The 767 passenger fleet has reached a mature age. The aircraft has a base maintenance cycle of six years, and the majority of the active passenger fleet is in its third or higher base maintenance cycle. An examination of how the 767's base maintenance requirements increase with successive base check cycles is made here.

Assessing the 767's ageing maintenance

The 767 family's maintenance programme was developed together with the programme for the 757 family. The two types therefore have similar maintenance programmes, although their task groupings have changed since the two entered service in 1982 and 1983 respectively.

Like the 757, the 767 has a base check cycle of four checks, the fourth of which is the heaviest and finishes the cycle. The task intervals in these checks are related to flight hours (FH), flight cycles (FC) and calendar time. As with the 757, the calendar intervals in the 767's maintenance programme override the FH and FC intervals, at typical rates of aircraft utilisation, in most of the task groups. The base check intervals are therefore determined by calendar intervals. The basic base check interval started at 15 months, but was raised to 18 months in 1994. The heavy check and base check cycle interval is therefore six years. Taking into account actual airline utilisation of check intervals, base checks are likely to be performed about once every 15 months, and base check cycles will be completed every five years.

The implications of these timings are that the oldest aircraft in the fleet will be in their sixth base check cycles, while most will be in their third, fourth and fifth base check cycles. Although the 767 has served as a long-haul workhorse since the late 1980s, large numbers are being retired and phased out by primary operators. As the fleet ages, and aircraft are reaching base maintenance maturity, how the 767's base maintenance requirements are changing is becoming an issue.

Ageing maintenance

The aircraft's maintenance planning document (MPD) can be grouped into numbers of tasks with equal intervals. These can broadly be classed in three groups: line maintenance tasks; A check tasks; and C or base check tasks, with intervals that are multiples of 18 months.

There are also three groups of base check tasks with higher intervals than the main groups of base check tasks. These can be regarded as ageing aircraft maintenance tasks, all with intervals determined only by FCs. The lowest intervals are 18,000FC and 20,000FC.

There is a group of 77 tasks with an initial interval of 25,000FC. This large group is sub-divided into five groups. Four of the groups have repeat intervals that vary between every successive base check and every fourth base check. Given typical rates of utilisation for aircraft used on long-haul operations, the initial interval of 25,000FC is likely to be reached at 30-32 years. These tasks are therefore likely to represent a retirement watershed for some aircraft. The initial interval of 25,000FC has already been reached at an earlier age for aircraft used on short-haul, high-frequency operations, in particular the 767-300s operated by Hawaiian Airlines, Japan Airlines (JAL), All Nippon Airways (ANA) and Delta Airlines.

Further groups of tasks have initial intervals of 30,000FC, 40,000FC, 50,000FC, 62,000FC, 70,000FC, 80,000FC and 90,000FC. The lower interval of 30,000FC is only likely to be reached at about 40 years of age for aircraft utilised on long-haul missions, but may now be reached by the oldest 767-300s within another three to five years of operation. Some of these aircraft have now accumulated a total of 37,000FC, and operate at a rate of 1,500FC per year. The 30,000FC group of tasks totals 12 inspections, while the 40,000FC group of tasks totals 33. These may have to be performed on the oldest 767-300s, although they may be replaced by new 787s before the tasks come due.

The 50,000FC group of tasks is the largest, totalling 83 inspections. These are unlikely to be required by long-haul aircraft, and would certainly represent a retirement watershed for 767-300s that have been used on short-haul operations.

There are many groups of base check tasks with the initial intervals that are multiples of 18 months compared with the groups of regular base check tasks in the 757's MPD. Each group has a different repeat interval *(see table, page 41)*. This makes base maintenance planning complicated, and results in base checks that have 832-1,711 MPD tasks.

All tasks in the MPD are classed in four ways, according to whether they are lubrication, systems, zonal and structural inspection tasks. These MPD tasks therefore have different levels of access required to make the inspections possible, with the structures tasks generally requiring the higher levels of access. The number of man-hours (MH) required to perform routine inspections for MPD tasks will therefore vary widely between checks. They will also generally increase as the aircraft progresses through successive base check cycles.

In addition to the routine inspections that are required by these tasks, non-routine rectifications arise from the findings. The level of findings, and so the

767 ACTIVE FLEET SUMMARY

Age range	767 -200	767 -200ER	767 -300	767 -300ER	767 -400ER	767 -200F	767 -300F	Total
1-6 years				48			20	**68**
7-11 years		2		62	13		7	**84**
12-16 years		10	15	137	24		23	**209**
17-22 years		3	26	162		4	20	**215**
23-26 years		33	40	107		6	8	**194**
27-31 years	11	14	4			45	0	**74**
Total	**11**	**62**	**85**	**516**	**37**	**55**	**78**	**844**

number MH required, to perform non-routine rectifications will therefore increase with each base check cycle.

The effect of these two factors is that the 767's base check maintenance requirements will increase with age.

The biggest change to the 767's MPD was an increase in the base check calendar interval from 15 to 18 months in 1994. Until 1994, aircraft were going through a base check cycle about once a year, so they were completing a base check cycle every four to four-and-a-half years. There are have been three annual revisions to the 767's MPD in most years, but the most significant and largest change came in April 2012. This abandoned the traditional grouping of tasks into block checks, and the assigning of tasks with interval criteria, to allow airlines to group tasks into checks according to their pattern of aircraft utilisation and operation.

Nevertheless, most tasks retain the same intervals and interval criteria, so many will be grouped in the same way. Moreover, the change in the MPD to a new system of individual intervals for each task is so recent that all aircraft in the fleet will have their base maintenance managed according to the task groups.

Fleet profile

There are 844 active 767s aged from just a few months to 29 years. There are also 71 parked aircraft.

The 767 fleet comprises five main models: the 767-200, 767-200ER, 767-300, 767-300ER and 767-400ER. The three ER models are mostly all utilised for long-haul services. Typical annual rates of utilisation are 3,500-4,000FH and 700-900FC, with FC times averaging 5.0FH.

The 767-200 was the first model into service, and was mainly selected by US operators for US domestic services, so they consequently accumulated an average FH:FC ratio of 3-4FH per FC. There are only 11 active aircraft, many of which are now with secondary operators. They are at an age where they are all in their sixth base check cycles.

