The A380 & 747-8 need to achieve equal or lower airframe maintenance costs than the 747-400. The A380's & 747-8's design, maintenance programmes, and their ability to reduce their line and base maintenance requirements and burden are examined.

The A380's & 747-8's design & maintenance requirements

The ultra-large A380 and 747-8 have entered service to fill a unique role, and must provide a reduction in cash operating costs over the 747-400. The two main bastions for the A380 and 747-8 to overcome are fuel burn performance and total aircraft maintenance costs, both in their early years of operation and at maturity. Their designs have used several techniques to reduce maintenance requirements so that maintenance costs per seat-mile should ultimately be lower than the 747-400's. This article examines how the design characteristics of the A380's and 747-8's maintenance programmes reduce maintenance costs.

Maintenance reduction

An overall reduction in aircraft maintenance costs can be achieved by targeting all elements of maintenance: line and light maintenance; base and heavy airframe maintenance; engine shop visits and management; rotable component repairs and management; and heavy component repairs and overhaul.

Maintenance requirements are affected therefore by the frequency of each maintenance element, and the labour, material or component inputs of each maintenance event. These requirements increase with aircraft age, partly because maintenance events must be performed more frequently, and partly because a higher incidence of defects and 'non-routine' maintenance has to be performed as the aircraft ages. This leads to a rise in cash operating costs, and the aircraft ultimately becoming uneconomic to operate, but can be partially offset by the steady escalation of check intervals during the aircraft's operational life.

Two approaches to lowering aircraft maintenance costs are therefore both to reduce the aircraft's maintenance requirements, and the rate at which the aircraft's maintenance requirements increase as it ages.

Reducing the aircraft's maintenance requirements can be achieved by having fewer tasks, longer intervals between tasks, and simpler, more maintenance-friendly designs that allow tasks to be completed with less labour and fewer parts and materials. A reduction in the rate of increase in maintenance is achieved by: a higher rate of fatigue testing to limit the increase in structural maintenance tasks; the use of more reliable system components; and the use of modern composite and carbon fibre materials to reduce the incidence of corrosion, cracking and fatigue.

A380 MPD

The A380 has an average seat count of 485; 120 more than the average configuration of 747-400s. The A380's high capacity alone provides it with the ability to achieve economies of scale, and so a reduction in unit costs per available seat-mile (ASM).

Despite this, Airbus has used several techniques to reduce the A380's maintenance requirements over previous generation types such as the A330 and A340 programmes. As with all recent Airbus programmes, development of the A380's maintenance planning document (MPD) means that letter checks are no longer specified, and instead individual tasks have interval parameters and criteria. "This system has already been adopted in more recent revisions of the A320's MPD *(see A320 family 1st and 2nd airframe check cost analysis, Aircraft Commerce, April/May 2011, page 28)* and other Airbus types," says Geert Lemaire, maintenance marketing director at Airbus. "This gives airlines more maintenance planning flexibility. The traditional A check packages can now be split into small groups of tasks that form into smaller checks. These reduce the downtime taken by what were previously A checks, and so increase aircraft availability and utilisation."

Base checks have an interval of two years. "The A380 is the first aircraft to have a heavy structural check interval of 12 years from the date it entered service, although there are still lighter structural tasks at an intermediate interval of six years," explains Lemaire. "The aircraft is undergoing extensive fatigue testing, and should not have a supplemental structural inspection document (SSID) group of structural tasks."

Despite the elimination of letter checks with specified groups of tasks, the A380's MPD has groups of tasks with the same interval. Some operators are still likely to refer to these as A, C or structural check tasks. Task intervals are specified in flight hours (FH), flight cycles (FC) and calendar time. Each task, and group of tasks with the same interval, must be considered in relation to the aircraft's utilisation. Most airlines are likely to achieve 4,500-4,750FH per year; equal to 375-395FH per month. Aircraft are likely to be operated on average mission lengths of 8.0-10.0FH, and so complete 450-560FC each year.

"The A320's MPD has been conceived around an annual utilisation of up to 6,000FH," says Lemaire. "Base check tasks have intervals that are multiples of 24 months, 12,000FH, or a combination of the two. The 12,000FH interval is long enough for the 24-month interval to be fully utilised by all operators. That is, 6,000FH in 12 months is equal to 16FH per day, which is unlikely to be reached by any operator.

