The 777 fleet now exceeds 1,000 units. The oldest aircraft have been in operation for 18 years, and have completed two base check cycles. The 777 has no major ADs or ageing programmes, and a design that makes access for heavy tasks easier and overall reduces labour consumption & costs.

Assessing the 777's long-term base maintenance costs

The active 777 fleet has grown to more than 1,080 units since its entry into service 18 years ago. The oldest aircraft are -200s operated by United Airlines and Japan Airlines (JAL), and have accumulated 73,000 flight hours (FH) and 22,000 flight cycles (FC). The -200ER and -300ER are the most popular of six main variants, and there are a large number of -300ERs on order.

The 777's maintenance programme does not have individual tasks pre-arranged by Boeing into checks. Instead, it is a usage parameter programme.

There are more than 2,040 different maintenance tasks specified in the maintenance planning document (MPD), which has six main interval criteria and more than 145 different intervals. The 777's MPD allows operators to group tasks according to their operation, rate of aircraft utilisation, and FH:FC ratio. This allows an optimal grouping of tasks, so each operator will have different systems of nomenclature for its airframe base checks, and different intervals. There is therefore no fixed interval for the heaviest base checks or base check cycle, as is the case with older types like the 747-400.

Despite this, groups of operators have similar base check and base check cycle intervals because large groups of inspections in the MPD have the same intervals. There are large numbers of inspection tasks with an interval of 7,500FH, and another large number of structural tasks with a dual limit of 6,000FC and 1,125 days (DY). As a result many operators have arranged a system of base checks every 18 or 24 months, and alternating heavier base checks with structural tasks in every second base check. Several operators have then had a heavier check every eight years or every fourth base check, which effectively marks as a base check cycle completion. There are, however, a large number of MPD tasks with initial threshold intervals that are higher than the fourth base check. The overall effect of this is for the number of routine tasks to steadily increase throughout the life of the aircraft.

Fleet profile

As of April 2013, there were just over 1,000 active passenger-configured 777s, and another 75 777Fs in active service.

The passenger fleet is sub-divided between five main variants: the -200, -200ER, -300, -200LR and -300ER. The -200ER and -300ER are the two most popular variants, and account for 806 of the 1,000 passenger-configured aircraft in service. The youngest three variants, the -200, -200ER and -300, are powered by a choice of the GE90 Standard, PW4000-122 and Trent 800. There are 557 of these aircraft in active service. The -200LR, -300ER and -200F are powered exclusively by the GE90 Growth engine. There are 450 of these aircraft in service.

The active number, typical annual FH and FC utilisation, typical FH:FC ratio, daily rates of utilisation, and major operators for each passenger-configured variant are summarised *(see table, page 29)*.

The are also 75 777Fs in operation. These are used mainly on long-haul, international freight operations. The first 777F entered service in 2008. The 777F has a large number of tasks in the MPD that are unique to it. The maintenance requirements of the 777F therefore differ to passenger-configured aircraft, so the 777F is not analysed here.

The base maintenance requirements of passenger-configured aircraft operated on medium- and long-haul styles of operation are examined here. The annual rates of utilisation for medium-haul aircraft are 2,700FH and 1,000FC, equal to an average of 7.5FH and 2.8FC per day over the year. It is also equal to an average FC time of 2.7FH.

The rates of utilisation for long-haul aircraft are 4,800FH and 530FC per year, equal to an average FC time of 9FH. This reflects the operation of the majority of -200ERs, -200LRs and -300ERs. This is also equal to 13FH and 1.45FC per day.

MPD development

The 777's MPD has a total of more than 2,040 tasks, split between 1,600 airframe-related tasks, and 448 engine-related tasks. Engine-related tasks are those that concern engine borescopes, accessories, engine-related rotable components, and some inspections of the engine pylons and nacelles. The 448 engine-related tasks apply to all three main engine variants, so only about one-third of these apply to the particular engine type operated. There are, however, more tasks for one particular engine variant than there are for other engine variants. A maximum of 154 tasks applies to the PW4000, 142 for the Rolls-Royce Trent 800 series, and 152 for the GE90 family.

Many of the 1,600 airframe tasks apply to just one or several, but not all six, of the main airframe variants. There are 100 tasks, for example that apply only to the 777F, so there are 1,500 tasks that apply to five main passenger variants of the 777. Fewer tasks apply to each of the five variants, however.

Taking the GE90 as the engine type, the maximum number of airframe- and engine-related tasks that apply to a particular passenger variant is therefore about 1,651 *(see table, page 32)*.

The MPD is divided into three main groups of tasks: the system, structural and zonal programmes. These are listed in section1, section 2 and section 3 of the MPD.

There are also special groups of tasks in Section 9 of the MPD.

The first is the certification maintenance requirement (CMR) tasks. These are special tasks, that were already in the MPD when the aircraft entered service. These are divided into two-star tasks, which can be escalated by the operator; and one-star tasks, which require special permission to be escalated.

The second group comprises airworthiness limitation (AWL) tasks. These were introduced into the MPD in several groups after the aircraft entered service.

AWL tasks can be sub-divided between structures and systems tasks.

AWL systems tasks encompass the Special Federal Aviation Regulation (SFAR) 88, that encompasses fuel tank safety (FTS) instructions, which was released in 2007.

SFAR 88 also gave rise to some additional AWL tasks, which are part of the systems programme. Airworthiness directive (AD) 2008-11-13 mandated operators to incorporate the AWL items relating to fuel tank systems to satisfy the SFAR 88 requirement.

The AWL structures section covers the supplemental structural inspection (SSI) programme. These are structural significant items that do not receive adequate fatigue damage detection from the tasks in section 2 of the MPD.

All AWL tasks were mandated by an airworthiness directive (AD), and have initial and repeat intervals that cannot be escalated. The tasks are either in the system or structural programme.

The introduction of SFAR 88 in 2007 added a large number of tasks to the MPD.

As with other younger types, the 777 has the corrosion prevention and control programme (CPCP) incorporated into the MPD. "This is partly through the zonal inspections," explains Jorgen Hoogendoorn, manager of planning department for widebody maintenance at AFI KLM E&M. "The zonal tasks include inspections for corrosion generally."

The zonal programme tasks include a general visual and, if required, a physical check of the general condition and security of attachment of the accessible systems and structures items contained in defined zones. This includes checks for degradation that are not covered in the MSG-3 analysis, such as: chafing of tubing; loose duct supports; damage to electrical wiring; cable and pulley wear; fluid leaks; electrical bonding; general condition of fasteners; cracked, chipped, or missing paint on composite structures; inadequate drainage; and general corrosion.

