The A320 has been in operation for more than 23 years. While it is still attracting orders, the oldest aircraft will now have completed two base check cycles. An examination of how the A320 family's maintenance programme has evolved and the inputs for both base check cycles reveals how its maintenance costs are likely to change with age.

A320 family 1st & 2nd base airframe check cost analysis

Since it entered service in 1988, the A320 family has grown to more than 4,200 in operation with 250 different operators. There are another 2,400 aircraft on firm order.

The A320 family was conceived with a maintenance programme that included a base maintenance cycle of eight checks, which had a full interval of nine years. This was increased to 12 years in 2005. This means that the oldest aircraft will have been through two base complete base maintenance cycles. Although the utilisation of man-hours (MH) and parts and materials in its first base maintenance cycles was low enough to make the A320 was economic to operate, the inputs used in its second and subsequent base maintenance cycles will determine how economic it will be to operate as a mature and ageing aircraft.

A320 family in operation

The A320 is operated in large numbers, and is popular on all continents. It is operated by full-service airlines and flag carriers, low-cost carriers and by inclusive-tour airlines. The aircraft is also operated in a variety of fleet sizes, as well as in mixed fleets of two, three or four of the family variants.

The A320 family is mainly used as a short-haul workhorse, with most flight times between 1.0 and 2.0 flight hours (FH). The annual utilisations of most aircraft are 2,000-3,000FH and 1,300-2,000 flight cycles (FC).

The A320 is the dominant variant, with more than 2,400 aircraft in operation and another 1,900 on firm order. The build profile of the A320 shows that 105 aircraft are more than 20 years old, 665 aircraft are 10-20 years old, and 1,600 aircraft are less than 10 years old.

There are 1,191 A319s in service, and another 230 on firm order. The A319 went into service in 1996, and 330 aircraft are more than 10 years old.

There are 615 A321s in operation, of which 190 are more than 10 years old.

There are 2,047 outstanding firm orders: 1,938 for the A320; 230 for the A321; 230 for the A319; and nine for the A318.

Maintenance requirements

Airframe maintenance can be divided into line maintenance, A checks and base check maintenance. Base maintenance checks will comprise: routine inspections; the rectification of defects that have arisen during operation; airworthiness directives (ADs), service bulletins (SBs), modifications and engineering orders (EOs); interior work on furnishings and the in-flight entertainment (IFE) system; and stripping and repainting. The routine inspections and some other elements will give rise to non-routine rectifications. The ratio of non-routine rectifications to routine inspections, expressed as a non-routine ratio, will increase with age. This will have a significant impact on the number of MH and the expenditure of materials and parts required to complete airframe checks as the aircraft get older.

Changes to the A320's maintenance programme mean that some of the routine inspections that were previously in the base checks are now included in the A checks by some operators' maintenance planning departments.

Line checks include inspections that are specified in the aircraft operations manual and its maintenance planning document (MPD). Line maintenance also consumes MH and materials and parts for the rectification of defects that arise during operation.

Component maintenance can be sub-divided between heavy and rotable components. Heavy components include: the tyres, wheels and brakes; landing gear; the auxiliary power unit (APU); and thrust reversers. These will not contribute significantly to an increase in the aircraft's overall airframe and component costs.

The cost of rotables provided by a total support package will rise with aircraft age, mainly due to warranties and repair rates changing in the first five to eight years of operation. Once mature rates are reached at about eight years, costs per FH for rotable support can escalate due to part price inflation.

The most important element of maintenance that will increase with age is the inputs of base checks. Routine tasks increase slightly with age, but non-routine rectifications rise significantly, and add several thousands of MH to subsequent base check cycles.

Maintenance programme

The A320's maintenance programme is derived from the MPD, which in turn comes from several documents. "The two main documents that specify the maintenance tasks are the maintenance review board (MRB) and the airworthiness limitation section (ALS)," explains Caetano Miguel Almeida, engineering maintenance programmes at TAP Engineering and Maintenance. "The ALS has five parts: "Safe Life Airworthiness Items" (ALS Part 1); "Damage Tolerance Airworthiness Limitation Items" (ALS Part 2); "Certification Maintenance Requirement" (CMR, ALS Part 3); "Ageing Systems Maintenance" (ALS Part 4); and "Fuel Airworthiness Limitation Items" (FAL Part 5). The MRB has the remainder of the maintenance tasks for the MRB process, which is related to the minimum approval tasks for a maintenance programme: visual inspections; or improvements in the reliability of the aircraft.