A380 MAINTENANCE PROGRAMME TASK GROUPS

Task group	Task interval	MPD tasks	LHT recommended tasks	Total tasks
48-hour check		6	8	14
8-day check		4	13	17
1A	750FH	10	24	34
2A	1,500FH	15	3	18
3A	2,250FH	0	17	17
4A	3,000FH	8	2	10
12-month	12 months	16	4	20
1C	24 months	168	19	187
2C	48 months	76	1	76
72-month	72 months	308	14	322
144-month	144 months	189	3	192
Additional tasks		545	26	571
Total		**1,344**	**134**	**1,478**

Singapore Airlines has the highest rate of utilisation at 14.5FH per day. This leaves almost 10 hours per day available for line maintenance. If the 24-month interval was aligned with an interval of 9,000FH or 10,000FH, then most aircraft could not fully utilise the 24-month interval. Many types have base check tasks with a 24-month interval, but the accompanying FH interval is short, so the airline has to give the check an 18-month interval."

A380 line maintenance

The A380's on-board maintenance system (OMS) diagnoses, and deals with, faults and technical defects in less time than on earlier generation aircraft.

The A380 has an on-board maintenance terminal (OMT) and two on-board information terminals (OIT); one for each pilot position. "The mechanics primarily use the OMT to access the A380's maintenance function, but can also use the OITs. The three units allow mechanics to work simultaneously," says Sami Smaoui, Airbus long-range fleet general manager at Air France Industries. "The OITs are mainly dedicated to electronic flight bags (EFBs), while the OMT is a full computer terminal with an integrated keyboard.

"The OITs and OMT are used to access different manuals, maintenance fault messages, post-flight reports, maintenance documents, the aircraft condition monitoring system, and the electronic technical log (ETL)," continues Smaoui. "We do not currently use the ETL because of problems in communication with the ground station."

After a flight, mechanics access the OMS via the OITs or OMT. They use hyperlinks between ECAM warnings/messages and associated fault codes to get to the relevant pages of the troubleshooting manual (TSM), so as to immediately and automatically get the correct analysis for the fault. Other hyperlinks are provided by the system to the relevant pages of the aircraft maintenance manual (AMM). These have all the maintenance task details.

"Airbus has introduced new failure classes on the A380. Class 1 is the most severe, and can result in a grounding. Class 6 is the least severe, and so can be deferred. These are filed so that the mechanics can review them later," explains Armin Bayer, project manager maintenance programs A350/A380 at Lufthansa Technik.

Mechanics access technical information relating to a fault and maintenance code, and find the source of the problem via hyperlinks that take them automatically to the relevant pages of the TSM, and later the AMM. This eliminates the need to manually search through pages of these manuals.

The system can automatically launch a system test from the flightdeck after manual selection, and report if the test has been passed or failed. During the system test, the OMS interfaces with the electronic circuit breaker, so that circuit breakers do not have to be manually pulled and tagged prior to a test, and then re-engaged after a test from an OMS interface. This 'automation' is a factor in saving time and labour diagnosing and clearing defects and faults. The aircraft then confirms full functionality after maintenance intervention has finished.

When all items have been closed, the OMS then automatically indicates whether the aircraft may be dispatched.

All these features of the A380's OMS allow faster diagnosis and treatment of technical defects and faults during line maintenance. The large number of line maintenance events over a period of a year or base maintenance cycle means the saving of a small amount of labour for each event still leads to a large saving in an aircraft's overall maintenance burden.

A380 A checks

Several groups of tasks have intervals similar to the traditional A checks. There are also groups of tasks with intervals that are multiples of the basic 'A' check interval. "Tasks that could be described as 1A tasks have an interval of 750FH," says Lemaire. "There are actually three different groups of tasks with similar intervals, especially when a typical rate of utilisation is considered. These are 750FH/1.5 months and 750FH/6.0 months, whichever limit is reached first. There are 20 tasks in these three groups."

An aircraft operating at 375-395FH per month can thus achieve 565-595FH in 45 days. The tasks with intervals of 750FH/1.5 months, and 750FH/6.0 months can thus be performed at an interval of every two months. The tasks at 1.5 months would have to be performed at this interval, however. Some airlines may prefer to fully utilise the interval of each task group, and form individual checks from a relatively small number of tasks. Others may prefer to perform block checks to simplify maintenance planning, but then sacrifice the interval utilisation of some tasks. In this case, all three groups would be performed together at a 45-day interval. These '1A' tasks' would then be performed at every 'A' check.

"The second group of tasks, which could be referred to as the '2A' tasks, is actually three different groups of tasks with different intervals," says Lemaire. "These are 1,500FH/3.0 months and 1,500FH/48 months, whichever limit is reached first. These three groups could conveniently be treated as one group, and carried out at a three-month interval, twice the 45-day interval of the 1A group. The 2A tasks would be performed every second 'A' check by an airline that preferred a block format.