777 ACTIVE PASSENGER FLEET & TYPICAL UTILISATION CHARACTERISTICS

Aircraft variant	Number active	Annual FH	Annual FC	FH:FC ratio	FH/ day	FC/ day	Main operators
777-200	86	2,500-3,000	925-1,100	2.7:1	7.5	2.8	Air China, JAL, ANA Thai & United
777-300	60	2,500-3,000	925-1,200	2.5-2.9:1	6.8-8.2	2.5-3.3	ANA, Cathay Pacific, JAL, Korean, SIA & Thai
777-200ER	411	4,500-5,000	460-630	6.5-10.0:1	12.3 -13.7	1.3-1.7	Air France, KLM, Air New Zealand, Alitalia, American, BA, Delta, Emirates & SIA
777-200LR	55	4,800-5,500	460-550	9.0-12.5:1	13.1 -15.0	1.3-1.5	Air Canada, Air India, Delta, Emirates & Qatar Airways
777-300ER	395	4,500-5,000	460-630	6.5-10.0:1	12.3 -13.7	1.3-1.7	Air France, Air Canada, Cathay Pacific, Etihad, EVA Air, SIA, THY, JAL, Qatar & Emirates

The electrical wiring interconnect system (EWIS) was introduced from a desire to treat the aircraft's wiring as a separate system. This analysis revealed where failures or damage to the wiring system may cause a fire or other failures in the aircraft.

The enhanced zonal analysis programme (EZAP) was introduced to generate inspections to maintain the integrity of EWIS. EZAP generated wiring tasks to prevent a wiring failure. Some of these tasks were already covered by the zonal programme. Others needed to be created. These tasks have a reference to EZAP in the MPD.

If there were insufficient zonal programme inspections, then new tasks were devised, and introduced to the system and zonal programmes of tasks.

There are also CPCP inspections in the structural programme. "There are 88 corrosion inspection tasks in the structural programme tasks, which are detailed in section 2 of the MPD," says George Sifnaios, 777 maintenance programs manager at Delta Air Lines. "There are actually three categories of tasks in the structural programme in the MPD: structural inspections, which are indicated with a letter S; corrosion inspections, which are indicated with a letter C; and fatigue inspections, which are indicated with a letter F."

All tasks in the MPD have an initial and repeat interval. In some cases the repeat interval is the same as the initial interval, but in others it is shorter. This is particularly the case with structural tasks with higher initial intervals. This means the number of routine tasks that have to be performed in base checks, particularly deeper and heavier structural tasks, are increasing in number and frequency as the aircraft ages.

There are six main types of interval criteria, and a total of 145 different task intervals. The six interval criteria are: FH; FC; combined FC and calendar time in DY; combined FH/DY; combined FH and FC; and calendar time (DY). There are also several other groups. In the case of two combined interval criteria, the interval for performing a task is determined on a whichever-comes-first (WCF) basis. For example, the interval for a 6,000FC/1,125DY tasks will be performed at 1,125DY if this number of days is reached before the aircraft has accumulated 6,000FC.

The largest group of tasks is those with a combined FC/DY interval, with a 804 in the MPD that relate to the airframe and the GE90 *(see table, page 32)*.

The second largest group of tasks is those with an FC interval, with 302 in the MPD that are related to the aircraft and the GE90 *(see table, page 32)*.

The third largest group of tasks is those with an FH interval, with 268 in the MPD that relate to the airframe and the GE90 *(see table, page 32)*.

There are also 134 tasks with an

The 777-300ER is one of the most numerous 777 variants in operation. These aircraft have replaced large numbers of 747-400s, and operate at rates of utilisation typical for long-haul aircraft.

interval specified in DY, with virtually all being airframe-related.

Another 135 airframe and GE90-related tasks with intervals that relate to the life limits of components, are recommended by the vendor, or are performed during an engine change. These are referred to as 'Other' task intervals *(see table, page 32)*.

In addition, there are a small number of tasks with intervals specified in a combination of FH/DY, and FH/FC. This last category only has tasks relating to the PW4000 and Trent 800, however.

The tasks in each of the three main programmes have to be examined in some detail to understand the 777's maintenance requirements.

System tasks

The system programme is the largest, with a total of 873 tasks. This includes about 247 engine-related tasks, although only 78 are relevant to the GE90.

There are also 45 tasks that relate exclusively to the 777F. This leaves 581 tasks that relate to passenger variants of the 777, and 657 when GE90 tasks are added *(see table, page 32)*.

The tasks within the system programme relate to air transport association (ATA) chapters as follows: 12-49, which relate to all the aircraft's different systems; 52, 54 and 56, for the aircraft's doors, engine nacelles and windows; 71 and 72 that relate to powerplant and individual engine types; and 73, 75, 77, 78 and 79 that relate to engine fuel, engine indication, exhaust and oil.

The FH initial intervals vary from 100FH to 30,000FH, with tasks of 6,000FH and higher mainly being included in base checks by many operators. The largest groups of tasks are those with initial intervals of 7,500FH, 12,000FH, 15,000FH, 18,000FH and 24,000FH.

The FC initial intervals vary from 100FC to 16,000FC. Tasks with intervals of about 1,000FC and higher are those usually included in base checks.

The combined FC and calendar task intervals start at 50FC/25DY and go up to 32,000FC/6,000DY. Tasks with an initial interval of 4,000FC/540DY and higher are usually included in base checks.

The combined FH/DY tasks account for a small number of tasks, as do the combined FH/FC tasks. Calendar tasks have initial intervals that vary from 1DY to 4,500DY.

There are also several other groups of tasks. The largest number relate to an engine change, life-limited rotables, and tasks that are vendor-recommended.

Structural tasks

The structural programme is almost as large as the system programme, with a total of 845 tasks. About 131 of these are engine-related, with 50 being relevant to the GE90, and another 50 unique to the 777F. This leaves 664 airframe tasks that are relevant to passenger variants. Together with tasks for a single engine type, there are 714 tasks *(see table, page 32)*.

The tasks in the structural programme relate to the following ATA chapters: 27 (flight controls); 52-55 and 57, which are all the structural sections of the aircraft that include the fuselage, doors, engine pylons, stabilisers and the wings; and 71, which is powerplant-related.

There are four main interval criteria for structural tasks. The most important are combined FC/DY tasks, with 381 tasks that relate to passenger-configured 777s and the GE90. Initial intervals start at 700FC/175DY and go up to 32,000FC/6,000DY.

The largest groups of tasks have initial intervals of:

- 6,000FC/1,125DY (21 tasks);
- 12,000FC/2,250DY (50 tasks);
- 16,000FC/3,000DY, and various repeat intervals (127 tasks);
- 16,000FC/3,750DY (16 tasks);
- 16,000FC/4,500DY (28 tasks); 24,000FC/4,500DY, and various repeat intervals (32 tasks);
- 28,000FC/5,250DY, and various repeat intervals (16 tasks); and
- 32,000FC/6,000DY, and various repeat intervals (43 tasks).

The calendar interval is likely to be reached first by most aircraft in operation. These intervals are equal to just over three, six, eight, 10, 12, 14 and 16 years. This is why many base maintenance programmes have base check intervals that are multiples of one or two years, and why the heaviest base checks have intervals that are eight and 16 years.