"The MPD has had 35 revisions since the A320 entered service in 1988. The 35th revision was issued in February 2011," continues Almeida. "The MPD is

A CHECK TASKS & ARRANGEMENT OF A CHECK PACKAGES

Original A check task groups & A check arrangement

A check task groups	Task group interval
1A	350FH, 500FH
2A	700FH, 1,000FH
4A	1,400FH, 2,000FH

Original arrangement of A checks - block checks

Check name	Task groups	Check interval
A1	1A	350FH, 500FH
A2	1A + 2A	700FH, 1,000FH
A3	1A	1,050FH, 1,500FH
A4	1A + 2A +4A	1,400FH, 2,000FH

Current A check task groups & A check arrangement - TAP Maintenance & Engineering

A check task groups	Number of tasks	Task group intervals
1A	43	750FH/750FC/4 months
2A	8	1,500FH/1,500FC/8 months
3A	5	2,250FH/2,250FC/12 months
4A	14	3,000FH/3,000FC/16 months

Arrangement of A checks - TAP Maintenance & Engineering

Check name	Number of tasks	Task groups	Check interval
A1	43	1A	750FH/750FC/4 months
A2	51	1A + 2A	1,500FH/1,500FC/8 months
A3	48	1A + 3A	2,250FH/2,250FC/12 months
A4	65	1A + 2A + 4A	3,000FH/3,000FC/16 months

revised when the MRB or ALS is updated. The MPD is also revised when major SBs, ADs, service information letters, or operator information telexes are issued. This is why the MPD has had 35 revisions, while the MRB has only had 15."

When originally issued, the A320's MPD had maintenance tasks arranged into several groups of checks: line checks, A checks, C checks, structural checks, and a zonal inspection programme. At the first issue of the A320 MRB report, the basic A check interval was 350FH, the interval for the group of 1A tasks. There are another two groups of A check tasks with intervals that were multiples of the basic 350FH: the 2A tasks with a 700FH interval; and the 4A tasks with a 1,400FH interval *(see table, this page)*.

To include all these tasks, A checks can be arranged into a cycle of four block checks, with a 350FH interval between each. The first, the A1 check, would have just the 1A tasks, the A2 would comprise the 1A and 2A tasks, the A3 would have just the 1A tasks, and the A4 would include the 1A, 2A and 4A tasks *(see table, this page)*. The basic interval was later increased to 500FH, so the A4 check's interval was extended to 2,000FH.

Like all other Airbus types, the A320's MPD was developed with a system of eight C checks and two structural checks. The eight C checks were derived from four multiples of C check tasks: the 1C, 2C, 4C and 8C tasks. The basic 1C interval was 15 months at the first MPD revision, and the corresponding multiples had intervals of 30, 60 and 120 months. These tasks could therefore be arranged into a series of eight block checks referred to as the C1 to C8 checks. The C4 and C8 were the largest, with the C4 comprising the 1C, 2C and 4C tasks, while the C8 included these three groups plus the 8C tasks *(see table, page 32)*. In contrast, the C1, C3 and C7 checks were lighter checks that comprised only the 1C tasks.

The structural checks were two groups of structural inspections, requiring deep access: the S1 and the S2, which originally had intervals of four and eight years.

The interval of the first structural inspection, S1, increased from four-and-a-half years (54 months) to five years, just as many of the earliest built aircraft came due for their first structural inspections. The second structural inspection then increased from eight-and-a-half years (102 months) to 10 years (120 months) as many of the earliest built aircraft came due for their first second group of structural inspections. The intervals of the C4 and C8 checks therefore matched the intervals of the S1 and S2 checks *(see table, page 32)*. The combined C4 and S1 checks, and the combined C8 and S2 checks, were the two largest in the A320's maintenance programme.

The zonal programme is a group of tasks that was arranged to coincide with the A, C and structural checks.

Another element of the A320 family's maintenance programme is the sampling programme, which affects the oldest fifth of each operator's fleet of A318s, A319s, A320s and A321s. Under the sampling programme, inspections are large structural items, and increase the routine MH required in the C8/S2 check. If there are findings on these oldest aircraft, then the inspections have to be performed on all other aircraft in the fleet.

There were many revisions to the A320's MPD as it progressed through service, and it was revised once every six to eight months.

New MPD philosophy

A major change to the A320's MPD came with the ninth revision of the MRB in June 2004, which triggered the 28th revision of the MPD in January 2005. "This changed completely from a system where the tasks were grouped into specified checks, to one where each task is treated individually and given two or three interval criteria," explains Almeida. "Most of the tasks that were previously in the A and C checks have been given intervals in three parameters: calendar time, FH and FC. Each task can therefore be planned into check packages according to usage parameters.