"A third group of tasks can be subdivided into four interval groups," continues Lemaire. "These are six months, 3,000FH, 400FC or 3,000FH, whichever limit is reached first, and 24 months or 3,000FH, whichever limit is reached first. These could all be treated as '4A' tasks, and carried out once every six months and every fourth A check.

"A fourth group of tasks comprises three groups with similar intervals of: 12 months; 6,000FH; and 24 months or 6,000FH, whichever limit is reached first. There are 15 of these tasks," says

Unlike all other Airbus aircraft, the A380 has entered service with a base check programme of six checks in its cycle. It is also the first aircraft to have a heavy structural check at a 12-year interval, although it does also have a light structural check at a six-year interval.

Lemaire. An airline that keeps a block system of arranging A checks could treat this as an 8A group of tasks, and perform it every eighth A check, which would be about once a year." This group could be referred to as the 8A tasks, since their interval is eight times the 1A interval.

If an operator plans A checks in a block format, the pattern of A checks is likely to be an A check carried out once every 45 days, and so eight checks per year. The task groups in each check can be summarised *(see table, page 46)*. The fourth and eighth checks, the A4 and A8 checks, are the largest since they have the largest number of tasks. This only applies to one method of arranging block checks. The freedom for operators to group and plan tasks into checks according to their operating schedules and rates of aircraft utilisation means task groups will not necessarily be grouped in this way, and groupings will vary by airline.

Some airlines have an equalised line maintenance programme. "Although there are large numbers of A check tasks at intervals of 750FH, 1,500FH, 3,000FH and 6,000FH, there are many other tasks with intervals that are not multiples of 750FH, referred to as out-of-phase (OOP) tasks. There are tasks with an interval of 1,000FH, for example, and lots of other tasks with odd intervals," says Smaoui. "These would have to be brought forward if a block check system were used for A checks, so the interval would not be fully utilised. Air France Industries KLM Engineering & Maintenance (AFI KLM E&M) therefore uses an equalised programme for A check tasks, so that all A check tasks can be carried out in the time that the aircraft is already going to be grounded between flights when line maintenance is carried out. It is also a more convenient way to plan OOP tasks and utilise more of their intervals. This system of planning checks means no additional downtime is needed for A checks, which require a longer downtime. Major airframe base checks are then only performed every two years.

"Another important issue is our own tasks that we have added to the maintenance programme so as to perform regular cabin maintenance," continues Smaoui. "These cabin tasks are not MPD tasks, but have to be performed regularly so that we can maintain a good cabin standard. We fit the planning of MPD tasks around our own cabin tasks, so the timing of these cabin tasks actually drives the organisation of maintenance. We like to perform cabin tasks once every six weeks, equal to 500FH. Combining the MPD tasks and cabin tasks means equalising A check type tasks."

Lufthansa Technik's analysis of the A380's MPD shows there are 10 tasks with intervals that relate to line checks. There are 10 1A tasks, 15 2A tasks, eight 4A tasks, and 16 12-month tasks. This totals 10 line check and 49 A check tasks; a total of 59 tasks. "We also have 21 of our own line check tasks, and another 50 of our own A check tasks," says Bayer. "These 71 additional tasks are mainly related to cabin items relating to maintaining certain standards."

Line & A check experience

Qantas organises tasks into block checks. "Our experience with the A330 indicates that the level of findings and non-routine defect ratio with the A380 will not be significantly lower because of its design," says Michael Killeen, A380 fleet manager at Qantas Engineering.

The man-hours (MH) Qantas uses for routine line checks are: 31 for the 7-day check; 34 for a 45-day check; 16 for the 90-day check; 25 for the six-monthly line check; and 60 for the annual line check. "We also need to have a programme to maintain the passenger cabin, since the MPD does not cover the cabin items," says Killeen. "For this we have a cabin focus review (CFR), and this is performed once every eight weeks. Routine labour requirements for each deck are 60MH."

Qantas follows a block check programme for the A checks, similar to that described. "Our system has a cycle of eight A checks, so a pattern of A1 to A8 check," continues Killeen. "The basic interval is 750FH, so the A8 check has an interval of 6,000FH. The routine labour we use for these checks is 236MH for the A1, and increases to 250MH for the A3/A5, and slightly higher at 270MH for the A7. The slightly heavier A checks, with additional tasks groups are the A2, A4 and A6 checks. These all use 315-340MH for routine tasks. The heaviest package is the A8 check, which uses 360MH for the routine inspections."

Consideration then has to be given for non-routine defects. The labour for this could be calculated using a non-routine ratio of 50%, which would add 130-180MH to the A check. Another element would be labour for Qantas's own tasks, cabin items and some modifications. Total labour for the checks could exceed 400MH for the lightest A1 workpackage, and be more than 600MH for the A8 check.