The longer 767-300 was introduced into service in 1986, and was selected mainly by JAL, ANA and Delta. A large portion of the fleet operates domestic Japanese routes, so these aircraft have accumulated the highest number of FCs. The -300s were manufactured up to the end of the 1990s. The oldest aircraft in the fleet have accumulated 45,000-60,000FH and 29,000-37,000FC. The youngest aircraft have accumulated up to 25,000FH and 15,000FC, although Delta's aircraft have had higher rates of utilisation.

There are 85 767-300s in operation. The majority of aircraft are in their third, fourth and fifth base check cycles.

The 767-200ER led the way for twin-engined, long-haul operations. They were operated in large numbers by United, American, USAirways and Continental. They were also used as long-haul mainstays by smaller carriers, such as EL AL, Air Mauritius, Ethiopian, VARIG, Aeromexico and TWA. The aircraft have been operated at an annual rate of about 3,700FH and 700FC, so they have a FH:FC ratio of 5.0:1. There are 62 active aircraft, mostly built from 1984 to 1993, and which have accumulated 75,000-100,000FH and 12,000-27,000FC. Most are in their third to sixth base check cycles *(see table, this page)*.

The 767-300ER accounts for most of all 767s, with 516 active aircraft. Most of the fleet was built from 1988 to 2006. The age of the fleet is varied, and most aircraft have been operated at a rate of 3,700FH and 760FC per year, a FH:FC ratio of about 5.0FH:FC. The majority of aircraft are in their third, fourth and fifth base maintenance cycles *(see table, this page)*.

There are also 37 767-400ERs in operation. These are exclusively operated by United and Delta, and utilised at similar rates to the -300ER fleet. Aircraft are either in their second or third base check cycles *(see table, this page)*.

In addition to the active passenger fleet of 711 aircraft, there are 133 active freighters, including 55 767-200/-200ERs and five 767-300s converted by Bedek Aviation, and seven -300s converted by Boeing. There are also 66 factory-built 767-300PFs *(see table, this page)*.

MPD tasks

There are a large number of task groups in the MPD. How these are arranged into line, A and base check packages depends on the types of tasks and their intervals.

Only lubrication and system tasks are likely to be included in line checks. The basic A check interval in the MPD was originally 250FH, but this had been raised to 750FH by December 2007. All tasks with intervals less than 750FH are therefore assumed to be included in line checks by most operators. MPD tasks with the lowest intervals are 48 and 72 elapsed hours, so clearly can be included in daily checks. There are tasks whose intervals vary from 100FH to 600FH.

The MPD generally has A check tasks either with a FH or FC interval. There are, however, a smaller number of task groups with intervals specified in calendar time. The main groups of A and C check tasks are either system, lubrication and zonal tasks with FH and calendar intervals, or structures tasks with FC and calendar intervals.

The basic 1A system task interval was 500FH by 1994, and was raised to 750FH in 2007. There are three other groups of this basic interval: the 2A, 4A and 6A tasks with corresponding intervals of 1,500FH, 3,000FH and 4,500FH.

The basic S1A structures tasks interval is 300FC. There are three main groups: the S1A, S2A and the S5A. These could theoretically be planned at separate intervals to the systems/zonal tasks. In practice, however, most airlines plan them together with the corresponding group of system/zonal tasks. That is, the 1A and S1A tasks will be planned together, and the 2A and S2A will be planned together. When organising checks in a block check pattern, there will therefore be a cycle of six A checks: A1 to A6 checks. The A6 check will include the 1A, 2A, 6A, S1A and S2A tasks. At typical annual rates of utilisation of 3,700FH for long-haul aircraft, A checks would come due once every 10-12 weeks, while the A6 check would come due once every 14 months.

The other tasks with intervals similar

to the main A check tasks would be planned into each relevant A check accordingly. The FH tasks, with intervals of 750-4,000FH, would be included in the appropriate A check as they come due. Tasks with a 750FH interval would be included in the A1 check if the operator wanted to avoid downtime for additional tasks between the A1 and A2 checks. Tasks with a 4,000FH interval are likely to be included in the 5A or 6A check.

There are also groups of tasks with intervals of 100FC to 900FC. Again these could be planned into A checks, depending on aircraft utilisation and the timing of each successive checks. Typical rates of utilisation of 700-800FC for long-haul aircraft mean that 100FC tasks would come due about once every 45 days, for example.

Finally, there are a small number of calendar task intervals of 180 days, and 12 months. These are likely to be planned into the most appropriate A check.

Systems tasks

The MPD has grouped most of the base check tasks in a similar pattern to the A check tasks. The basic 1C lubrication, systems and zonal tasks have an interval of 6,000FH and 18 months, so the main base check tasks have calendar intervals in addition to FH or FC intervals. There are six main groups of system tasks, with intervals that are multiples of the basic 6,000FH and 18 months *(see table, this page)*: the 2C, 3C, 4C, 6C and 8C. The base check cycle is four checks, so the 6C and 8C tasks come due for the first time during the second base check cycle. The largest groups of base check tasks are the 1C, 2C, 3C and 4C tasks. These have 662, 177, 23 and 212 tasks *(see table, this page)*.

These task groups are grouped into block checks for the four checks in the base check cycle by most operators. The C1 check will therefore have just the 1C tasks, while the C2 check will have the 1C and 2C tasks, the C3 will have the 1C and 3C tasks, and the C4 check will be the largest with the 1C, 2C and 4C tasks *(see table, page 42)*. The checks in the second base check cycle will get larger, since in addition to the task groups for each of the four checks, the C6 check will also have the 6C tasks, and the C8 check will also have the 8C tasks *(see table, page 42)*. The 6C and 8C groups have a relatively small number of tasks, however, so the checks in the second cycle do not increase that much in size as a result.