"The point about the new system is that operators have different rates of utilisation and FH:FC ratios, which meant that many tasks were not fully utilising their intervals," continues Almeida. "Grouping tasks into a particular check also meant the checks were large and required a long downtime. The new system of usage parameters means some C check tasks that do not require deep access or a long downtime to complete, can be planned into smaller checks, such as line or A checks if the operator feels that this is a better way to

C/BASE CHECK TASKS & ARRANGEMENT OF C/BASE CHECK PACKAGES

Original C check task groups & C check arrangement

C check task groups	Task group interval
1C	15 months
2C	30 months
3C	45 months
4C	60 months
S1 structural tasks	60 months
5C	75 months
6C	90 months
7C	105 months
8C	120 months
S2 structural tasks	120 months

Original arrangement of C checks - block checks

Check name	Task groups	Check interval
C1	1C	15 months
C2	1C + 2C	30 months
C3	1C	45 months
C4/S1	1C + 2C + 4C +S1	60 months
C5	1C	75 months
C6	1C + 2C	90 months
C7	1C	105 months
C8/S2	1C + 2C + 4C + 8C + S1 + S2	120 months

Current base check task groups & base check arrangement - TAP Maintenance & Engineering

C check task groups	Number of tasks	Task group intervals
20-month group	135	20 months/6,000FH/4,500FC
40-month group	42	40 months/12,000FH/9,000FC
60-month group	4	60 months/18,000FH/13,500FC
80-month group	349	80 months/24,000FH/18,000FC
S1 or 6-year		72 months
100-month group	2	100 months/30,000FH/22,500FC
120-month group	0	120 months/36,000FH/27,000FC
160-month group	326	160 months/48,000FH/36,000FC
S2 or 12-year		144 months

Arrangement of Base checks - TAP Maintenance & Engineering

Check name	Number of tasks	Task groups	Check interval
C1	135	1C	20 months/6,000FH/4,500FC
C2	177	1C + 2C	40 months/12,000FH/9,000FC
C3	139	1C + 3C	60 months/18,000FH/13,500FC
C4	526	1C+ 2C + 4C + 6-year	72 months/24,000FH/18,000FC
C5	137	1C + 5C	100 months/30,000FH/22,500FC
C6	181	1C + 2C + 3C + 6C	120 months/36,000FH/27,000FC
C7	135	1C	140 months/42,000FH/31,500FC
C8	852	1C + 2C + 4C + 8C + 6-year + 12-year	144 months/48,000FH/36,000FC

plan maintenance checks."

Despite the fundamental change in the way A320 operators can plan maintenance checks, Almeida explains that many operators still refer to checks as generic 'A' and 'C' checks, and also have target intervals for the former A, C and structural checks. "The checks have similar groups of tasks in many cases. The A check target interval was 600FH, 750FC and 100 days in the MPD revision issued in January 2005. This was changed to 750FH, 750FC and 120 days in the MPD issued in 2009 *(see table, page 30)*. The check is performed when one of these parameters is reached first," says Almeida. "There are four groups of tasks in our A check pages. The 1A tasks have an interval of 750FH, 750FC and 100 days. This group has 43 tasks. The other three groups have intervals that are two, three and four times these intervals *(see table, page 30)*. The 2A group has eight tasks, the 3A group has five, and the 4A group has 14.

"The C check interval was set at 6,000FH, 4,500FC and 20 months in the MPD revision issued in January 2005; and is performed when one of the parameters is reached," continues Almeida. "In our case, we have seven groups of base check tasks. The basic interval is as described, and the other six groups have intervals that are two, three, four, five, six and eight times this interval *(see table, this page)*. These seven groups of tasks have been derived from the original 1C, 2C, 4C and 8C tasks in the older MPD."

The 20-month group of tasks has 135 MPD tasks, the 40-month group has 42, the 60-month group has four, the 80-month group and 6-year group together have 349, the 80-month and 100-month groups only have a small number of tasks, and the 160-month group and 12-year group together have 326 tasks *(see table, this page)*.

The base check intervals will be extended to 7,500FH, 5,000FC and 24 months in the 16th revision of the MRB, which will be published later in 2011. The S1 and S2 groups of tasks now have intervals of 72 and 144 months *(see table, this page)*.

The seven groups of base check tasks and two groups of structural tasks are arranged into a system of eight checks. As with the original system, the fourth and eighth checks in the cycle have the most tasks and are the largest.

Combining the S1 with the C4 check limits it to an interval of 72 months, while combining the S2 with the C8 check limits its interval to 144 months.

The 24-month C-check interval that will come at the next MRB revision, and the 72-month and 144-month intervals for the S1 and S2 groups of tasks, means the S1 tasks could now be combined with

There have been 35 revisions to the A320's MPD. The most significant change came in 2005. This was the abandonment of the specified checks and a change to interval parameters for each task. This allows operators to plan tasks into checks in the most optimum way in relation to their operation.

the C3 check, and the S2 tasks combined with the C6 check. "The 4C and 8C tasks are not structural inspections, so no real deep access is required to perform them. They do not necessarily have to be combined with the S1 and S2 groups of inspections," explains Almeida.

A check inputs

Bilal Karaman, executive vice president of production at MNG Technic, explains that the labour requirements of A checks have changed little as the aircraft has aged. The overall contents and resulting reserves nevertheless have a significant effect on the aircraft's total maintenance costs.