A380 base checks

As described, the A380's MPD has been conceived with a base check interval of 24 months. "Although letter checks are not used, most tasks with higher intervals have an interval that is a multiple of 24 months," says Lemaire. "Most tasks allow a cycle of six base checks to be followed if an operator desires. This would have a light structural check at six years, and heavy structural check with a 12-year interval." This is on the basis that aircraft operate at about 6,000FH per year, and at 10FH per FC.

The old base check cycle system for Airbus aircraft was a cycle of eight checks, with the fourth and eighth checks being structural inspections for light and heavy tasks. There were thus three light checks, a structural check, another three

In addition to MPD tasks, Lufthansa has had to add a large number of its own tasks to the maintenance programme. Many of these tasks relate to interior items and maintaining an acceptable standard in the cabin, since there are no cabin items in the MPD.

light checks, and then the heavy structural check. The interval for the last heavy check has been 10-12 years for many Airbus types, and the interval between each base check has been 15 or 18 months. The A320's MPD has recently been revised to a base check cycle of six checks. The base check interval has been increased to 24 months, while the light and heavy structural check intervals have been changed to six and 12 years. The base check cycle can thus be completed in six checks, rather than eight, which eliminates the downtime of two checks.

The A380's base maintenance programme will follow the same basis. "The first advantage is only six checks in the cycle over a period of 12 years. This compares to eight checks over a period of 10 years in the case of many Airbus types," says Lemaire. "This also means the A380 is the first aircraft to have a heavy structural check at an interval of 12 years at its service entry date. The base check cycle, if using the traditional 'C' check nomenclature, would be C1, C2, C3, C4, C5 and C6 checks. The C3 and C6 checks would include the light and heavy structural tasks."

Although large groups of tasks have 24-month intervals, each task still has its own interval, and airlines are flexible in their base maintenance planning. An alternative is for tasks to be grouped into small, equalised packages. This only makes sense if they do not involve heavy inspections or a lot of access and downtime to perform. Tasks that are for deep structural inspections, and require deep access or a long downtime would still be better grouped together in a heavy base check. System-related tasks could be equalised into smaller checks, but structural tasks should be kept in the larger block structural inspections at six- and 12-year intervals.

Lemaire explains there are four main task groups. The first of these can generically be referred to as the 1C tasks, and totals about 150 tasks. These can be sub-divided into seven different 1C task groups according to their intervals: 24 months; 12,000FH; 24 months or 12,000FH, whichever is reached first; 72 months or 12,000FH, whichever is reached first; 1,500FC or 12,000FH, whichever is reached first; 2,200FC or 12,000FH, whichever is reached first; and 24 months or 15,000FH, whichever is reached first. These can all broadly be included as one group that has the dual interval of 12,000FH and 24 months. These would be included in every six of the base checks in the base check cycle.

The second main group of tasks can be regarded as the 2C tasks, and totals 70 MPD inspections. Lemaire explains his group is sub-divided into seven groups that have intervals of: 48 months; 24,000FH; 24,000FH or 4,400FC, whichever is reached first; 24,000FH or 72 months, whichever is reached first; 24,000FH or 3,200FC, whichever is reached first; 4,400FC or 48 months, whichever is reached first; and 24,000FH or 48 months, whichever is reached first. These would be performed every second base check, at the C2, C4 and C6 checks.

The third and fourth groups of tasks can be referred to as the 72-month and 144-month tasks. These are the light and heavy structural inspections. There are 298 and 1912 tasks in these two groups.

The light structures tasks mainly relate to corrosion in specific areas. "These include galleys and toilets, the cargo floor and the floor structure," says Lemaire. "The A380 has a lot of composites, such as carbon fibre reinforced plastic (CFRP), which limits corrosion. The primary structure includes: the wings, especially the spars and ribs; the keel beam; the centre wingbox; the fuselage panels and frames; the vertical and horizontal tail; and the bulkheads, which are made from CFRP. Because of this the 6-year, light structures check is smaller than the 747's D check, which has the same interval," claims Lemaire.

The C3 check, the light structural check, will have the 1C and 3C tasks, totalling 453 MPD base check tasks.

The heavy structures check at 12 years will be a repeat of the 6-year tasks plus the fatigue inspections that have a 12-year interval. "The fatigue inspections are heavy structural inspections," says Lemaire. "These are in the same areas of the aircraft as the corrosion inspections, but are specifically for visually inspecting for fatigue. That is, checking for cracks."

The C6 check will thus include the 1C, 2C, 3C and 6C tasks, a total of 709 MPD base check tasks.