Structures tasks

The basic S1C structures tasks have an interval of 3,000FC and 18 months. Virtually all 767s have not reached the 3,000FC limit within the 18-month limit, and long-haul aircraft generally only accumulate about 1,200FC in this period. There are several groups of structures tasks, but four main groups (the S1C, S2C, S3C and S4C) have intervals that are multiples of the basic S1C interval. Since the calendar interval is identical to the systems' tasks calendar interval, corresponding multiples will be planned into the same checks by most operators to minimise downtime for maintenance. This means that 1C and S1C tasks are grouped together, 2C and S2C tasks are grouped together, 3C and S3C tasks are grouped together and 4C and S4C tasks are grouped together *(see table, page 42)*. The C4 check will therefore also include the S1C, S2C and S4C tasks.

Other groups of tasks include the S8C and S12C, which will first come due at the C8 and C12 checks. There are also another four groups of structures tasks which have repeat intervals that are different to their initial intervals. The first of these is the S4C, S2C group of tasks, with an initial interval of 12,000FC and 72 months (so they will first be included in the C4 check), and then a repeat interval of 6,000FC and 36 months (so will be included in every second C check thereafter). There are also the S6C, S2C; S8C, S4C; and S12C, S4C tasks *(see table, page 42)*. These are typically arranged into block checks according to their intervals *(see table, page 42)*.

767 C/BASE CHECK TASK GROUPS

System/FH tasks	Initial interval FH/months	Repeat interval FH/months	Number of MPD tasks
1C	6,000/18	6,000/18	662
6,000FH	6,000FH	6,000FH	4
2C	12,000/36	12,000/36	177
10,800FH	10,800FH	10,800FH	1
3C	18,000/54	18,000/54	23
15,000FH	15,000FH	15,000FH	3
18,000FH	18,000FH	18,000FH	1
4C	24,000/72	24,000/72	212
6C	36,000/108	36,000/108	20
8C	48,000/144	48,000/144	42
Structure/FC tasks	**Initial interval FC/months**	**Repeat interval FC/months**	**Number of MPD tasks**
S1C	3,000/18	3,000/18	154
15 months	15	15	1
18 months	18	18	5
2-year	24	24	6
S2C	6,000/36	6,000/36	110
3-year	36	36	5
S3C	9,000/54	9,000/54	18
3,000FC	3,000FC	3,000FC	2
S4C	12,000/72	12,000/72	227
S4C, Rpt S2C	12,000/72	6,000/36	4
5-year	60	60	8
7-year	84	84	1
S6C, Rpr S2C	18,000/108	6,000/36	1
S8C	24,000/144	24,000/144	11
S8C, S4C	24,000/144	12,000/72	54
10-year	120	120	12
S12C	36,000/216	36,000/216	2
S12C, RPT S4C	36,000/216	12,000/72	11

767 BASE CHECK MAIN FH & SYSTEM TASKS & POSSIBLE GROUPING IN BLOCK CHECK ARRANGEMENT

Base/C check	Actual FH interval	Likely FH interval	Actual mth interval	Likely mth interval	FH task Groups	Number of MPD tasks
C1	6,000	4,750	18	15	1C + 6,000FH	666
C2	12,000	9,500	36	30	1C + 6,000FH + 2C + 10,800FH	844
C3	18,000	14,250	54	45	1C + 6,000FH + 3C + 15,000FH + 18,000FH	693
C4	24,000	19,000	72	60	1C + 6,000FH + 2C + 10,800FH + 4C	1,056
C5	30,000	23,750	90	75	1C + 6,000FH	666
C6	36,000	28,500	108	90	1C + 6,000FH + 2C + 10,800FH + 3C + 15,000FH + 18,000FH+ 6C	891
C7	42,000	33,250	126	105	1C + 6,000FH	666
C8	48,000	38,000	144	120	1C + 6,000FH + 2C + 10,800FH + 4C + 8C	1,098
C9	54,000	42,750	162	135	1C + 6,000FH + 3C + 15,000FH + 18,000FH	693
C10	60,000	47,500	180	150	1C + 6,000FH + 2C + 10,800FH	844
C11	66,000	52,250	198	165	1C + 6,000FH	666
C12	72,000	57,000	216	180	1C + 6,000FH + 2C + 10,800FH + 3C + 15,000FH + 18,000FH + 4C +6C	1,103
C13	78,000	61,750	234	195	1C + 6,000FH	666
C14	84,000	66,500	252	210	1C + 6,000FH + 2C + 10,800FH	844
C15	90,000	71,250	270	225	1C + 6,000FH + 3C + 15,000FH + 18,000FH	693
C16	96,000	76,000	288	240	1C + 6,000FH + 2C + 10,800FH + 4C + 8C	1,098
C17	102,000	80,750	306	255	1C + 6,000FH	666
C18	108,000	85,500	324	270	1C + 6,000FH + 2C + 10,800FH + 3C + 15,000FH + 18,000FH + 6C	891
C19	114,000	90,250	342	285	1C + 6,000FH	666
C20	120,000	95,000	360	300	1C + 6,000FH + 2C + 10,800FH + 4C	1,056