The other important group of structural tasks are those with FC intervals. There are 280 tasks that relate to passenger-configured 777s and the GE90. There are just four initial intervals of 8,000FC (2 tasks), 16,000FC (13), 30,000FC (112) and 40,000FC (158).

There is also a single calendar task, with an initial and repeat interval of 750 days.

There are also 52 engine change and other tasks with various intervals.

S, C & F tasks

The 714 tasks that apply to all passenger variants and the GE90 are also sub-divided into structural (S), corrosion (C), and fatigue (F) tasks.

There are 310 S tasks, 294 of which have intervals that are a FC/DY combination. Initial intervals range from 700FC/175DY to 32,000FC/6,000DY. The largest number of tasks are those with initial intervals of 16,000FC and 3,000-4,500DY (123 tasks), and an initial interval of 12,000FC/2,250DY (56

SUMMARY OF 777 MPD TASK INTERVALS FOR PASSENGER-CONFIGURED 777S PLUS GE90 ENGINE

Interval criteria	System tasks	Structural tasks	Zonal tasks	Total tasks	Interval range	Number of intervals
FH	251		17	268	100FH/100FH to 30,000FH/30,000FH	40
FC	22	280		302	100FC/100FC to 40,000FC/16,000FC	28
FC/DY	161	378	262	801	50FC/25DY & 50FC/25DY to 32,000FC/6,000DY to 32,000FC/6,000DY	42
FC/DY multiple		3		3	12,000FC/2,250DY, 28,000FC/5,250DY	1
DY	132	1	1	134	1DY/1DY to 4,500DY/4,500DY	28
FH/DY	8			8	3,000FH/400DY & 3,000FH/400DY to 25,000FH/5 years & 25,000FH/5 years	4
Other	83	52		135	Various	N/A
Total	**657**	**714**	**280**	**1,651**		**145**

tasks). There are also 21 tasks with an initial interval of 6,000FC/1,125DY.

Another 15 S tasks have FC intervals, and most have an initial interval of 16,000FC.

There are 88 C tasks. All of these have FC/DY intervals. The three largest groups are those with initial intervals of 16,000FC/3,000-4,500DY (47 tasks), an initial interval of 24,000FC/4,500DY (23), and an initial interval of 32,000FC/6,000DY (12).

There are 317 F tasks, from the fatigue programme. All F tasks have initial and repeat FC intervals.

The fatigue programme includes some specific tasks, where non-destructive tests are conducted on specific sections of the airframe that may be susceptible to fatigue with accumulated FH and FC in operation.

The fatigue programme has to be given special consideration, since tasks are grouped into three categories of intervals.

SSI Programme

"The fatigue programme actually relates to two sections of the MPD and the damage tolerance rating (DTR) manual," explains Sifnaios. "That is, Section 9 of the MPD is the entire supplemental structural inspection (SSI) programme. The SSI tasks are listed with brief explanations in section 9, and have a detailed cross reference description to the SSI in more detail, together with a recommended repeat interval provided in the structures section 2 of the MPD. The tasks in Section 9 and Section 2 are therefore in fact the same tasks. A different repeat interval can be calculated using the DTR form," explains Sifnaios. "An example is SSI item 55-17-I03 in section 9, whose equivalent in section 2 is MPD item number 55-705-01. This has an initial interval of 30,000FC, and a recommended repeat interval of 16,000FC.

The SSI tasks can be divided into three main groups. These can be referred to as Group 1; Group 2; and Group 3, or flight length sensitive (FLS) tasks.

The initial interval for Group 1 tasks is 30,000FC, and 40,000FC for Group 2. There are 107 Group 1 tasks (93 airframe and 14 for the GE90) and 158 Group 2 tasks. Most Group 1 and all Group 2 tasks are heavy tasks that require deep access, and also have the potential for significant non-routine rectifications.

The 30,000FC and 40,000FC initial intervals are high for most aircraft in the fleet.

The 777-200s with the highest total utilisations have accumulated 22,000FC and 25,000-73,000FH. These aircraft are 16-17 years old, and so accumulate about 1,300FC per year. These aircraft will therefore be about 22 years of age when they reach the threshold of 30,000FC.

Long-haul -200ERs, -200LRs and -300ERs accumulate only 450-600FC per year. These aircraft will therefore reach 30,000FC at an age of 50 years or more, and will have reached 40,000FC at an age of 66 years or more. It is unlikely, therefore, that the Group 1 and Group 2 tasks will ever be performed.

The FLS group are tasks that are sensitive to flight length and depend on both accumulated FH and FC to determine the implementation threshold with the use of a 'FLS threshold curve' graph.

The graph allows an initial 30,000FC interval when up to 45,000FH have been accumulated. This reduces to 15,000FC when up to 90,000FH have been accumulated. So, for aircraft that have a total of 90,000FH or more, these tasks have to be performed, regardless of the number of FC accumulated. Since the majority of aircraft are used on long-haul missions, and have an FH:FC ratio averaging 9.0FH:FC, aircraft will reach the 90,000FH threshold at about 10,000FC, after 18 years of operation. The tasks will come due at this point. In contrast, the -200ER with the highest utilisation to date has accumulated 77,000FH, and is 15 years old. The tasks will therefore have to be performed if the operator wants to keep the aircraft operational for more than 18 years.

The graph for tasks with an initial interval of 40,000FC allows this initial interval to be used when up to a total of 60,000FH have been accumulated. The FC interval then reduces at a constant rate to 20,000FC for a corresponding total utilisation of 120,000FH. This will be equal to 13,500FC at average FH:FC ratios of operation. This will be reached after about 24 years of operation. These tasks may represent a retirement watershed, given the probable age of the aircraft when they come due.

Zonal tasks

The zonal programme has a total of 376 tasks in the MPD, and five of these are exclusive to the 777F. There are 280 tasks that relate to all passenger variants and the GE90, with 255 being airframe-related.

The tasks in the zonal programme

Delta started its 777 operation with a C check interval of 12 months, and a heavy check at eight years. It re-optimised its maintenance programme to change the C check interval to 7,500FH/500 days, and a heavy check every sixth C check, equal to about eight years.

relate to ATA chapter 32, which relates to landing gear; and the same chapters in the structural programme. Zonal tasks are similar to structural tasks.

The zonal programme has four main interval types. The most important is the FC/DY tasks, with 262 items. Their initial intervals start at 400FC/175DY and go up to 24,000FC/4,500DY. Base check tasks start with an interval of 4,000FC/750DY.

The largest groups are:

- 6,000FC/1,125DY (126 tasks);
- 8,000FC/1,500DY (14);
- 12,000FC/2,250DY (32);
- 16,000FC/2,250DY (18)
- 16,000FC/3,000DY (23); and
- 16,000FC/4,500DY (30).