"Several features in the A380's design mean its MPD has fewer tasks than the A340," says Smaoui. "While it is difficult to compare the A380 with the A340, because the A340 has had 20 years of service and so the number of tasks in its MPD have increased over this period, the A380 has fewer tasks than the A340 had when it was a young aircraft. The MSG-3 principles allowed some, mainly operational, tasks in the A340's MPD not to be included in the A380's MPD. This elimination was possible because systems problems and defects now cause ECAM messages on the flightdeck, so the defects can be detected and then fixed during line maintenance. It was therefore agreed these tasks were not required. The design of the aircraft's structure meant that some of the structural inspections are able to have intervals of 12 or even 24 years," says Smaoui. "This is because of the materials used. A 24-year interval means some tasks will not even come due for the first time until the second heavy check."

As described, the A380 does not have an SSID. "The fatigue testing on the entire A380 means an SSID is not needed for certification. The required fatigue-related tasks are included in the MPD from service entry," explains Lemaire. "The old way of dealing with fatigue was to add tasks as the aircraft type gained operational experience. The SSID is often several hundred tasks."

The A380 is currently undergoing fatigue testing, so tasks could be added to the MPD. "Normally Airbus has to add structural inspections if it cannot add structural modifications that cancel the need for regular inspections," says Smaoui. "The other issue is that SSID tasks are often FC-driven, and do not have intervals that match the regular base check intervals. There are 200-300 fatigue tasks for the A380 that will be added to the maintenance programme over the next three years. Examples of these intervals are 8,000FC and 60,000FH. There are many others with much higher intervals."

Instead of an SSID programme of tasks, Bayer explains that the A380 will have airworthiness limitation item (ALI) tasks. "The current intervals for these tasks come from calculations. The intervals will be updated once the fatigue testing has been completed," says Bayer. "The ALI tasks are included in the 72-month group, 144-month group, and a group of additional tasks that have a lot of different intervals; many of which are structural tasks."

Data from Lufthansa Technik show that in addition to 10 line maintenance tasks, 49 A check tasks, 168 1C tasks, 75 2C tasks, 308 72-month tasks, and 189 144-month tasks, there are 545 OOP or additional tasks. "Many of these tasks are cost-intensive structural inspections that are likely to be added to the 72-month check," says Bayer. "Other additional tasks have FH and FC intervals, so the aircraft utilisation determines the checks into which these tasks will be included. Some of these additional tasks have high initial thresholds, and shorter repeat intervals. An example is 50,000FH and 20,000FH. The aircraft's MPD maintenance task requirements therefore start to rise after it reaches 10 years of age. At least half the 545 additional tasks are structural tasks or those with high initial thresholds."

Lufthansa Technik data show a total of 740 base check tasks with multiples of the regular 24-month interval, and another 545 additional tasks with varying intervals. In addition to MPD tasks, it has 37 base check tasks of its own, and a further 26 with varying intervals.

Lufthansa Technik's data show the A380 has 1,344 MPD tasks, sub-divided into 59 line and A check tasks, 740 base check tasks, and 545 additional tasks. Lufthansa's own recommended tasks add another 134 to the aircraft's maintenance programme. This is divided between 71 line and A check tasks, 37 base check tasks, and 26 additional tasks.

Base check experience

AFI KLM E&M will keep the MPD base check intervals. "Our oldest aircraft is 30 months, and we have already completed the first C1 checks," says Smaoui. "Our maintenance programme is only valid up to an age of three years. We have therefore not yet included the 72- and 144-month tasks in our maintenance programme. We will have to plan these into block checks because of the deep access and long downtime they require."

Qantas, which is also one of the first A380 operators, uses a block check system for base maintenance. It completed its first C1 check in late 2010. Its first C2 check is due in October 2012.

"Our first C1 checks on the A380s involved 400 tasks," says Killeen. "The MPD tasks only needed 470MH. The whole workscope included an element of routine inspections, which in turn include aircraft preparation and testing, access and the routine inspections; non-routine rectifications; cabin items and cleaning; modifications; and other items. The entire workscope consumed a total of about 9,800MH. Clearly there is an escalation factor for routine inspections because of access and aircraft preparation.

"The C1 check needed 3,300MH for the routine inspections, which had an MPD labour requirement of 470MH," says Killeen. "In our experience a multiplication factor of seven should be used to get from MPD MH to actual MH for the routine inspections.