Ibrahim Saied, production control manager at Egyptair Maintenance & Engineering, estimates the total routine MH for the A checks as 95MH for the A1 and A3 checks, 162MH for the A2, and 210MH for the A4.

Saied adds that non-routine ratios for A checks are low, and range from 0.25 for the lower checks to 0.35 for the largest A4 check. Once MH for non-routine rectifications and additional labour for administration, customer items and lower line checks, have been taken into consideration, totals are 150MH for the A1 and A3 checks, 250MH for the A2 and 340MH for the A4.

About 20MH can be added to each check for interior cleaning, and another 15-30MH for ADs, SBs and EOs. Saied also recommends including a few MH for small amounts of paint work and component changes.

Some interior refurbishment work is also undertaken during A checks. There will be some ad hoc repairs at each check, and a budget of 20MH and $400 of materials should be used for these. Seat covers are cleaned every second A check, and 160MH is required to remove and replace them. A small allowance of $500 for dry cleaning should also be made. Finally, aisle carpet is often replaced every second A check. This uses 15-20MH, while the new carpet costs about $2,500.

Total labour for interior refurbishment will therefore be 20MH in the A1 and A3 checks, and 200MH in the A2 and A4 checks. The related cost of materials will be $400-500 in the A1 and A3 checks, and $3,500 in the A2 and A4 checks.

The total labour for the four A checks will be about 1,600MH, while the cost of materials, consumables and parts will be $35,000-40,000.

Using a generic labour rate of $70 per MH, total cost of labour and material inputs will be $150,000. While the MPD interval for the A4 check is 2,800FH, the actual interval achieved for the cycle is likely to be close to 2,000FH, so the reserve for the A checks will be $75 per FH.

Base check organisation

The system of grouping tasks into the eight C checks in the cycle, the C1 to C8 checks, under the old MPD system grouped the 1C, 2C, 4C, 8C, S1 and S2 check tasks into block checks. The C4 was the second largest check because it included the 1C, 2C, 4C and S1 tasks. The C8 was the largest, since it included all the tasks that were in the C4 check, plus the 8C tasks and the S2 check tasks. The grouping of tasks in the eight checks is summarised *(see table, page 32)*.

The ability to group tasks to optimise aircraft downtime and utilisation under the new MPD system of usage parameters for each task, means some tasks that were previously included in the C checks may no longer be included in the base checks. "Many operators keep the old nomenclature of C checks, and still have a system of C1 to C8 checks," says Karaman. "Some operators refer to the new base checks as 'B' checks, and so have a series of B1 to B8 checks. These can have fewer routine tasks than the old C checks, so they will need fewer MH to complete the routine inspections. The A checks will, however, be larger."

There are several ways operators can group tasks into packages. TAP Engineering and Maintenance, for example, now has seven groups of base check tasks, as well as the two groups of structural tasks with 6-year and 12-year intervals. These are the same as the S1 and S2 tasks in the old MPD.

TAP arranges these nine groups of base check tasks into the cycle of eight base checks is summarised *(see table, page 32)*. TAP generically refers to these eight checks as C1 to C8 checks. As with the old system, the C4 and C8 checks are the two largest. The C4 check has four groups of tasks, which total 526 inspections. The C8 check has six groups of tasks, which total 852 inspections. This compares to the C1 check, which only has the 1C tasks, and total 135 inspections *(see table, page 32)*.

Air France has already managed to have the interval for its 20-month tasks extended to 24 months, and the interval for its 40-month tasks extended to 48 months. However, the interval for the third group of tasks, the 80-month group, has not been extended.

Air France has nevertheless decided to change from having eight base checks in the cycle to six. The 24-month base check interval means the third check has an interval of 72 months, and the sixth check has an interval of 144, coinciding exactly with the S1 and S2 tasks. The only compromise is that to avoid additional downtime, the 80-month tasks must be performed early at 72 months and again at 144 months.

Base check contents

There are up to eight or nine elements of base checks that combine to determine the total amount of labour and material inputs. The content of each of these

Despite the change in the MPD to interval parameters for individual tasks, most airlines still group tasks into similar groups that were used in the past. These groups of tasks are then usually formed into a cycle of eight base checks, which have a similar number of tasks and workscope to the previous system of specified checks.

elements ultimately drives the total MH and materials used in maintaining the aircraft. Not all elements will be included in each base check, but most checks will include at least six different elements.

Routine inspections

The first element is the routine inspections. The MPD now allows these to be arranged in different ways. The current 20-month interval for the base checks means most airlines are still organising base check tasks into a cycle of eight base checks, as C1 to C8 checks, or Base 1 to Base 8 checks.

The number of routine inspections, and therefore the number of MH required to complete them, will depend on how many tasks are included in each of the eight checks. An example of how these checks are arranged and the number of tasks in each check is given by TAP Engineering and Maintenance *(see table, page 32).*

The two groups of structural tasks are the largest, with several hundred tasks. The largest checks are therefore the C4 and C8, or Base 4 and Base 8 checks.