These DY intervals are equal to just over three years, just over four years, just over six years, just over eight years, and just over 12 years, respectively.

There are also 19 FH tasks, but most of these are line check items.

Task intervals

As described, there are six main types of task interval. There are 145 different intervals for tasks in the MPD for these six interval types *(see table, page 32)*. The dividing line between line and A check, and base check tasks will be an interval of about 400 days. This is only in the case of some airlines' maintenance programmes, however. In other operators' programmes, base check tasks will be those with an interval of 730 days or higher.

There are 40 different intervals for FH tasks, between 100FH and 30,000FH, accounting for 268 tasks. About 188 of these have intervals of 6,000FH or higher, and are most likely to be included in base checks.

There are 28 different FC task intervals between 100FC and 40,000FC *(see table, page 32)*, and a total of 302 tasks. There are 296 tasks with intervals higher than 800FC. These are most likely to be included in base checks in the case of long-haul aircraft.

There are 43 different FC/DY intervals between 50FC/25DY and 32,000FC/6,000DY. There are a total of 803 tasks, 736 of which have intervals of 4,000FC/540DY and higher, and are most likely to be included in base checks.

There are 28 different calendar intervals, between just one day and 4,500DY, and a total of 134 tasks. There are 117 of these with intervals of 400DY or more, and are most likely to be included in base checks.

There are just four different FH/DY intervals and eight tasks, seven of which are included in base checks.

There are also 135 tasks with special intervals. These are connected to an engine change, the changing of the auxiliary power unit (APU), the changing of the landing gear, the life limit of particular rotable components, an interval recommended by the component vendor, and other particular intervals.

Overall, there are 1,479 tasks relevant to the airframe and the GE90, with 90 different intervals, that make them appropriate for including in base checks. These vary from: 6,000FH to 30,000FH; from 800FC to 40,000FC; from 4,000FC/540DY to 32,000FC/6,000DY; from 6,000FH/400DY to 25,000FH/5 years; and from 400DY to 4,500DY.

The large number and the variety of task intervals means that simply grouping tasks into base checks is not possible. It also means that the grouping of tasks into base checks will not be consistent between operators according to rates of utilisation and FH:FC ratio.

The four largest groups of tasks are those with FH, FC, DY, and FC/DY intervals, accounting for 1,337 of the 1,479 base check tasks.

The FC/DY group has the largest number of tasks at 736. Most of these, 342 tasks, are from the structural programme, while 141 are system tasks and 250 are zonal inspection tasks.

The second largest group of base checks has FC intervals. Of the 296 base check tasks, 280 are from the structural programme, while the remaining 16 are system tasks.

The third largest group comprises 188 base tasks with FH intervals. All except three are from the system programme.

There are 117 tasks with calendar intervals in days. All but one are system tasks.

Task grouping

As described, the order and time that each group of tasks with a particular interval comes due depends on aircraft utilisation. This analysis assumes a generic long-haul aircraft generating 4,800FH and 530FC per year. This is equal to an FH:FC ratio of 9FH per FC, and daily utilisations of 13FH and 1.45FC.

This means that the different task groups come due at a large number of different intervals. The timing of these tasks coming due in calendar days can be calculated using the generic rates of utilisation.

An example is the 100FH tasks coming due once every eight days, and the 30,000FH tasks coming due every 2,308 days, equal to six years and four months.

Meanwhile, 100FC tasks come due every 60 days, and 16,000FC tasks will come due every 11,000 days, equal to 30 years.

The FC/DY tasks will come due depending on which interval is reached first. The ratios of FC to DY in most FC/DY intervals are between 3.6:1 and 8.0:1. This means the DY interval will be

There are 1,500 tasks in the MPD that apply to the airframe of passenger-configured aircraft. Not all of these apply to all five of the main passenger variants. About another 150 tasks apply to the engine variant fitted to the aircraft.

reached first for virtually all the FC/DY intervals. This means that the FC/DY tasks with initial intervals from 50FC/25DY to 32,000FC/6,000DY will come due between 25 and 6,000 days.

The shortest and longest intervals for tasks in the MPD are one day and 6,000DY. The problem is that when all the task intervals are converted to the equivalent number of days, there are a large number of intervals, each with a small number of tasks. For example there are: 12 FH tasks with a 462-day interval; two with a 500-day interval; one with a 538-day interval; 57 with a 577-day interval; one with a 692-day interval; and eight with a 769-day interval. This pattern is repeated throughout the task groups.

Sifnaios explains the complexity of grouping tasks into base checks. "The 777's maintenance programme is a usage parameter maintenance programme, so the grouping of tasks has to consider aircraft operation and utilisation, operational needs, maintenance stations, and probable ground time. A base maintenance programme can be based on phases or multiples of number of days or hours, or a combination of the two.

"We have base checks every 7,500FH and 500DY, whichever comes first," continues Sifnaios. "The problem, however, is that tasks due between 500DY and 1,000DY will have to be brought forward to be included in the base check, which means interval utilisation will be low on a lot of tasks. It is not possible to capture all items in the base checks, however.

"It is challenging to optimise the maintenance programme," continues Sifnaios. "One of the important issues to consider is the efficiencies to be gained from grouping the tasks in the same area of the aircraft that requires a lot of access, because they will lead to the check having a longer downtime. For example, a deep access task in the fuel tanks that has an interval of 4,000DY, will be brought forward to 3,000DY because there are other tasks that require access to the fuel tanks. Issues like these mean that there is a lot of compromise with the interval utilisation of a lot of tasks, but you gain in aircraft downtime and man-hour (MH) savings."

Deep access tasks

A main consideration in grouping tasks into checks is the groups of tasks that require deep access. The escalation factor that has to be applied to MPD estimated man-hours (MH) is higher than for other tasks that do not require such deep access.

Many of the MPD tasks that relate to ATA chapters 20-49 and 70-80 have mainly system-related tasks, because they relate to the aircraft's various systems and engine controls. Chapter 27 for flight controls is an exception to this, as some of the tasks require deep access, for lubrication and other issues.

Many of the tasks for these ATA chapters are operational checks (OPC), functional checks (FNC), service (SVC) tasks, discard (DIS) tasks, and visual check (VCK) tasks. Most of these tasks do not involve deep access. "Many of the OPC tasks, for example, are simple push-button tasks, since operational checks can be made via the aircraft's central maintenance computer," says Hoogendoorn. "The equivalent tasks on older aircraft required deeper access, because they involved using a laptop computer in the area of the aircraft being tested. This could have been in fuel or flight controls, for example, so required a lot of access and opening and closing of panels. The 777 is a fly-by-wire aircraft, so there is no need to calibrate the control cables of the flight controls. The older aircraft types also had a larger number of hard-timed components that had to be removed. A larger number of components on the 777 are condition-monitored, and the components are better designed and so are more reliable."