"The non-routine ratio in this check is about 50%, so 3,300MH were required

747-8 & 747-400 MAINTENANCE PROGRAMME TASK GROUPS

Task group	Task interval	MPD tasks	LHT recommended tasks	Total tasks
747-8 maintenance task groups				
Daily	24 hours	9	2	11
1A	1,000FH	65	24	89
2A	2,000FH	5	3	8
3A	3,000FH	1	32	33
4A	4,000FH	4	1	5
5A	5,000FH	3		3
6A	6,000FH	1	7	8
1C	10,000FH/24 months	220	39	259
2C	20,000FH/48 months	110	8	118
3C	30,000FH/72 months	26		26
1D	8 years/ 8 years/ 6 years	184	37	221
2D	16 years	9		9
Additional tasks		235	43	278
Total		**872**	**196**	**1,068**
747-400 maintenance task groups				
Daily	24 hours	9	5	14
1A	1,000FH	67	30	97
2A	2,000FH	2	3	5
3A	3,000FH	23	40	63
6A	6,000FH	8	8	16
1C	24 months	199	103	302
2C	48 months	129	18	147
1D	8 years/ 8 years/ 6 years	181	84	265
2D	16 years		1	1
SSID		119		119
Additional tasks		365	77	442
Total		**1,102**	**369**	**1,471**

for non-routine rectifications," continues Killeen. "We have found we need to use 1,500-2,000MH on the 747-400ER for cabin items in a C check, so 3,500MH can be required for the A380 because of its full-length and wider upper deck.

"Modifications added a large requirement to the C1 check," continues Killeen. "The A380 has required a large number of airworthiness directives (ADs) and service bulletins (SBs), and a lot of 'fixes' were built into the early C checks. The A380 has had seven ADs and 13 SBs to fix flap track fairings that were too light. A lot of brackets holding the flap track fairings were too light and prone to breaking. SBs were also issued to fix side stay bushes on the landing gear, and required a large input. The estimated labour for all the modifications in the C1 check was 600MH, and we used a multiplication factor of two to get a planned figure of 1,200MH. The total of the four main elements was 9,650MH, which turned out to be 3-5% accurate. We will use the same multiplication factors for the C2 checks."

Killeen expects the A380 to have a typical rate of increase in MH inputs for its airframe checks as it ages, compared to current generation aircraft. "The A380's maintenance requirements should rise at about the same rate as the 747's, because routine inspections and requirements are increasing, and the non-routine ratio is rising at a fairly typical rate," says Killeen.

"We expect the C2 check to require 15,000-20,000MH," continues Killeen. "Another 82 MPD tasks fall within the 48-72 month period, and must all be included in the C2 check. The C4 check, which will include the light structural tasks, is expected to use 30,000-35,000MH. Although the C8 check, which has the heavy structural inspections, is not due for another nine years, it is forecast to have a labour requirement of 50,000-55,000MH."

747-8

The 747-8 has been conceived with the aim of having the same maintenance cost per trip as the 747-400. "Since the 747-8 will be configured with 50-60 more seats than the -400, the 747-8 will have a 10% lower cost per seat if the target of an equal trip cost is achieved," says Khwaja Ali, director of maintenance economics at Boeing. "The issue was how to achieve an equal maintenance cost per trip while maintaining maximum system commonality with the 747-400. In fact we believe we have achieved a 3% lower airframe maintenance cost per trip on the 747-8 compared to the -400. This means the 747-8 should actually have a 12% lower cost per seat."

Boeing has employed a two-pronged approach to achieve this. "First we improved check intervals through escalations following experience with the 747-400," says Ali. "The 747-400's D check interval, for example, is six years. The 747-8 has an eight-year interval for the first two D checks, which is reduced to six years for the third and subsequent D checks. We have also managed to increase C and A check intervals.

"Other changes come through the aircraft's design," continues Ali. "The wing is brand new, and uses simpler flaps. These are single- and double-slotted in different sections along the wing. The use of single- and double-slotted flaps on the 747-8, instead of the triple-slotted flaps on the 747-400, means they have a simpler moving mechanism, which uses fewer cables and moving parts, has fewer lubrication points and tasks, and is likely to have fewer defects. The spoilers on the upper wing surface are controlled by a fly-by-wire system. This eliminates inspections of hydraulic cables, and also means that defects will automatically be reported on the flightdeck. This allows inspection tasks to be removed from the MPD."

Other systems tasks have been eliminated because system failures and defects are reported electronically on the flightdeck. "Such reporting allows 'hidden' failures to be detected, and so eliminates the need for regular inspections," says Ali. "Defects and failures reported on the flightdeck are referred to as 'evident' failures. This type of condition-monitoring philosophy allows regular inspection tasks to be removed from the MPD."

Boeing has also reduced the number

Lufthansa lists 1,344 tasks in the A380's MPD, and has another 134 of its own tasks in its maintenance programme taking the total to 1,478. The 747-8' current MPD has 872 tasks, although there will be AWL tasks to add. Lufthansa has another 196 of its own tasks in its maintenance programme.

of structures tasks, and an escalation in their intervals. "This has been possible because of a better treatment for corrosion. This, and the analysis of findings from 747-400 airframe checks, have contributed to a longer D check interval for the 747-8," says Ali. "Overall, 80% of the 747-400's D check tasks were escalated to eight years, and the remainder were reduced down to the third C checks so that an eight-year D check interval is possible. The tasks that were moved down to the third C check must have low access requirements. Only tasks with deeper access requirements have been kept in the escalated D check.