The extension of the base check interval to 24 months means that some operators will be able to re-organise their base check cycles into a system of six checks, as Air France has done. The deletion of two base checks in the cycle will clearly reduce total downtime and MH expenditure, and provide savings in maintenance inputs.

This analysis, however, examines the base check inputs on the basis of an aircraft going through two consecutive base check cycles. The first base check cycle uses the old MPD. Check intervals are 15 months, and block checks are arranged using the 1C, 2C, 4C and 8C tasks, as well as the S1 and S2 tasks. The C4 and C8 checks are the largest.

The second base check cycle will switch to the new MPD system, and checks are arranged from tasks that have usage parameter intervals. The base check interval in this second cycle is 18 months. There are eight checks in this cycle, and again the fourth and eighth checks are the largest because of the two sets of structural tasks. The full cycle interval is 144 months.

The MH and material cost inputs are compared for two subsequent base check cycles to analyse how the aircraft's base maintenance costs are changing as it ages.

Routine inspections start with MPD and maintenance programme job cards. The workscope will also include other tasks that are regarded by some operators as routine, such as: out-of-phase (OOP) tasks; some operator-specific items; some regular interior maintenance; smaller checks that are included in the base check; and the changing of large components, including engines, landing gear, auxiliary power unit (APU), and thrust reversers. This is different to the changing of small system rotables, which is regarded as a separate element later.

Allowances should be made for MH used to gain access for the inspections in each check: about 200MH for each of the six light checks in the first base check cycle; and about 1,200MH for each of the two heavy checks. The total for the first base check cycle is about 3,400MH.

For routine inspections in the first base check cycle, about 850MH can be used for the C1 check, rising to 1,600MH for the C3 check. The larger C2 check will use about 1,750MH.

The workscopes of the C5, C6 and C7 checks are similar to those of the C1, C2 and C3 checks, and so have a similar MH requirement.

The C4 check, which involves the 1C, 2C and 4C tasks, will typically use about 2,600MH. In the aircraft's first base check cycle, the structural tasks were the 5-year items, which required another 2,000MH. The total for the whole check was therefore about 4,600MH, including the changing of some heavy components, some OOP tasks, a few lower checks, and the operator's own requirements.

The scope of the combined and C8 and 10-year tasks will generate a larger check than the combined C4 and 5-year tasks. The C8 has more tasks than the C4, so the C8 will use about 4,000MH. The check will also include a repeat of the 5-year tasks, as well as the 10-year tasks. Up to 4,000MH should be allowed for the two groups of structural inspections being performed together. The whole check will use about 8,000MH for the routine inspections.

The eight checks in the first cycle will therefore require 20,000-21,000MH for routine inspections.

Additional MH will be required for administration and supervision, docking, aircraft preparation and testing. An allowance of 100MH each for the lighter checks and 200MH for each of the heavy checks should be made, totalling an extra 1,000MH for the eight checks in the cycle.

Access, docking and routine inspections will take the total for the first cycle to 26,000MH *(see table, page 39).*

The sampling programme tasks in the C8/S2 check can add up to 2,500MH to the check and the cycle total for aircraft that are included in the programme.

The MH used for access and routine inspections for each check will be higher in the second base check cycle. "This is because there are more FH- and FC-based task cards that come due in the C check packages in the second base check cycle," says Celal Kalkan, production planning manager, at MNG Technic.

The six lighter checks can use about 400MH for access, and the larger C2 and C6 checks can require about 1,000MH. The two heavy checks will again require about 1,200MH for access, while the

The two groups of tasks that were largely unaffected by the change to interval parameters are the structural tasks; the S1 and S2 tasks. These are still combined with the fourth and eighth base checks by most operators. The interval of the S2 tasks and eighth check has been extended over the years of operational service from eight to 12 years.

total for access for the eight base checks will be about 6,000MH.

The six lighter checks will each use 100-250MH more for routine inspections compared to the first cycle. In the second cycle, with the extension of the C or base check interval, the C4 check will be combined with the 6-year tasks, and the C8 check will be combined with the 12-year tasks. The C4/S1 check in the second cycle can require up to 3,000MH more for routine tasks than in the first base check cycle, mainly because of structural inspections.

The total MH for the eight checks will therefore be up to 25,000MH, or 5,000MH more than in the first base check cycle. Once MH for access and docking are added, 32,500MH will be needed for the second cycle *(see table, page 39)*.

Non-routine rectifications

Routine inspections reveal defects that require MH to perform non-routine rectifications. The number of MH required for non-routine rectifications is defined by a non-routine ratio. This generally increases with age, due to deterioration of parts and components. Higher non-routine ratios are also experienced in checks that have higher degrees of access and structure that needs to be opened for heavier inspections.