767 BASE CHECK MAIN FC & CALENDAR TASKS & POSSIBLE GROUPING IN BLOCK CHECK ARRANGEMENT

Base/C check	Actual FC interval	Likely FC interval	Actual mth interval	Likely mth interval	FC & calendar task groups	Number of MPD tasks
C1	3,000	950	18	15	S1C + 15MTH + 18MTH + 2-YEAR	166
C2	6,000	1,900	36	30	S1C + 15MTH + 18MTH + 2-YEAR + S2C + 3-YEAR	281
C3	9,000	2,850	54	45	S1C + 15MTH + 18MTH + 2-YEAR + S3C + 3,000FC	186
C4	12,000	3,800	72	60	S1C + 15MTH + 18MTH + 2-YEAR + S4C + S4C, RPT S2C + 5-YEAR	520
C5	15,000	4,750	90	75	S1C + 15MTH + 18MTH + 2-YEAR + 7-YEAR	167
C6	18,000	5,700	108	90	S1C + 15MTH + 18MTH + 2-YEAR + S2C + 3-YEAR + S3C + 6,000FC + S4C, RPT S2C + S6C, RPT S2C	306
C7	21,000	6,650	126	105	S1C + 15MTH + 18MTH + 2-YEAR	166
C8	24,000	7,600	144	120	S1C + 15MTH + 18MTH + 2-YEAR + S2C + 3-YEAR + S4C + S4C, RPT S2C + 5-YEAR + S6C, RPT S2C + S8C + 10-YEAR + S8C, RPT S4C	598
C9	27,000	8,550	162	135	S1C + 15MTH + 18MTH + 2-YEAR + S3C + 3,000FC	186
C10	30,000	9,500	180	150	S1C + 15MTH + 18MTH + 2-YEAR + S2C + 3-YEAR + S4C, RPT S2C + 7-YEAR + S6C, RPT S2C	287
C11	33,000	10,450	198	165	S1C + 15MTH + 18MTH + 2-YEAR	186
C12	36,000	11,400	216	180	S1C + 15MTH + 18MTH + 2-YEAR + S2C + 3-YEAR + S3C + 3,000FC + S4C + S4C, RPT S2C + 5-YEAR + S6C, RPT S2C + S8C, RPT S4C + S12C + S12C, RPT S4C	608
C13	39,000	12,350	234	195	S1C + 15MTH + 18MTH + 2-YEAR	166
C14	42,000	13,300	252	210	S1C + 15MTH + 18MTH + 2-YEAR + S2C + 3-YEAR + S4C,RPT S2C + S6C, RPT S2C	286
C15	45,000	14,250	270	225	S1C + 15MTH + 18MTH + 2-YEAR + S3C + 3,000FC + 7-YEAR	187
C16	48,000	15,200	288	240	S1C + 15MTH + 18MTH + 2-YEAR + S2C + 3-YEAR + S4C + S4C, RPT S2C + 5-YEAR + S6C, RPT S2C + S8C + 10-YEAR + S8C, RPT S4C + S12C, RPT S4C	609
C17	51,000	16,150	306	255	S1C + 15MTH + 18MTH + 2-YEAR	166
C18	54,000	17,100	324	270	S1C + 15MTH + 18MTH + 2-YEAR + S2C + 3-YEAR + 3,000FC + S4C, RPT S2C + S6C, RPT S2C	306
C19	57,000	18,050	342	285	S1C + 15MTH + 18MTH + 2-YEAR	166
C20	60,000	19,000	360	300	S1C + 15MTH + 18MTH + 2-YEAR + S2C + 3-YEAR + S4C + S4C, RPT S2C + 5-YEAR + 7-YEAR + S6C, RPT S2C + S8C, RPT S4C + S12C, RPT S4C	587

For an aircraft operating at an annual utilisation of 3,800FH and 760FC per year

Additional tasks

There are several other groups of tasks that have FH, FC and calendar intervals. Their intervals do not match those of the main system and structures tasks. These groups also have a small number of tasks. Maintenance planners therefore refer to these groups as out-of-phase (OOP) tasks.

There are four groups of FH-related checks: the 6,000FH, 10,800FH, 15,000FH and 18,000FH tasks. These only have a small number of tasks *(see table, page 41)*. Given a typical rate of utilisation of 3,800FH per year for long-haul aircraft, the 6,000FH tasks could be grouped with the 1C tasks, the 10,800FH tasks with the 2C tasks, and the 15,000FH and 18,000FH with the 3C.

There is one small group of tasks with a 3,000FC limit. As they have just a FC-related limit they could be grouped together with the 3C tasks, and

The majority of base check tasks have intervals that are either multiples of 6,000FH and 18 months, or 3,000FC and 18 months. There are, however, 12 or so groups of out-of-phase tasks with FH, or calendar intervals. These will have to be planned into base checks according to the aircraft's rate of utilisation and timing of the base checks.

performed every third base check.

There are seven groups of calendar tasks, with intervals ranging from15 months to 10 years. These can all be grouped according to their nearest check. The 10-year tasks, for example, could be grouped with the 8C tasks and so performed once every eight base checks.

Base check arrangement

How the different tasks are grouped will depend on several factors. One main influence will be aircraft utilisation: while the 15,000FH and 18,000FH tasks, for example, could be grouped with 3C tasks on long-haul aircraft because annual rates of utilisation are 3,700-4,000FH for many aircraft, they could also be grouped with 5C and 6C, or even 8C tasks for aircraft operating short-haul missions at annual utilisations of 2,250-2,500FH.

This analysis considers likely base check organisation for aircraft operating long-haul missions at utilisations of about 3,800FH and 760FC year, and so at a FH:FC ratio of about 5.0:1. Given likely utilisation of check intervals by most operators, base checks will be performed once every 15 months. This will be equal to every 4,750FH and 950FC. While the FH intervals of systems tasks will be almost fully utilised, only a minority of the FC intervals of structures tasks will be utilised. That is, many of the FC tasks have intervals that are multiples of 3,000FC, but the checks will be performed about once every 950FC because of the calendar intervals.

The grouping of tasks over five base check cycles has been considered, so that the probable number of MPD base check tasks in the C1 to C20 checks can be calculated, and therefore the increase in base maintenance requirements considered over the life of the aircraft. The analysis assumes that all the task groups remain in phase over the period of the five base cycles, equal to 300 months or 25 years *(see table, page 42)*.

The FH, and FC and calendar tasks for the 20 checks are summarised, as is the number of MPD base check tasks in each of these checks *(see table, page 42)*. The number of MPD tasks in the first base check cycle starts with 832 for the C1 check, increasing slightly to 879 tasks for the C3 check. The C2 check has 1,125 MPD tasks, and the large C4 check has 1,576 tasks *(see table, page 48)*.

The number of tasks for the four checks for the second base check cycle increases, so that the C5 check has 833 tasks, the C6 check has 1,197, and the C8 check has 1,696 *(see table, page 48)*. The C12 check does not have many more tasks than the C8 check, because the additional tasks from the S12C group are offset by the absence of the S8C group.

The number of tasks in the following three base check cycles does not differ much from the second base check cycle.

The overall pattern that emerges is that the second and fourth checks in every base check cycle are the heavier checks. This is mainly because the 2C, 4C, S2C and S4C groups of tasks have a large number of inspections.

Three elements are added to the base check MPD tasks: tasks with shorter intervals, normally included in line and A checks; outstanding defects that have arisen during the aircraft's operation, all of which are usually cleared by most operators when a base check comes due; and operator-specific items that are not MPD items. Many are related to the interior.