Some system programme tasks do, however, involve deep access. These are mainly for ATA chapters 27, 28, 33, 47, and 52; which are flight controls, the fuel system, lights, the inert gas system, and doors.

There are 162 tasks in the system programme that require deep access, and most have high intervals that would mean they are included in the base checks. These tasks include: lubrication of flight controls; deep inspections that require the removal of panels and grilles; inspections of the lower cargo compartment; inspections and lubrication tasks around the passenger doors; and some deep functional checks in the area around the fuel tanks.

The structural programme has a large number of tasks that require deep access. Only 32 structural tasks with lower intervals can be included in line or A checks, and the other 682 tasks will be grouped into base checks. These 682 comprise 277 S tasks, 88 C tasks, and 317 F tasks.

Of the 277 S tasks that are included in base checks, 163 require deep access. These all relate to ATA chapters 52-55 and 57. The structural tasks also have sub-numbers of -400, -500, -600 and -700. Some S tasks require the removal of sidewall panels in the cargo bay, ceiling panels in the fuselage, and insulation blankets from the fuselage walls, as well as several internal inspections of the passenger compartment. "There are a lot of EZAP tasks in the system programme, and these require cleaning to remove dust in certain areas to prevent fire," explains Hoogendoorn. "The 777's design means it is easy to carry out these cleaning tasks, because access is easier and fewer areas need to be cleaned, for example a few particular areas of the cargo compartment. It is also easier to remove panels and floorboards when required.

The tasks in the 777's MPD have 145 different intervals. When converted into the equivalent number of days according to aircraft utilisation, they vary from between one day and more than 50 years. Operators can group tasks according to their rate of aircraft utilisation.

This compares to cleaning the whole cargo compartment, which was required in older aircraft types. Most system tasks in the 777's MPD generally have easy access and test requirements because of its different maintenance philosophy compared to older types."

There are also a lot of internal inspections of flaps, slats and flight controls. There are also some tasks that involve the removal of wing-body fairing panels to allow internal inspections.

Of the 88 C tasks, 81 need relatively deep access. These are all internal inspections relating to ATA chapters, 52, 53, 55 and 57 (the doors, fuselage, stabilisers, and wings respectively).

Despite the deep access required for these inspections, the number of additional MH used to gain access and then close areas up again is not regarded as high for similar or equivalent inspections on older generation aircraft.

"First, this is because fewer items require removal for some of the deeper inspections to take place," says Hoogendoorn. "Compared to the 747, the deep tasks require the removal of fewer interior items, such as galleys, toilets and seats. There is also a lower incidence of corrosion on items like the seat racks. Also, while there are tasks in types like the 737 Classic that require an inspection of the complete upper and lower fuselage lobes, and therefore the complete removal and re-installation of the aircraft interior, the 777 does not have equivalent tasks. Boeing learned the lessons and found a better way to design the aircraft to inspect for corrosion. There are also fewer areas of the aircraft susceptible to corrosion. We have recently performed the first heavy checks, the C4 checks, on the oldest aircraft. We found very limited corrosion, and also found that these C4 checks were actually like regular C checks."

Sifnaios explains that the few tasks that require deep access are certain inspections on the flightdeck, and the door frame inspections in the wing centre section because all items within 20 inches, including galleys, must be removed.

The 81 deep access C tasks mainly relate to internal fuselage, passenger door, wingbox, cargo doors, stabilisers and wing inspections. All have FC/DY tasks, with the initial intervals starting at 16,000FC/3,000DY and going up to 32,000FC/6,000DY.

The 36 Group 3 F tasks relate mainly to wing structures.

The 280 tasks in the zonal programme are all external and internal visual inspections, and 179 of the 254 tasks that are grouped into base checks require deep access. All relate to doors, the fuselage, landing gear wells, stabilisers and wings. A minority of these deep access tasks relates to external inspections of the stabilisers and wings. Most, however, concern a lot of interior fuselage inspections, and some inspections of the fuel tank, wing and internal stabiliser.

There are therefore 836 tasks that require relatively deep access, 495 of which are from the structural programme.

Base check programmes

The relatively low access required by system tasks means that most can be grouped into regular base checks. Planning base checks or optimising a base check programme must take into account the fact that tasks with a deep access requirement will make the checks in which they are included heavier.

Many airline base check programmes are broadly based on a base check interval of 18 or 24 months, equal to 550DY and 730DY. Heavier checks, with structural and deeper access tasks, have then been carried out every second or fourth base check. The heaviest check in the cycle is then the fourth or eighth base check.

Since the vast majority of the deep access tasks have interval criteria of FC or FC/DY, their actual intervals will determine how frequently heavier checks have to be performed. There are 268 deep access tasks with FC intervals, and 503 tasks with FC/DY intervals.

There are several large groups of tasks with FC/DY intervals. Because of the utilisation rates of long-haul aircraft, the DY interval will determine when the tasks come due. The FC/DY intervals with the largest groups of tasks are:

- 750DY (20 tasks),
- 1,125DY (188),
- 1,500DY (41),
- 2,250DY (119),
- 3,000-4,000DY (205),
- 4,500DY (104),
- 5,250DY (16) and
- 6,000DY (39).

These are equal to 2 years, 3.1 years, 4.1 years, 6.2 years, 8.2-10.9 years, and 12.3 years. Large numbers of DY tasks also have the same intervals, so these have been grouped into multiples of two years. The only exception is the total of 208 FC/DY and DY tasks at 1,125DY, equal to 3.1 years. These would have to be brought forward to two years, or 730 DY, to maintain a base check pattern of two-year multiples.

The largest group of FC/DY tasks is those with 8.2-10.9 year intervals, with 205 tasks. These would be consolidated into an eight-year interval, and combined with the 16 3,000-3,750DY tasks.

Egyptair has arranged its base check programme around a multiple of two-year checks. It has arranged its base check programme into phases of 500FH. Its base check interval is 7,500FH/750DY.

KLM follows a similar pattern. "We operate our fleet at about 5,500FH and 700FC per year, at an FH:FC ratio of

8.0:1. Our basic A check interval is 1,500FH, while the basic C check interval is 24 months/730DY. This is equal to about 11,000FH and 1,400FC," says Hoogendoorn. "Therefore, all tasks in the MPD with an interval of less than 1,500FH are arranged into line checks, while tasks with intervals between 1,500FH/two years or 11,000FH are grouped into A checks. Most tasks with intervals the equivalent of two years and higher are arranged into base checks, but there are some that can drop out into the line checks if they have easy access and can be performed relatively easily."

KLM's base check programme means that the fourth C check, the C4, is the heavy check. The interval for this check is 2,920DY, equal to about eight years, 44,000FH and 5,500FC. KLM's aircraft will therefore complete their second base check cycles at about 16 years, and their third base check cycles at 24 years. By this time the aircraft will have accumulated 132,000FH and 16,800FC.