The ratio will be as little as 15-20% of routine inspections in the C1 check. This will rise to 55% in the next few checks, and 60-80% in the second half the base check cycle. Some of the earlier built A320s recorded non-routine ratios of 90-110% at the first combined C8 and 10-year checks.

The non-routine ratio only applies to the MH for the routine inspections, and not to the MH used for access. With the non-routine ratios described, the first eight checks will use 13,000-14,000MH for non-routine rectifications *(see table, page 39)*.

The three main elements of access, routine inspections and non-routine rectifications will therefore use 38,000-39,000MH in the first base check cycle.

The non-routine ratio has been known to increase in the second base check cycle. It has been 70-80% at the C1 check (referred to as the C9 check by some operators), and risen to 120% in the latter part of the cycle. The total MH needed for non-routine rectifications in the second base check cycle would therefore be 20,000-22,000MH, depending on the condition and operational style of the aircraft *(see table, page 39)*.

The sub-total for access, routine inspections and non-routine rectifications in the second base check cycle would therefore be up to 54,000MH *(see table, page 39)*.

Component changes

There are further elements of base checks that require routine inspections, and additional MH for non-routine rectifications: component changes; and the incorporation of ADs, SBs and EOs.

Component changes relate to hard-timed and condition-monitored components, and life-limited parts that are all planned to be removed or tested during the base checks. These account for a minority of rotable components on the aircraft, but nevertheless will require some MH for removal and installation. The issue here is that testing or inspecting some of these components will reveal any that are malfunctioning, which means the need to repair or replace a component, thereby generating a non-routine action.

Also, the functional tests that are some of the routine tasks and inspections involve the testing of other rotable components that are removed for maintenance on a non-routine basis.

An allowance of 100-150MH should be made for each of the smaller base checks, and 200-400MH for the two larger ones. The eight checks of the cycle will need a total of 1,000-1,300MH.

ADs, SBs & EOs

ADs, SBs and EOs can be grouped as one category. The quantity of labour required for them is highly variable. ADs and SBs only apply to certain aircraft line numbers, and can be affected by aircraft configuration, while an airline applies the SBs and modifications to its aircraft at its discretion.

EOs can involve major modifications such as interior refurbishment programmes or the installation of new avionics, in-flight entertainment systems or seats. The modifications being applied will vary not only between different fleets, but also within each fleet.

The ADs carried out will depend on an aircraft's line number and age.

Many ADs, SBs and EOs can also be included in any A or base check, but few only need the downtime and access provided by certain checks to be performed.

While the A320 family has not been plagued by any large AD in particular, the older aircraft are suffering from corrosion on the rear wing spar. This specifically affects the area between rib 4 and rib 27, and is dealt with by SBs 57-1154 and 57-1155. One option is an ultrasonic inspection of the after spar top skin overhang, with further inspections at every second C check interval. The other option is a modification that terminates the need for any further inspections.

Another issue has been with the main landing gear support fitting at rib 5 in the wing structure. This is dealt with in EAD 2011-0011/SB 57A1166.

The overall amount of labour

required to perform ADs, SBs and EOs at each check therefore varies widely. The MH used can vary from a few hundred to a few thousand in extreme cases. Moreover, the number of MH required is unrelated to the age of the aircraft. The early-build line numbers of some aircraft types sometimes need a large number of inspections and modifications to be performed, while some major ADs can affect younger examples of other types.

An MH budget is hard to estimate because the ADs, SBs and EOs being issued vary. An allowance of 200-350MH should be made for lighter checks.

Many operators take the opportunity of the two heavier base checks to perform the larger ADs, SBs and modifications. Past examples include the installation of the traffic collision avoidance system (TCAS). The number of MH required for the largest EOs can exceed 2,000. An allowance of 750MH for the C4 or fourth base check, and 1,750MH for the C8 or eighth base check has been made in this analysis, and for both base check cycles.

The total labour input for EOs, ADs and SBs for the eight checks in the cycle is a budget of 4,000MH. "The MH needed for EOs, ADs and SBs in the second base check cycle is likely to be higher than in the first, because more ADs and SBs come due as the aircraft accumulates more FH and FC and gets closer to the inspection and modification thresholds specified in the ADs and SBs," says Kalkan.

Cosmetic maintenance

Further elements of base checks relate to mainly cosmetic rather than mandatory maintenance. The first of these is interior cleaning, which is required at all checks.

Interior cleaning is limited to washing and vacuuming, and will use only 100-150MH in each base check; totalling 900MH for the eight checks in the cycle. Any further work required on interior items will be regarded as refurbishment.

Interior refurbishment involves some exterior painting, and the repair, refurbishment and replacement of interior items, such as seat belts, seat covers, lightbulbs, panels and bulkheads. This is performed as a result of findings.

Lighter C or base checks will be used for inspections and repairs above the basic tasks of cleaning. Saied recommends a small allowance of 100MH for this. "Up to 100MH, and an average of 50MH can be used just for findings in these lighter C checks."