Base check inputs

The labour man-hour (MH), material, consumable and rotable component replacement and repair costs incurred during base checks comprise several elements.

The labour portion includes routine inspections for scheduled task cards, and the non-routine rectification of defects found during the routine inspections. The sub-total of these two will account for most of the labour used in each check.

The labour for routine inspections covers aircraft preparation, access to make routine inspections possible, routine inspections, and administration. It can also include the operator's own special tasks.

The number of MPD base check tasks gradually rises from the first to the third base check cycle, and stays approximately level thereafter. The amount of MH used for the routine portion of the check will not just depend on the number of tasks, however. The type of tasks included in the specific task groups will have a large influence on MH required, since MH used to gain access will depend on the type of tasks included.

The MH used for the non-routine portion increase with each check in the four checks of the base check cycle, and also with each successive base check cycle. The increase in defects, and their severity, is one of the main reasons why the total MH increase as the aircraft ages.

Base checks also include: interior cleaning and refurbishment; engineering orders (EOs), airworthiness directives (ADs), and service bulletins (SBs); component changes; and stripping and repainting.

There will be an associated cost for materials, consumables, life-limited parts, rotables that fail functional and system tests that are part of the routine inspections, materials and parts used for interior cleaning and refurbishment, and any stripper and paint used.

Routine inspections

The MH used for routine inspections comprise several elements, including: aircraft preparation and docking; opening and gaining access to make the inspection; technical cleaning of some components in the case of some of the

The grouping of the all the different task groups into base checks is a complex task for maintenance planners. Besides task groups with straightforward multiples of the basic task intervals, there are some task groups with initial intervals and shorter repeat intervals. This results in the number of MPD tasks in successive checks varying, rather than remaining constant.

inspections; and closing access.

The MH quoted by the manufacturer in the task cards in the MPD are generally regarded as only being enough time to make the inspection, plus a small allowance for access. "All access panels associated with an inspection are given some MH allowance in the MPD estimates, but they tend to be only a fraction of what is really required," says Peter Cooper, planning manager at Civil Aviation Services.

Maintenance planners have to escalate the MPD MH to account for the other elements of routine maintenance.

"The MPD MH for the base check tasks quoted start at about 450MH for the C1 check, and other checks with similar tasks. These are the C5, C7, C11, C13, C17 and C19 checks," says David Peretz, aircraft MRO program manager at Bedek Aviation. "The slightly larger checks have an MPD labour count of about 475MH. These are the C3 and C9 checks. MPD labour increases to 670MH for the C2 check, and then to 800-830MH for the C6, C10, C14, and C18 checks. The heavy C4 check has an MPD labour count of 1,200MH, rising to 1,300-1,400MH for the fourth check in the next four base check cycles. With the task groups as described, the C16 check is actually the heaviest.

"The escalation factor to arrive at the actual MH used in the check for the routine inspections is: 3.0 for the lighter C1 and C3 checks, and the same multiples in the later base check cycles; 4.0 for the C2 check and same multiple in the other base check cycles; and 5.0 for the C4 check and reciprocating multiples in the other base check cycles," adds Peretz. "This takes the labour for the routine inspections to 1,300-1,500MH for the C1, C3, C5, C7, C9, C11, C13 and C17 checks. The labour required for the C15 and C19 checks is slightly higher at 1,800MH and 2,000MH.

"The C2 check requires about 2,600MH, and the same multiple check in the next four base check cycles uses 3,200-3,400MH," adds Peretz. "The C4 check requires 5,800MH for routine inspections, rising to 6,500-7,100MH for the heavy check in each cycle, depending on the actual base check cycle."

Cooper provides some further insight into the escalation factors. He estimates the labour required for routine inspections to be 1,700-1,800MH for the C1, C3, C5, C7, C9, C11 and C13 checks. "This includes 200MH for open access and a similar amount for closed access. This compares to a total MPD allowance of 100MH for access," says Cooper. The escalation factors for the access for lighter base checks is in the order of 4.0. Another 1,300-1,400MH are required for the actual inspections and some technical cleaning. This compares to the MPD estimate of about 300MH. The escalation factor for this element of the check is therefore 5.0.

"The labour required for the routine inspections for the C2 check, and the same multiple in following base check cycles, is about 3,200MH," continues Cooper. "This includes about 1,100MH for access, and about another 2,200MH for the inspections and technical cleaning. The MPD allowances for access and the inspections are 170-190MH and 450-470MH, so the escalation factors for these two portions are 5.0-5.5.

"The C4 uses a total of 5,500MH. This includes 2,100MH for access, compared to an MPD allowance of 310MH. The escalation factor for the access portion of the C4 is therefore about 7.0, because the tasks require deeper access," adds Cooper. "The higher escalation factor for the C4 check is explained by deeper access required for tasks that involve underfloor inspections. The MPD estimates for this do not take into account cabin items that have to be removed.

"This escalation factor rises in the C12 check, the heaviest of all heavy checks in the base check cycles, because of the tasks included. The C12 check has the scheduled task of removing both engines and both pylons to make the scheduled pylon inspection, and then reinstalling all of them. This uses 1,000MH," continues Cooper. "The C12 check in particular uses about 3,500MH for access, with an escalation factor of 7.0-10.0 from the MPD estimates. About 4,400MH should be allowed for the inspections and technical cleaning, escalated by a factor of 5.0, which is the same for all other inspections, from the MPD allowance of 950MH. The total for the check is therefore about 7,500MH."

EL AL Maintenance & Engineering has a similar experience. "We have found that the labour inputs for the routine inspections on the lighter checks, such as the C7, C9, C11, C13 and C15 checks, are 3,500-4,400MH, depending on the base check cycle," says Moshe Tabib, managing production services engineer at EL AL Maintenance & Engineering. "These are high compared to other operators' maintenance programmes, but our maintenance programme results in similar MH inputs for the second check on each base check cycle. This compares to wide differences between the light and second checks. We have also found that our heavy checks, the fourth checks in each base check cycle, have a smaller labour requirement than others. Labour consumption has been as low as 5,000MH for the C16 check, and averaged 5,700MH for the C8 and 6,800MH for the C12 checks."