"There are a lot of system tasks with an interval of 1,125DY, and similar, so these are brought forward into the C check," explains Hoogendoorn. "There are also a lot of tasks with an interval of 3,000DY, and these are performed every second C check."

Delta Air Lines started its maintenance programme with a C check every 12 months, and heavy check with structural tasks every second base check at a two-year interval. The heaviest check was the C8 check, at eight years. This was later re-optimised to a programme of a C check every 7,500FH/500DY, equal to 16-17 months. The checks increase in size as task thresholds are reached. The heaviest check is the sixth check, which comes due at about eight years. "We chose the 500DY as a base check multiple because of our average aircraft utilisation, and when task intervals are converted to an equivalent number of days, most are in multiples of 500DY," says Sifnaios.

This system means that Delta has had a heavy check interval of eight years under both its original and current base maintenance programmes. The second base check cycle will be completed at 16 years, and the third at 24 years.

As described, some of the Group 3 F tasks will come due for the first time at 10,000FC, and others at 13,500FC. This will be equal to about 18 and 24 years. These would therefore ideally be included in the second heavy check at about 16 years, even though this may mean bringing them forward and performing them a few years early.

"The problem is that Boeing will not release the details of how to perform the FLS early enough before they come due," says Sifnaios. "This will make it impossible for us to plan them into a heavy check, which will be due at 15-16 years. They will therefore have to be performed later in their own separate check at 18-19 years, a special check halfway between the second and third heavy check. This will be expensive, since most of these tasks require deep access."

Turkish Airlines (THY) operates a fleet of 12 777-300ERs, the first of which was delivered in 2010. Like other operators, THY has had to optimise the 777's maintenance programme. It has taken the 1,125DY interval of a large number of tasks as its C check interval. Most tasks have intervals at two, three, four, five, six, eight, 10 and 12 years. "We therefore see the C4 check at 12 years as the heavy interval," says Elvin Coskun, lead engineer Boeing aircraft at Turkish Technic. "We therefore have a system of A and B checks for tasks lower than three years.

"The base A check interval is 1,500FH, and the base B check interval is 730DY," continues Coskun. "There are 95 to more than 120 routine tasks in the A check packages. There are 90-100 routine tasks in the B check packages. This includes tasks with four- and five-year intervals. This is instead of bringing them forward into C checks at three years. We have only performed C1 checks so far, and these had 336 routine tasks."

Major ADs & SBs

The 777 has had relatively few major ADs and SBs issued against it. The SFAR 88 and EWIS programmes were

A large number of tasks come due at 1,125 days, equal to just over 3 years. These tasks include a large number of structural inspections. A large number of operators have arranged their base maintenance programmes into a basic C check interval of 500 days. Many structural inspections are therefore performed every second C check.

mandated by ADs, as was the SSID.

Part of SFAR 88 is for a nitrogen generating system (NGS) to be installed on the aircraft by 2017, and Boeing issued a service bulletin (SB) for this in spring 2013. Younger aircraft had the NGS installed on the production line.

"One fairly large SB was SB 777-27-A0071. This required a replacement of bushings on the flaps, and was included in the C4 check," says Hoogendoorn.

The biggest SB affecting the 777 is SB 777-53A0054, covered by AD 2013-07-11. This is a scribe line mark inspection that includes an airframe physical survey. An estimated 3,000-4,000MH can be used, since it involves chemical stripping, water cleaning and repainting. This is the largest SB to affect the 777.

Another large SB is SB 777-570050, which concerns installation of wire bundle sleeving, and fuel tank wiring fastener cap sealing. This is estimated to use 1,000MH.

Another big SB is the modification of the fuselage floor beam at body station 246. This is estimated to use about 1,000MH, and would clearly need to be made in a heavy check.

Several other large SBs relate to engine pylon and nacelle, wing and fuselage structures. About 25 major SBs use 100-1,000MH. As with all aircraft types, there are larger numbers of SBs that use smaller amounts of labour.

Base check inputs

There are several ways an operator can arrange its base check programme. This will influence the number of tasks and MH used in base checks, as well as the content of lower line and A checks. Because operators are free to group tasks into any particular check, two airlines that have the same basic C check interval will still have different contents in their C checks. This is because one operator may bring forward a certain group of tasks and perform them early in a C check, while the other may group them into an A check.

Here the contents, and labour, and materials and parts used for the base checks of two successive base check cycles are assessed. A programme where the basic C check interval is 15 months and the heaviest check is the sixth check, the C6 check, at 90 months is used, since this is one of the most common programmes followed. The second base check cycle is thus the C7 to C12 checks.

Using a generic aircraft that completes about 4,800FH and 530FC per day, the base check interval of 15 months is equal to 6,000FH and 660FC. The six checks of the cycle will be completed every 36,000FH and 4,000FC.

Several elements are included in the contents of base checks, starting with routine inspections. Defects and non-routine rectifications will arise from these. The sub-total of these two accounts for a large percentage of the total labour used in each check.

Routine inspections will combine: MPD inspections; the operator's own additional tasks, which usually relate to maintaining the aircraft's interior at a particular level; and preparing the aircraft for maintenance, such as putting docking into place. Several items will also be added to base checks.

The first will be cabin cleaning. While routine work will include some customer items for cleaning, an allowance should be made for cabin and interior cleaning.

The second element will be labour for changing rotables and heavy components, such as the APU, thrust reversers and the landing gear. A large number of MH is also used for an engine change.

A third major additional element is labour used for engineering orders (EOs), ADs and SBs. This can be relatively small for smaller C checks. The large or heavy base checks will always be used to complete large modifications and perform the biggest ADs and SBs.

Some interior refurbishment will always be performed in the cabin at each check, although the frequency of this varies with each operator.

Aircraft are stripped and repainted about once every five or six years, depending on the operator.

Routine inspections

Routine inspections are the base point of every check, and the amount of labour and materials used to complete the check.

As described, the 777 benefits from a modern design and the experience of previous generation aircraft. This has reduced the number of routine tasks, their frequency, and the number of MH used to perform them in several ways.

The MH used for the routine portion of a check will include aircraft preparation and docking. Compared to previous generation aircraft, the 777 uses few MH for routine inspections. This is partly explained by the aircraft's design, which allows easy access to make inspections easier. Moreover, the extent of some inspections has shrunk, with smaller areas of the aircraft needing to be inspected.

The C1 and C2 checks use 900-1,700MH for routine tasks, depending on the operator's maintenance programme. The C2 check will have a higher content, since this is the C check where tasks with a 1,125DY interval first come due.

The C3 check or C4 check will be intermediate checks in the cycle, and so can use 2,200-2,500MH.

The lighter of these two checks and the C5 check will be similar in size to the C1 and C2 checks.

The C6 check will come due at 90 months, by when the aircraft will have accumulated about 36,000FH and 4,000FC. Routine labour consumption for this check can be up to 3,300MH, although the actual content will depend

Many airline base maintenance programmes for the 777 see the heaviest base checks with the deepest tasks being performed about once every eight years. The oldest 777s will have now completed two base check cycles.

on an operator's maintenance programme.