Lighter C checks are also used as an opportunity to remove and replace carpets, and clean or replace seat covers. This can add an average of 200MH per C check. The cost of new carpet, which is required at every C check, is about $5,000, while new seat covers, which are also usually replaced at every C check, cost $20,000.

The total labour that can be used during lighter C checks is therefore about 300MH, while an allowance of $25,000-30,000 should be made for materials.

The two heavy checks require the removal of galleys, toilets, all panels, passenger storage units (PSUs), overhead bins, bulkheads and cabin dividers, and flooring to allow access for structural inspections. This provides an opportunity to refurbish and replace damaged or broken items, and redecorate others.

The removal and reinstallation of main interior items can consume at least 500MH, and the total can increase by 1,000-1,500MH, depending on the level of findings, repairs and redecoration required. "I would allow a small budget of at least 700MH for findings in relation to interior items," says Saied.

An allowance of $30,000 for

SUMMARY OF 1ST & 2ND BASE CHECK INPUTS FOR A320 FAMILY

Check	Routine MH	Non-routine MH	Interior MH	ADs, SBs & EOs MH	Strip & repaint	Other MH	Total MH	Total materials $	Total inputs $
1st base check cycle									
Light C checks	1,250-2,200	200-1,400	400-500	200-400	60-100	100	2,000 -4,500	62,000 -75,000	165,000 -300,000
C4/S1 check	5,500-6,000	2,500-2,800	2,400	750	1,500	200	13,500	290,000	965,000
C8/S2	9,000	6,000	3,000	1,750	1,500	200	21,500	550,000	1,625,000
Total for 8 checks in the cycle	**26,000**	**13,500**	**7,700**	**4,000**	**3,000**	**1,000**	**55,000**	**1,250,000**	**4,000,000**
Reserve for interval of 23,850FH -$/FH									**168**
2nd base check cycle									
Light C checks	1,350-3,200	900-1,700	400-500	200-400	60-100	100	3,000 -5,600	78,000 -90,000	230,000 -370,000
C4/S1 check	10,000	6,900	2,400	750	1,500	200	22,000	360,000	1,450,000
C8/S2	9,400	6,800	3,000	2,000	1,500	200	24,000	700,000	1,900,000
Total for 8 checks in the cycle	**32,500**	**22,000**	**8,000**	**4,500**	**3,000**	**1,000**	**71,000**	**1,550,000**	**5,100,000**
Reserve for interval of 27,500FH -$/FH									**185**

materials and consumables in repairing the larger interior items should be made. A further $15,000 should be reserved for materials and parts used to repair smaller items such as lights, dado rails, and for decorating materials.

Heavy checks are often used for the replacement of seat cushions, as well as the inspection and repair of seat frames. These two tasks can use about 800MH for an A320. The total labour required for the C4 or fourth base check can therefore reach 2,000-2,300MH, and be about 500MH higher in the C8 or eighth base check.

A shipset of seat cushions costs $7,000 for an A320, while $2,000 should be budgeted for parts used in repairing seat frames. A further $15,000 should be allowed for miscellaneous items. This will take the total cost of materials and consumables in the check to $70,000. This will rise to $120,000 in the larger C8/D check, when more refurbishment of interior items takes place.

The labour used for interior repairs, as required, and for scheduled removal, replacement and refurbishment of all types of cabin items will therefore total 5,500-7,000 per base check cycle. The final total will depend on the amount of repairs required.

The total cost of materials, consumables and parts used for interior refurbishment in the eight checks of the first base cycle will be $370,000, rising by about $50,000 in the second base check cycle, due to the greater amount of redecoration being required, and therefore parts being consumed.

Stripping and repainting

Another element of cosmetic maintenance is the regular stripping and repainting of aircraft. On older aircraft this was traditionally done together with the D check. Many aircraft are now stripped and repainted outside heavy maintenance checks. Most airlines typically repaint their aircraft every five to six years. This analysis assumes that the aircraft is stripped and repainted twice every base check cycle.

Stripping and repainting an aircraft the size of an A320 consumes about 1,500MH and $25,000 in paint and other materials. Being performed twice in each base check will take the total labour requirement to 3,000MH and the cost of materials to $50,000.

Besides the two major repaints, Saied says that some repaint work will need to be done during light C checks because of some findings. He recommends an allowance of 60-100MH per check.

Total inputs

Component changes, ADs, SBs and EOs, interior cleaning, interior refurbishment, and stripping and repainting add 15,000-16,000MH to the basic requirement of routine inspections and non-routine rectifications for the eight checks in the cycle.

The total MH for the first base check cycle can therefore be up to 55,000MH.