"The maintenance programme was conceived to minimise the aircraft's downtime for maintenance by having longer check intervals, and fewer tasks in each workpackage," says Ali. "This has increased aircraft availability by four-and-a-half days, equal to an additional 50-60FH per year utilisation."

Another element of maintenance on the 747-8 is that there are two models: the -8F and the -8I. "There is a lot of commonality between the two models, but there are some differences in maintenance practices and requirements," says Mike Abendt, 747-8 maintenance program engineer at Boeing. "These are with the cargo loading system on the 747-8F, and the in-flight entertainment (IFE) and interior equipment on the -8I model. There are maintenance-related differences between the large freight door on the -8F, and the 10 main passenger doors on the -8I, and structural differences in the floor that mean the -8F requires a stronger floor."

747-8 MPD

As with the 787, the 747-8's MPD has been conceived so that traditional letter checks are no longer used, and tasks are treated individually with their own intervals to provide airlines with more flexible maintenance planning. Interval criteria are specified in FH, FC and calendar time.

Large numbers of tasks still have similar or the same intervals. Tasks can still generically be referred to as 'A', 'C' and 'D' check tasks. "The A check interval is 1,000FH, and there are several groups of tasks with multiples of this. There are also several tasks with OOP intervals that do not coincide with the regular A checks. Examples are 1,200FH and 750FH. Some of these can be planned into more frequent line checks, or brought forward to more frequent intervals," says Abendt. "The C check interval is a combination of 10,000FH and 24 months, whichever is reached first. This allows an aircraft utilisation of up to 5,000FH per year without compromising the calendar interval. Like A checks, there are OOP or drop-out base check tasks with intervals that do not coincide with the regular C checks. Examples are 15,000FH, 36 months, and 18 months.

"The D check interval is eight years for the first and second D checks, and six years for the third and subsequent checks. Leading up to the first two D checks, there are three C checks prior to the D check, and a fourth C check that coincides with the D check," adds Abendt.

Several groups of tasks have multiples of these basic intervals. Lufthansa Technik data show there are 65 tasks that could be classed as '1A', and have an interval of 1,000FH *(see table, page 52)*. There are also five '2A' tasks with an interval of 2,000FH, a single '3A' task with an interval of 3,000FH, four '4A' tasks with an interval of 4,000FH, three '5A' tasks with an interval of 5,000FH, and a single '6A' task with an interval of 6,000FH. If arranged in a block check format, not all these task groups would actually get in phase until the 60th check. The size of the check workpackages would thus vary. Most tasks are 1A items, however, and heavier A checks would only have another 10-12 tasks.

There are three groups of C check tasks. There are 220 MPD inspections that could be referred to as '1C' tasks *(see table, page 52)*. Another 110 MPD tasks can be referred to as '2C' tasks, since they have an interval of 20,000FH and 48 months. There are 26 inspections that could be referred to as '3C' tasks, since they have an interval of 30,000FH and 72 months.

If arranged in a block check format, the C2 check would have 330 tasks, while the C3 check would have 246.

There are two groups of D check tasks. The '1D' tasks have an initial interval of eight years, followed by a repeat interval of eight years, and a repeat interval thereafter of six years. There are 184 inspections in this group of tasks.

The second group of D check tasks is small, with only nine inspections, and has an interval of 16 years.

The C check tasks that have to be included in the first two D checks will be the 1C and 2C items, which total 330 inspections. The first D check will have an additional 184 1D tasks, taking the total number of MPD inspections to 514. The second D check will have 193 1D and 2D tasks, plus the 1C and 2C tasks, taking the total number of MPD base check tasks to 523.

In all, there are 549 C and D MPD check tasks for the 747-8. This compares to 509 for the 747-400.

The 747-400, however, has 119 SSID tasks and a further 365 'drop-out' or OOP tasks. Both of these groups of inspections have intervals that do not coincide with multiples of the A, C and D check intervals.

The 747-8 has 235 additional or

Boeing's aim with the 747-8 is to have similar labour and material inputs as the 747-400, but achieve lower maintenance costs per seat through the 747-8's higher seat count. The 747-8 has fewer tasks in its MPD and longer check intervals. It is not year clear how labour and material inputs for base checks will compare with the 747-400.