Overall, the estimated routine MH inputs for the first base check cycle are 11,000-12,000MH. This rises by 1,000-1,500MH for the second base check cycle. "A large rise is seen from the second base check cycle to the third, since the C12 check uses up to 1,300MH more than the C8 check," says Cooper. "Total labour for the routine portion of the four checks therefore totals 13,800MH." This compares to about 18,600MH for EL AL Maintenance & Engineering.

"The total for the fourth base cycle is 1,400MH less, at about 13,400MH," says Cooper. "This is because the C16 check is a smaller workpackage than the C12 check, and the C16 uses 6,800MH."

Peretz estimates a similar total. "The labour used for routine portion of the four checks totals about 13,400MH. The requirement for the fifth base check is a overall a few hundred MH less than the fourth cycle, mainly because the workpackages in the fifth cycle are slightly smaller."

Tabib at EL AL Maintenance & Engineering similarly comments that the total input for the routine portion of the four checks of the fourth cycle is about 1,400MH less than the third cycle.

Defects & non-routine

The routine inspections for the MPD workpackage task cards always result in defects and non-routine rectifications that incur a substantial amount of additional labour. The quantity of labour used to complete the rectifications and defects can be expressed as a ratio of routine MH used.

Care has to be taken with what is included in a quoted defect ratio. "This concerns the dividing line between MPD tasks and cosmetic maintenance, and the requirements of the operator with respect to cosmetic items," explains Peretz. "The defect ratio of MH used for clearing defects can be increased substantially if all cabin defects were to be rectified in the base check. This can include repairing all window panels and wallpaper scratches, for example. If the defects for cosmetic items are included then the defect ratio can increase by another 20-50 percentage points."

With cabin items included, the defect or non-routine ratio generally starts low at the first base checks, at only 0.50-0.80. It rises for each check in the base check cycle, and reaches a peak at the fourth, because this is a larger workpackage, and also includes more inspections for ADs. A larger number of outstanding defects that have accumulated during operation have to be cleared.

Non-routine ratios tend to be lower for the first check of a base check cycle following a heavy check. They rise again with successive checks in the base check cycle.

The non-routine ratio will reach 0.60-0.80 for the C4 check, the first heavy check, at the lower end of the scale, but can be as high as 1.00 for some aircraft. This can therefore add 3,000MH, and as many as 5,000MH, to the workpackage.

Ratios for the first checks in the second base check cycle will be about 0.60, but then climb to 0.80-1.00 for the second heavy check: the C8 check. This ratio can generate a requirement for a further 4,800-6,100MH, depending on the exact workscope and non-routine ratio incurred.

Ratios for the early checks in the third base cycle will be about 0.10 higher compared to the equivalent check in the second cycle. It will therefore be 0.90-1.10 for the C12 check. This will add 7,000-8,000MH to the routine portion of the check. Total non-routine labour for four checks in the third base check cycle will be 9,500-11,000MH. This is in addition to the 12,500-13,000MH used for the routine inspections.

Non-routine ratios continue to climb in the fourth base check cycle. EL AL's experience shows these to be 0.85-1.00 for the three lower checks, and up to as much as 1.20-1.35 for the C16 check. This is to be expected, since the aircraft will be about 20 years old by this stage. Such non-routine ratios will add another 6,000MH for the three lower checks, and 7,500-8,000MH for the C16 check. In total, non-routine defects will require 14,000MH in the fourth base check cycle.

Non-routine ratios can be expected to continue to climb in the fifth base check cycle. Again, planned ratios can be about 0.10 higher compared to equivalent checks in the previous base check cycle. This can therefore take the labour used for non-routine rectifications in the fifth base check to about 15,000MH.

SUMMARY OF MH USED FOR FIVE BASE CHECK CYCLES - PASSENGER-CONFIGURED 767

Check	Number MPD tasks	MPD MH	Routine MH	Defect ratio	Non-routine MH	Sub-total MH	Interior clean MH	Interior refurb MH	ADs, SBs & EOs MH	Heavy comp change MH	Strip & paint MH	Total MH	Total material costs-$
C1	832	448	1,500	0.50	750	2,250	400		300	150		3,100	54,250
C2	1,125	670	2,900	0.60	1,740	4,640	600		1,000	150		6,390	111,825
C3	879	476	1,600	0.70	1,120	2,720	400		600	150		3,870	67,725
C4	1,576	1,218	5,600	0.80	4,480	10,080	800	3,000	1,100	450	4,000	19,430	450,000
Total 1st base cycle		**2,810**	**11,600**		**8,090**	**19,690**	**2,200**	**3,000**	**3,000**	**900**	**4,000**	**32,790**	**983,825**
C5	833	447	1,500	0.60	900	2,400	400		500	150		3,450	60,375
C6	1,197	829	3,300	0.70	2,310	5,610	600		1,000	150		7,360	128,800
C7	832	447	1,500	0.80	1,200	2,700	400		700	150		3,950	69,125
C8	1,696	1,363	6,700	0.90	6,030	12,730	800	3,000	1,400	2,100	4,000	24,030	550,525
Total 2nd base cycle		**3,087**	**13,000**		**10,440**	**23,440**	**2,200**	**3,000**	**3,600**	**2,550**	**4,000**	**38,790**	**1,358,825**
C9	879	476	1,600	0.70	1,120	2,720	400		500	150		3,770	65,975
C10	1,131	803	3,200	0.80	2,560	5,760	600		1,100	150		7,610	133,175
C11	852	447	1,500	0.90	1,350	2,850	400		700	150		4,100	71,750
C12	1,711	1,351	7,500	1.00	7,500	15,000	800	3,000	2,500	950	4,000	26,250	609,375
Total 3rd base cycle		**3,076**	**13,800**		**12,530**	**26,330**	**2,200**	**3,000**	**4,800**	**1,400**	**4,000**	**41,730**	**1,630,275**
C13	832	447	1,500	0.85	1,275	2,775	400		500	150		3,825	66,938
C14	1,130	802	3,200	0.90	2,880	6,080	600		1,000	150		7,830	137,025
C15	880	540	1,900	1.00	1,900	3,800	400		700	150		5,050	88,375
C16	1,707	1,378	6,800	1.20	8,160	14,960	800	3,000	1,200	2,350	4,000	26,310	620,425
Total 4th base cycle		**3,167**	**13,400**		**14,215**	**27,615**	**2,200**	**3,000**	**3,400**	**2,800**	**4,000**	**43,015**	**1,712,763**
C17	832	447	1,600	0.90	1,440	3,040	400		600	150		4,190	73,325
C18	1,197	858	3,200	1.00	3,200	6,400	600		1,100	150		8,250	144,375
C19	832	447	1,825	1.05	1,916	3,741	400		800	150		5,091	89,075
C20	1,643	1,300	6,650	1.30	8,645	15,295	800	3,000	1,400	950	4,000	25,445	625,288
Total 5th base cycle		**3,054**	**13,275**		**15,200**	**28,475**	**2,200**	**3,000**	**3,900**	**1,400**	**4,000**	**42,975**	**1,932,063**
Overall total			**65,075**		**60,475**	**125,550**	**11,000**	**15,000**	**18,700**	**9,050**	**20,000**	**199,300**	**7,617,750**