The total for each of the lighter C checks will be 2,000-4,500MH, depending on the workscope. Each of these checks will use materials and consumable parts, and an allowance of $32,000-45,000 can be used for each lighter check in the first base check cycle. Rotable parts may be swapped. Maintaining an inventory of rotables and repairing parts is viewed as an element of maintenance cost that is separate from airframe check costs.

The total for the C4 or fourth base check in the first base check cycle, combined with the first group of structural inspections, will be 13,000-14,000MH. The actual total could fall to 11,000-12,000MH if a lower non-routine ratio, a smaller requirement for ADs and EOs, and a smaller interior workscope are required.

The C4 check will use $80,000 of

The A320 family experiences a rise in MH used for both routine inspections and non-routine rectifications in its second base check cycle compared to its first base check cycle. The basic check interval has also been increased to 18 months in most cases, and this increase has partially offset the rise in labour and material inputs.

materials and consumables. A similar amount should be allowed for the structural inspections, taking the total to $160,000.

The total input for the combined C8 check, first and second groups of structural inspections, in the first base check cycle can reach 22,000MH. Again, the elements with the most variable number of MH are the non-routine rectifications, interior refurbishment, and ADs and EOs.

An allowance of $90,000 for materials and consumables should be made for the C8 check, and $120,000 for the two groups of structural inspections. The total allowance for materials and consumables in this first C8/S2 check will therefore be $210,000.

The total allowance for materials and consumables for the first base check cycle will be $700,000-750,000.

An allowance also has to be made for repairing some of the rotables removed during checks as a result of inspections: $50,000 for the first C4/S1 check; and $100,000 for the first C8/S2 check.

The cost of materials and parts used for the repair, refurbishment and replacement of cabin items is $370,000. Finally, $50,000-60,000 would be used for the two repaints during the cycle.

The overall cost of materials, parts and consumables used in the first base check cycle would be $1.25 million.

Consumption of materials and consumables will rise by 30% in the second base check cycle, mainly due to the increase in non-routine ratio. Allowing for this would take the cost for the second base check cycle to $850,000-900,000.

The cost of repairing rotables during the two heavy checks can rise to $200,000.

The cost of materials and parts used in interior refurbishment would also be higher, while the cost of paint would change little. The overall cost of materials, consumables and parts used in the second base check cycle would therefore reach $1.5-1.6 million.

With the increased routine inspections, higher non-routine ratios and increased labour requirement for interior refurbishment, up to 71,000MH can be required for second base check cycle.

The inputs for the lighter base checks will be 3,000-5,600MH, depending on workscope.

The first heavy check of this second cycle will use up to 22,000MH; 8,000-9,000MH more than the same check in the first base check cycle. The overall total for this check is more variable. It is more likely to escalate than in the first base check cycle because of the possibility of an escalating requirement for non-routine rectifications and a larger need to repair and replace interior furnishings.

The second heavy check of the second base check cycle will use 22,000-24,000MH; 2,000-3,000MH more than the eighth check in the first base cycle. Like the first heavy check in the cycle, the labour and material inputs will be more variable by the time the aircraft has reached this age.

Total base cycle costs

The total cost for both base check cycles will depend on average labour rates for all elements of maintenance. *Aircraft Commerce* has used a generic average labour rate of $50 per MH, although this is now low compared to the rate charged by many maintenance providers in North America and Western Europe. Labour rates are lower, however, in Eastern Europe, North Africa and the Middle East, and in the Asia Pacific. A global average for base maintenance is currently $60 per MH.

At $50 per MH, the total cost of labour for the eight checks in the first base cycle will be $2.75 million. The cost of materials and all parts will take the total to $4.0 million.

The standard interval during the first base check cycle is 15 months. Given that typical interval utilisation is about 85%, the actual interval is assumed to be 13 months. The total interval for the check is therefore 104 months. At an aircraft utilisation of 2,750FH per year, the cost of the eight checks is equal to a reserve of $168 per FH *(see table, page 39)*.

At $50 per MH, the cost of labour for the eight base checks in the second cycle will be $3.55 million. Materials and parts will cost $5.1 million.

The longer base check interval of 18 months means the actual interval between checks will be 15 months, so the full cycle interval will be close to 120 months. At the same rate of annual utilisation, the cost of the eight checks will be equal to a reserve of $185 per FH.

While the reserve has risen due to higher inputs in the second base check cycle, these higher costs have been partly offset by the longer intervals between checks. These reserves per FH will vary with the different labour rates that apply to different geographical regions.

Extending the base check interval to 24 months, and creating a cycle of six checks will generate a lot of savings. The number of routine tasks will be reduced, leading to fewer MH being required for non-routine rectifications, with the total falling by 4,000-5,000MH. Fewer checks in the cycle will also lead to reductions in MH consumption in other parts of the base check. This will have a positive impact on reducing overall requirements used over the complete cycle, and contribute to a lower base check reserve.

There are small differences between the number of MH used for the A320, and for the A319 and A321, related mainly to structural inspections. AC