Total routine labour for these six checks in the first cycle will be 10,000-11,000MH, depending on the exact maintenance programme and rate of aircraft utilisation. This is over up to 90 months, or seven and a half years.

This compares to about 22,500MH used for the routine inspections used for four checks of the first base check cycle for a 747-400. This included about 13,000MH for routine inspections in the D check *(see Assessing the 747-400's ageing maintenance requirements, Aircraft Commerce, August/September 2012, page 43)*. Not only does the 747-400 use at least 100% more labour for routine inspections, but this is for four base checks and over an interval of 60 months. On this basis, the 777 is using only about 30% of the labour MH used by the 747-400.

The 777's routine maintenance requirements will increase as it progresses through the second base check cycle. This is partly because the repeat intervals of some task groups are shorter than their initial intervals, and partly because more tasks come due for the first time during the second base check cycle, including 157 FC/DY tasks and 23 new DY tasks.

The six checks of the second base check will be completed between 36,000FH and 72,000FH, between 4,000FC and 8,000FC, and between 90 months and 180 months.

Broad estimates are that the routine MH for the second base check cycle will be 1,500-2,000MH higher for the six checks.

Defect ratio & non-routine

The defect ratio in the first base check cycle has been similar to some aircraft types, although overall the 777 still consumes relatively few MH for the main routine and non-routine portions of base check maintenance. Operators may include the MH used to clear outstanding defects as non-routine labour.

There is less occurrence of the defects that are typically seen with older generation aircraft. These are issues with aircraft structure that result in cracks, corrosion, delamination, and wear or moisture damage with flight controls.

The non-routine ratio for the C1 and C2 checks has been 60-80%, resulting in the use of 850-1,400MH. A conservative budget may be for the non-routine ratio to increase to an average of 100% over the remaining four checks in the cycle.

The overall effect would be for a total of 9,500-10,500MH of non-routine labour for the six checks in the cycle. Some operators, however, have experienced lower non-routine ratios of about 70% in the first base check cycle.

The non-routine ratio for defects will be higher during the second base check cycle. Conservative estimates are that apart from the C7 check, the first check in the cycle, the non-routine or defect ratio will be up to about 125%. Some operators, however, are budgeting for a rate of about 100%.

On the basis of a consumption of about 11,000MH for routine inspections, the labour used for defects and non-routine rectifications will be up to 13,500MH. This includes about 4,500MH for the C12 check, the second heavy check.

Routine & non-routine

The total labour used for routine inspections and non-routine defects and rectifications is therefore 20,000-21,000MH for the six checks of the first base check cycle *(see table, page 40)*. This rises to about 25,000MH for the second base check cycle.

This is small compared to the 747-400 in its first and second base check cycles. The total for four checks was about 40,000MH for the first cycle, and 47,000MH for the second.

In addition to an increased number of FC/DY and DY tasks coming due in the second base check cycle, there are more tasks that come due for the first time after the second base check cycle.

A small group of tasks comes due for the first time at 16,000FC. These will therefore not come due until the end of the fourth base check cycle.

There are also the Group 3 'F' tasks from the structural programme. Their intervals are FLS, so they are likely to come due at 10,000-13,500FC.

There are also 37 FC/DY tasks that will come due for the first time during the third base check cycle.

Moreover, many tasks that came due for the first time during the second base check cycle have shorter repeat intervals. They therefore come due again during the third base check cycle.

Several other elements of a base check can increase the labour required by more than 50%.

Interior cleaning

Interior cleaning is a relatively minor issue, but nevertheless an allowance or MH should be made. The first five smaller checks in the cycle could use about 600MH for an aircraft the size of the 777. The C6 check will use about twice this, since more deep inspections are made, and more interior items are removed.

Interior refurbishment

Some interior refurbishment and cleaning are combined, since refurbishing cabin items also provides the opportunity for deeper cleaning.

Interior refurbishment includes several elements that have to be

SUMMARY OF MH & MATERIAL INPUTS FOR TWO BASE CHECK CYCLES OF PASSENGER-CONFIGURED 777-200/-300

Check	Interval -months	Total Routine MH	Defect ratio	Non-routine MH	Sub-total routine, non-routine & other MH	Interior clean MH	Interior refurb MH	EOs, SBs, ADs MH	Engine & heavy comp change MH	Strip/ paint MH	Total MH	Total materials cost- $
C1	15	1,200	70%	840	2,040	600	500	500			3,640	69,520
C2	30	1,700	80%	1,360	3,060	600	2,200	500			6,360	177,480
C3	45	1,500	100%	1,500	3,000	600	500	800			4,900	175,200
C4	60	2,400	100%	2,400	4,800	800	2,200	500		4,500	12,800	350,400
C5	75	800	100%	800	1,600	600	500	500			3,200	61,600
C6	90	3,000	100%	3,000	4,800	1,200	6,000	3,000	2,000		17,000	587,000
Total for cycle		**10,600**		**9,900**	**19,300**	**4,400**	**11,900**	**5,800**	**2,000**	**4,500**	**49,100**	**1,422,000**
C7	105	1,200	80%	960	2,160	600	500	500			3,760	94,240
C8	120	2,400	125%	3,000	5,400	600	2,200	500		4,500	13,200	439,800
C9	135	1,500	125%	1,875	3,375	600	500	800			5,275	213,600
C10	150	1,700	125%	2,125	3,825	800	2,200	500			7,325	235,800
C11	165	800	125%	1,000	1,800	600	500	500			3,400	85,600
C12	180	3,500	125%	4,400	7,900	1,200	6,000	3,000	2,000	4,500	24,600	910,400
Total for cycle		**11,100**		**13,360**	**24,460**	**4,400**	**11,900**	**5,800**	**2,000**	**9,000**	**57,560**	**1,980,000**

performed at differing frequencies.

The first of these is the replacement of cabin carpets. Aisle carpets should be replaced about once every C check, while those in the seating areas should be replaced about once every four to five years.

Seat covers should be cleaned once every C check, which will require their removal, and then be replaced once every three to four years, or every second C check. About 350MH will be used for this.

Replacement of seat cushions will take place about once every five years, or every third C check, and will use about 800MH. Maintenance on seat frames will have a similar frequency, and will use 1,000MH.

Refurbishment of larger items is more likely to occur during heavier checks. It may be planned to coincide with inspections that require the removal of large items. It will therefore include the removal, refurbishment and reinstallation of panels, bins, passenger service units, galleys, toilets, and flooring material in servicing areas. The labour used for these larger items can be up to about 6,000MH *(see The costs of large widebody interior refurbishment, Aircraft Commerce, October/November 2011, page 28).*

The labour used for interior repairs and refurbishment can therefore be about 500MH per check for three lighter C checks in the base check cycle, and about 2,000MH per check for two checks in the cycle that include seat cushion replacement and seat frame maintenance. The refurbishment of larger cabin items will use about 6,000MH in the C6 check *(see table, this page)*. This quantity of labour may be used in the C4 check, at an interval of about five years. This total compares to about 10,000MH used for the refurbishment of large interior items on a 747-400 in a D check.