Routine & non-routine

The total of routine inspections and non-routine rectifications steadily rises every base check cycle *(see table, this page)*, starting at 20,000MH in the first base check cycle, and climbing to 23,500MH in the second.

The third cycle, with the heaviest C12 check, uses 26,500MH. Higher non-routine ratios in the fourth base check take the total to 27,500MH, despite routine inspections using a few hundred MH less than the third base check cycle. By comparison EL AL used 36,000MH in the third and fourth base check cycles.

The total for the fifth base check cycle rises to 29,000MH *(see table, this page)*. The labour for routine inspections and non-routine rectifications steadily rises for each base check cycle; the largest jump being from the first to the second because of the large increase in tasks at the C8 check.

Interior work

Interior work comprises two elements: cleaning and repairing small defects; and refurbishment of major interior equipment. Most of these items are cosmetic and not related to aircraft airworthiness, so they are not specified in the MPD. This results in a high degree of variation between operators.

Interior cleaning will normally include handwashing and cleaning sidewall and ceiling panels and bulkheads, cabin carpets, lavatories, galleys, and overhead bins. This work can be done on a regular basis during all C checks.

A few hundred MH should be budgeted for each check, from just 200MH in the lighter checks, and up to 400MH. The larger second and fourth checks in the cycle use 600-800MH. A total of 2,200MH will be used for the four checks in the cycle *(see table, this page)*. This labour allowance excludes that for regular cleaning and replacement of seat covers and cushions.

The main cabin items of seats, carpets, flooring in service areas, lavatories, galleys, overhead bins, and sidewall panels must be removed during the fourth heavy check at the end of each base cycle to create access for deep inspections. This creates an opportunity to refurbish these larger items.

"An allowance of 3,000MH would be enough to refurbish major monuments during the fourth heavy check," says Peretz. This will therefore be the labour expenditure during each base cycle for interior refurbishment.

EOs, ADs & SBs

The 767 has been affected by several major ADs, two of which have also affected the 757 *(see Assessing the 757's ageing maintenance requirements, Aircraft Commerce, February/March 2012, page 34)*.

The first major AD to affect the 767 is AD 2003-14-09. "This was related to the wing trailing-edge flap-collar fittings, torque tubes and splined bushing. The AD was incorporated in SB 57A0066," says Peretz. "The second major AD is the engine pylon modification programme: AD 2004-16-12. This also affected the 757, so the AD was a similar number. The AD incorporated several SBs for the

The 767's MPD tasks and base check routine requirements increase from the first to the second base check cycle. Thereafter the number of MPD tasks varies but remains relatively stable with successive base check cycles.

different engine types powering the 767 family. SB 54-0800 is for Pratt & Whitney-powered aircraft, while SB 54-0081 applies to General Electric-powered aircraft."

This AD requires removal of both engines and pylons, and their reinstallation after the modification has taken place. "There is also a task in the 12C group of tasks in the MPD to inspect the engine pylons. The pylon modification AD has a 20-year age for compliance, so it makes sense to apply the AD at the same time as the scheduled pylon inspections, when the engines and pylons have to be removed anyway," says Tabib.

As described, the scheduled inspection uses about 1,000MH for engine and pylon removal and reinstallation. Synchronising the AD with the scheduled inspection would clearly save labour. "Incorporating the AD can use up to 3,000MH if it is not synchronised with the scheduled inspection," says Peretz. "The AD requires a downtime of 21 days, so it makes sense to combine it with a heavy check. A small number of aircraft will have already been through their C12 checks when the AD was issued, so it would need to be included in later checks. Other aircraft may need to have the AD incorporated in the C4 or C8 checks."

Another AD relating to engine pylons was AD 2004-01-02, which requires modification of the aft pitch load fitting of the diagonal brace of the nacelle strut in each engine pylon.

A third AD relating to engine pylons is AD 2005-19-23. It involves inspections to fastener holes in the midspar fitting of the engine pylons. The AD was superseded by AD 2010-14-18.

Another major AD is AD 2006-07-14, and concerns the main landing gear bogie beam.

A fifth major AD is AD 2009-18-02, which covers the application of a sealant to the inner walls of the fuel tank. A similar AD also affected the 757: AD 2009-23-19.

A sixth major AD was issued more recently in 2010: AD 2010-06-16, covering fuselage skin scribe line. This was issued as a need to make inspections of scribe lines on the fuselage skin at lap joints, certain external approved repairs, skin around external features such as antennas, and the skin at the decals. Corrective actions could result if necessary.

A recent AD is AD 2012-09-04, which supersedes an AD issued in 2004 - AD 2004-19-06. "This is an inspection of the fail-safe strip at body station 955 after cracks were found in some aircraft," explains Tabib. "This is a crack in the fuselage ring near the wheel well, and needs 1,000-2,500MH, depending on the findings made in the inspections."

In addition to these major ADs and SBs, smaller ADs and SBs are issued on a regular basis, and included in every base check, while the larger ones described will usually be scheduled into the heavy checks. A budget for labour for ADs and SBs in smaller checks will be 300-600MH for the first base check cycle, steadily increasing with each successive base check cycle. Second checks should have a larger analysis, and some checks can see this exceed 1,000MH.

