FH and replacement \$6 per FH.

The final element of components is that of LRUs. Most airlines now elect to sub-contract LRU support and repair because of the desire to divest in inventory and repair shops.

Spare parts providers now provide a service to airlines with small fleets whereby the inventory is leased to them and repairs are dealt with on an exchange basis. The result is LRU inventory supply and repair and exchange on a power-by-the-hour basis.

This cost comprises two elements. The first includes the lease of the inventory.

The lease rate for components is typically 1.0–1.5% per month of the inventory cost depending on aircraft age. A spares supplier should have costs of 1.0% per month for an A320. Expenditure on inventory per aircraft reduces as fleet size increases. The aim of spares suppliers is to capitalise on economies of scale and so consequently they service fleets for several carriers, reducing inventory per aircraft. Inventory for large fleets will be in the order of about 5% of aircraft cost per aircraft in the fleet. A spares supplier should therefore be able to lease LRU inventory at a rate of \$17,500 per month for \$2 million worth of inventory per aircraft. This will give rise to a lease rate equal to about \$70 per FH.

Exchange fees are based on typical failure rates. The market rate for the A320 is about \$135 per FH. The cost for LRU supplied on a PBH basis for the A320 is therefore about \$205.

## Summary of costs

The table (see page 46) summarises all the checks and component maintenance and their associated costs. These are a result of the two factors of C checks being performed every 15 months and the aircraft achieving an annual utilisation of 3,100FH. The labour cost used throughout is \$50 per MH and results in the check costs shown in the table. Total costs are US\$509 per FH.

Many aircraft are operated differently to this. The C check is performed annually in many cases so that it falls conveniently at the same time every year. This will have a serious impact on C check-related costs, although the aircraft could still have their

Most elements of maintenance for the three members of the A320 family are similar. Major differences arise for interiors, cargo compartments and doors during structural checks. This means costs for each family member will differ by just a few dollars per FH.

five-year and nine-year checks performed at the appropriate time.

Annual utilisation will have an influence on virtually all cost elements. Many operators fly cycles shorter than 1 hour and 52 minutes used here.

Another important consideration is that the costs of the five-year and nine-year checks will be higher for mature aircraft in their second and third heavy check cycles. The first cycle of these checks shows their FH cost to be about \$120, but this could rise to about \$135 per FH for well-maintained aircraft.

One unknown factor with the A320 is the level to which the defect ratio will climb in older aircraft. A modest rise will increase nine-year check MH consumption to 19,000, while a more severe increase will see it rise to 21,000MH. The same unknown factor applies to C checks.

Finally, the A319 and A321 will have similar check and component costs in some cases and different costs in others. Line maintenance, A checks and components should all have similar FH charges.

The largest differences between A320 family members will come with MHs required for structural and interior work in the five-year and nine-year checks. These differences are unlikely to amount to more than 1,500MH in the nine-year check between two adjacent A320 family members. At a rate of \$50 per MH, the difference between checks will result in a cost per FH difference of less than \$3.

By comparison the 737-300/-400/-500 series has similar FH charges (see *The 737-200 and -300/-400/-500 series: a guide to maintenance costs, page 28, Aircraft Commerce, January/February 1999*). This analysis included everything that is analysed here, and in the same way, except for the leasing charges for LRU inventory as part of the PBH rate. This would have raised the 737-300's FH costs by about another \$70, making them \$530 per FH.

The A320's advantage, of course, is that it is a larger aircraft family than the 737-300/-400/-500. The A319/20/21 will therefore have lower costs per seat, especially when the 186-seat A321 is compared to the 145-seat 737-400. The general consensus is that the A320 family has a better quality of construction than the 737 and that the A320 experiences a lower defect ratio. The A320 is also expected to experience a lower rise in defect ratio as it ages. **AC**