The total labour used for all interior repairs and refurbishment items in the six checks of the base check cycle is therefore 11,500-12,000MH; similar to the labour used for routine inspections.

Even more labour will be used if the operator goes through a complete interior re-design, or a programme to change seat and galley configuration, and install a new in-flight entertainment (IFE) system.

ADs, SBs & EOs

The major ADs and SBs affecting the 777 have been described. These have been relatively few and small in terms of labour and resources required compared to several other older generation types. Again, the 777 has benefited from the experience of older types, and its own design. The 777 has not yet suffered from major ADs, such as the pylon modifications that affected the 747, and required several thousand MH to complete.

The light C checks in the base check cycle will be used to perform smaller ADs and SBs, as well as smaller EOs. A budget should be provided, and some airlines have used about 500MH. The heavier checks are usually kept for the largest ADs and SBs, provided that intervals permit this. Some operators have used 2,000-3,000MH for ADs and SBs in this check.

The total labour used in the base check cycle for ADs, SBs and EOs is therefore 5,500-6,000MH *(see table, this page)*. At this stage in the 777's years of operation there have been no big ADs issued. While it is impossible to forecast what may happen in the future, the low level of structural problems and low defect and non-routine ratio indicates that few major ADs and SBs are likely to be issued. A similar budget of MH for the second base check cycle can therefore be used.

Heavy component changes

An allowance has to be made for the labour used for changing heavy components, such as landing gears and thrust reversers; engines; and larger rotables. An engine change can use 25-35MH. The largest item will by the complete change of all three landing gear legs. This will take up to seven days, and is estimated to use a total of 1,200MH. The interval for gear change is up to 10 years, and so less than once per base check cycle.

An average of 2,000MH for all component changes for all six checks in the cycle can be used as an approximate guide.

Strip & repaint

Stripping and repainting an aircraft the size of the 777 uses about 4,500MH, although this can approach 6,000MH for the 777-300, as is the case with the 747.

With stripping and repainting done every five to six years, and so every fourth C check, it will be performed three times in the first two base check cycles, at the C4, C8 and C12 checks. The second base check cycle will therefore have two strip and repaint events *(see table, this page)*.

The cost of the paint material will be about $60,000.

Total labour inputs

The total labour inputs for these elements are 3,200-6,500MH per check for the four light C checks, during the first base check cycle. About two-thirds

The 777 uses only about 40% of the labour per FH for base maintenance over the interval of a full base check cycle that the 747-400 consumes. The 777 has benefitted from a design that allows easier access to deeper inspections.

of this input comes from routine inspections and non-routine rectifications that arise as a result.

The intermediate check in the first base check cycle will consume up to 13,000MH, while the C6 check will use 17,000MH. This will take the total labour consumption for the six checks in the cycle to about 49,000MH *(see table, page 40)*. This is a conservative total, and could be lower for some operators. This is because some airlines will experience lower non-routine ratios, and use less labour for interior refurbishment.

The second base check cycle can be expected to have a higher labour requirement, mainly due to a higher non-routine ratio and also because the aircraft is stripped and repainted one more time than in the first base check cycle. The total labour consumption is estimated to be 58,000MH, about 10,000MH more than in the first base cycle *(see table, page 40)*.

Another small increase can be expected for the third base check cycle. This is due to more routine tasks coming due, increasing the workscopes of base checks, and a further increase in non-routine ratio.

The 777, however, has so far had no problems with any ageing programmes that have been experienced by older types, so no labour has to be budgeted for this on the 777. In contrast, the 747-400 has used an increasing amount of labour for ageing programmes over recent years in its later base check cycles. These include issues such as the repair assessment programme (RAP), further SSI tasks, and the widespread fatigue damage (WFD) programme. "There is little reason to believe that the 777 could have additional maintenance requirements and tasks added through ageing aircraft programmes at this stage," says Hoogendoorn.

The total labour used for these first two base cycles contrasts with that used for the 747-400. Taking all elements of the base checks into consideration, the 747-400 used about 73,000MH and 93,500MH in the first and second cycles. These were over intervals of about 60 months per cycle. When adjusted for the difference in interval, the 777 is using about 45% of the MH that the 747-400 used in its first two base check cycles. The 777's overall consumption of labour for all base maintenance items is equal to about 1.3MH per FH.

Materials & parts

The cost of materials and parts has to be considered as several elements. The first is the consumption of materials, parts and consumables for all the labour used in the check. This is because all elements, including interior refurbishment, painting, as well as the main routine and non-routine portions all use materials, consumables and expendables. This budget also has to include the replacement of life-limited components and parts, such as oxygen bottles.

A broad budget is $18 per MH and $24 per MH for the first and second base check cycles. This results in costs per check from $65,000 for the lightest C1 check to $600,000 for the heavy C12 check. The cost per base check is therefore $900,000 for the first base cycle, and $1.4 million for the second.

Further costs of materials are incurred for additional elements of stripping and painting, interior refurbishment, and special parts for the larger ADs.

As described, the cost of paint will be $65,000. The cost of items used in interior refurbishment are: $13,000 for carpet; $50,000 for seat covers; $80,000 for seat cushions; and $3,000 for cleaning seat covers and materials and parts used in seat frame maintenance. The cost of parts and materials in the refurbishment of large items totals $110,000. This can be exceeded if several large items are replaced through a cabin re-design policy.

Overall, the cost of materials and parts for interior refurbishment ranges from just $4,000 for two C checks up to $260,000 for the C6/12 check.

The cost of materials for these additional items will be $540,000 for the first base cycle, and close to $600,000 for the second. This will take total cost of materials and parts to about $1.42 million and $1.98 million for the first and second base cycles *(see table, page 40)*. These materials and parts costs would be higher, however, if the operator were to perform interior refurbishment more frequently. An example would be every fourth C check, at the same time the aircraft is repainted.

Summary

Despite having a complex maintenance programme, the 777 has clearly gained from the experience of older generation aircraft and modern design technology. Labour and material cost inputs are considerable lower than the 747-400. With a labour cost of $60 per MH, total cost of labour and materials amortised over the maximum possible interval of 36,000FH equals a reserve for base check inputs of $121 per FH for the first base check cycle, and $152 per FH for the second base check cycle. These are similar to reserves made for narrowbody aircraft.

In contrast, the 747-400 consumed about 95,000MH and $2.6 million in materials and parts in its second base check cycle. Amortised over the maximum possible 24,000FH interval of the four checks, this is equal to a reserve of $344 per FH.

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