Budgets for heavy checks should allow at least 1,000MH for the larger ADs, and one of the heavy checks should have an allowance of at least 2,500MH in order to address the pylon modification.

Heavy component changes

Component changes performed during base checks can be sub-divided between heavy components, and system rotables.

Heavy components include: thrust reversers and engine cowls; the auxiliary power unit (APU); landing gear; and engines.

An engine change will use about 240MH. Typical engine removal intervals of about 15,000FH means engines are being removed on average once every two years. Although some engine changes would have to be performed during A checks, the labour allowance can be budgeted for in C checks. This would be an average of 150MH per C check.

A landing gear shipset would be changed about once every second heavy check, and uses about 900MH.

System rotables have to be removed during checks either because they are LLPs or because they fail functional tests.

A few hundred MH should be added to heavy checks for the APU and some system rotables.

The result of this is that the three light C checks in each cycle should be allocated an average budget of 150MH to allow for engine changes. The fourth check in each cycle would require from 450MH at the C4 to 2,100-2,350MH at the C8 and C16 because of landing gear, APU and system rotable changes.

Stripping & painting

Aircraft are generally stripped and repainted once every five or six years, and the fourth check at the end of the base cycle represents an ideal opportunity to perform this process. The labour used is up to about 4,000MH, depending on how elaborate the airline's livery scheme is. Paint materials cost about $60,000.

MH summary

The additional labour for interior cleaning, interior refurbishment, ADs and SBs, component changes, and stripping and repainting totals 850-1,900MH for each of the three lighter checks in the base check cycle. These additional items use about 9,000MH for the first C4

The 767 has both a pylon inspection as a regular MPD inspection at the C12 check, as well as a major AD that requires modification of the engine pylon. Incorporating the AD requires a lot of labour man-hours, and is best scheduled with a C12 check.

check, and this climbs with each base cycle to about 11,000MH, depending on how heavy the requirement is for ADs and SBs *(see table, page 48)*.

The total for labour for these additional elements for the four checks in the cycle reaches about 13,000MH for the first cycle, and climbs to more than 15,000MH in the second cycle. The main variations are the burden for ADs and SBs, and the timing of heavy component changes.

The total overall labour requirement is about 3,000MH for the C1 check, and this steadily climbs to about 4,100MH by the C17 in the fifth base check cycle *(see table, page 48)*. Labour requirements for other light checks vary from 3,500MH to 5,000MH.

The C2 checks are larger, and use about 6,400MH in the first base cycle. This climbs to 7,400MH, and steadily rises to 7,800MH in the fourth cycle and 8,250MH in the fifth *(see table, page 48)*.

Totals for the heavy checks start at 19,000-20,000MH for the C4 check, and rise to 24,000MH for the C8, and 28,000MH for the C12 *(see table, page 48)*. Labour requirements are similar for the C16 and C20 checks.

The total labour for the four checks in the cycle steadily increases from the first to the fourth cycle; rising from 33,000MH in the first cycle to 43,000MH in the fourth *(see table, page 48)*. Labour used in the fifth cycle will be similar, or possibly higher.

Materials & parts

There are four main elements to the cost of materials, consumables and parts, used in: the base check routine inspections; non-routine rectifications and incorporating the ADs and SBs; the replacement of life-limited and test-failed rotables; parts and components used in the refurbishment of major interior items of galleys, lavatories, bulkheads, panels and overhead bins; and paint.

The cost of consumables and parts used in base checks depends on the type of tasks included, the level of access required, and the level of disassembly. "A budget of $18 per MH for the four checks in the cycle provides an average guide to what the likely cost of materials and consumables will be," says Peretz. This results in a cost of $55,000 for the smallest C1 check, and climbs to about $75,000 for the C17 check in the fifth base cycle. Materials and consumables for the C2 check will therefore be about $112,000, rising to about $145,000 in the C18 check. Materials and consumables will start at $340,000 in the C4 check, and will have risen to $450,000-500,000 by the C16 and C20 checks.

The total for the first base check cycle reaches about $575,000. This rises steadily by $100,000 during the second cycle, by another $50,000 in the third cycle, and reaches up to $750,000-800,000 at maturity.

The second element of materials will be for the replacement of rotables. Some of this will be predictable, since it includes life-limited parts. Other rotables will fail at random, and this portion will increase with age and each base check cycle.

Like the 757, an allowance of $250,000-300,000 should be made for the first base check cycle. This could rise by several hundred thousand dollars per cycle, and have reached or even exceeded $1 million by the fifth base check cycle.

Items used during interior refurbishment include the hardware of decorative foils, replacement panels and bulkheads, galley and toilet wall coverings and replacement components, cabin dividers, window shades and perspex windows, flooring material and carpet. Materials such as primers, cleaners and some consumables will also be used. A budget of $40,000-50,000 could be used for the C4 check, and this will steadily increase by about $20,000 for each heavy check. It could reach $100,000-120,000 by the fourth or fifth heavy checks, but whether this cost is actually incurred depends on whether the operator considers it worth refurbishing the interior items at this stage of the aircraft's life.

As described, the cost of paint will be up to about $60,000, but can be lower at $40,000 for a simple livery.

The total cost of materials, consumables, rotables, interior refurbishment parts, and stripper and paint reaches almost $1 million in the first base check cycle. This steadily rises by another $400,000 in the second cycle, and a further $1.63 million in the third cycle. It reaches $1.9 million the fifth base check cycle *(see table, page 48)*.

Summary

Base check maintenance requirements steadily rise with successive base checks due to several factors. The first is an increase in base check requirements after the first cycle. The second is a steady rise in the non-routine ratio with each base check cycle. There is also a peak in MH used for EOs, ADs and SBs, but the requirement will fluctuate. The cost for materials and consumables will also increase as MH rise, especially those required to rectify defects found during routine inspections. There will also be a steady increase in the cost of repairing failed rotable components during base checks as the aircraft ages.

The MH requirement of the fifth base check cycle was about 30% higher than the first cycle, while the total cost of materials more than doubles from the first to the fifth. AC