OOP tasks. "The 747-8 does not have any SSID tasks, but the fatigue testing on the aircraft is not complete yet," says Rainer Winter, project manager maintenance programs 747/MD-11 at Lufthansa Technik. "This places an operational limit on the 747-8 for the next three years, so the aircraft's operating certificate is only valid for three years. This means Boeing has to complete the fatigue testing in this time limit.

"From the fatigue testing, there will be damage tolerance requirements (DTR) derived for each structural significant item (SSI)," continues Winter. "Boeing has to present all DTRs to the Federal Aviation Administration (FAA). From this a new airworthiness limitation (AWL) document will be provided, which will include an additional set of structural tasks to replace the SSID. We expect the 747-8 to have a similar number of tasks to the number the 747-400 has in its SSID; which was 119 tasks. These were only for the wings, however. They had an initial inspection threshold of 115,000FH or 20,000FC, whichever was reached first. There are also 112 tasks for the fuselage, 40 for the empennage and two for each engine pylon. These 154 tasks all have a threshold of 20,000FC.

"The AWLs for the 747-8 will all be FC-related tasks, and have FH and FC intervals," continues Winter. "The 199 tasks for structures in the wings will have dual intervals of 115,000FH and 20,000FC, whichever is reached first. When they come due depends on the average FH:FC ratio achieved during operation. The remaining AWL tasks will be defined in the future, and so it is not possible to say what their intervals will be, or how many tasks there will be."

In addition to MPD tasks, Lufthansa has its own tasks: 196 for the 747-8, compared to 369 of its own additional tasks for the 747-400. "Most of the tasks that we have added relate to the aircraft's cabin and its interior," says Winter. "These cover cleaning, IFE and other cabin item functions, some system functional checks, and carpet and seat cover cleaning. Our own recommended tasks use 20-30% of the total labour cost. They are high frequency tasks, and so in proportion to MPD tasks use more MH. The main reasons why we are able to have about 170 fewer of our own tasks on the 747-8 compared to the 747-400 is because of the 747-8's different wing, engines, flight controls and new systems. The aircraft is expected to have better reliability, and some cabin tasks have been combined, so we have been able to add in fewer of our own tasks."

Overall, Lufthansa Technik's data show a total of 872 MPD tasks for the 747-8, and 1,102 for the 747-400 *(see table, page 52)*. The 747-8, however, will have AWL tasks added once fatigue testing has been completed.

The 747-8 has nine daily check tasks, 79 A check tasks, 549 C and D check tasks, and 235 additional tasks. Lufthansa's own recommended tasks will be two for line maintenance, 67 for A checks, 84 for C and D checks, and 43 additional tasks; a total of 278 *(see table, page 52)*. The overall total for the 747-8 under Lufthansa's maintenance programme is 1,068, although more will be added when the AWL tasks are issued.

These numbers compare to the 747-400's MPD nine daily check tasks, 100 A check tasks, 509 C and D check tasks, 119 SSID tasks, and 365 additional tasks. Lufthansa's own recommended tasks are five for daily checks, 81 for A checks, 206 for C and D checks, and 77 additional tasks; a total of 441 *(see table, page 52)*. The 747-400 has an overall total of 1,471 tasks under Lufthansa's programme.

"The 747's four-engine configuration means it will have more system-related tasks than two-engined types. Some structural tasks are affected by the number of engines," says Abendt. "The main difference in MPD tasks between the 747-400 and -8 is in the number of A and base check tasks. Some of the 747-8's design features aid a reduction in number of tasks. The 747-400, for example, had a oil filter change task. The 747-8's GEnx engines have sufficient engine health monitoring (EHM) capability to send a message to the flightdeck when a filter actually needs changing. This capability eliminated the need to make it a scheduled task. A lot of other system tasks have not been eliminated on the 747-8, but their intervals have been extended relative to the 747-400's MPD."

747-8 line maintenance

The 747-8 does not have an advanced OMS like that on the A380. The 747-8 has the same central maintenance computer (CMC) as the 747-400, but the 747-8's CMC is enhanced. "The CMC receives and displays fault messages, and these are diagnosed and interpreted in almost the same way as they are on the 747-400," says Abendt. "The CMC now has a library of 15,000 messages and a memory of 1,000 faults. The GEnx engines on the aircraft provide a lot more information and data for interpretation. This allows better analysis for the timing of engine removals.

"We now have a maintenance laptop that can be used together with the CMC," continues Abendt. "It carries all the different maintenance manuals. Its main function is to use the fault isolation manual (FIM) to analyse and diagnose EICAS messages. Once these have been diagnosed, the mechanic has all the other manuals on the laptop in an electronic format." This is different to the 787's OMT, which has hyperlinks between fault codes and messages, and the relevant pages in all the manuals. AC