Boeing said the 737NG would offer 15% lower maintenance costs over its predecessor, and designed the aircraft with a flexible maintenance programme. The first aircraft are soon due their first heavy checks and indications are that the aircraft has lived up to its promise.

737NG delivers promise of maintenance efficiency

The 737 series has won 5,372 orders to date, making it the world's most successful jetliner; it continues to sell. The 737 New Generation (NG) was launched in late 1993, selling 2,240 in 10 years, making the 737NG the most successful of 737 families. Despite the loss of many 737 customers to the A320 family, the 737NG continues to sell in large numbers.

Boeing's main objective with the 737NG was to offer an aircraft that would provide comparable aircraft sizes and seat-mile operating costs to the A320 family. These would be achieved through faster speed, lower fuel burn and lower maintenance costs than the preceding 737-300/-400/-500 family. The first 737NGs were delivered in 1996 and are due their first structural C checks in 2004/2005. The overall maintenance costs of these aircraft will indicate whether the 737NG has achieved its objectives.

737NG in operation

There are four 737NG variants of increasing size, starting with the -600 and followed by the -700, -800 and -900. The 737-600 competes closest with the A318, the -700 with the A319, the -800 with the A320 and the -900 with the A321.

The -700 has sold 930 units, and the -800 series 1,095 units; the two having taken the lion's share of orders for the 737NG. Only a further 28 orders for the -800 are required to make it the most successful of all 737 variants, although there have already been 11 sales for the 737-800BBJ business jet version. The -600 and -900 have had limited success with only 72 and 57 orders each.

The 737NG's largest customers include four major US carriers: Southwest (266); Continental (187); American (124); and Delta (132). Alaska Airlines, AirTran and Westjet are other big North American operators. The largest 737NG sales in Europe have been made to easyJet (32), Ryanair (153), Air Berlin (26), SAS (57) and Turkish Airlines (26). The 737NG has also sold in large numbers to Chinese airlines and major operating lessors, such as GECAS, ILFC and CIT.

The 737NG's 2,500-3,200nm range capability means that it is operated in a wider variety of roles than the earlier -300/-400/-500 family. Besides the traditional market of short-haul operations with flight cycles (FCs) in the region of 1.0-1.5 flight hours (FHs), the 737NG is operated on FCs ranging 1.0-2.5FHs. Airlines such as American and Delta operate the 737-800 on both short-haul and medium-haul domestic US sectors, and airlines in China use the 737NG for similar purposes on trans-China routes. KLM in Europe, for example, operates its 737-800s/-900s from Amsterdam to destinations in Europe and the Middle East. The 737NG is also operated by several European charter carriers for average flight times that exceed 2.0FH.

As a consequence, annual rates of utilisation are high in most operators' cases, being in the region of 2,750-3,000FH. This would be equal to 1,830-2,000FCs each year for an average FC time of 1.5FH.

Maintenance programme

The 737NG was designed with flexibility to allow operators to optimise their maintenance programme, check contents and check intervals with their operation, utilisation and average flight cycle time.

Boeing has not grouped task cards into pre-defined checks in the maintenance planning document (MPD), but instead allows airlines themselves to group tasks into their own formulated checks.

Each task card has its own initial inspection and repeat intervals. These intervals are specified either in FHs, FCs, or calendar time or a combination of two or all three of these. In the case of two or three interval criteria, the task is performed at whichever interval is reached first. The rate of aircraft utilisation will determine when an inspection becomes due.

Task cards might be grouped into checks so that items with similar intervals are performed in the same check, or when it is convenient to perform them together. Airlines can therefore take into account aircraft downtime, depth of maintenance and access, manpower requirement, availability of materials or tooling, airline schedule, their own in-house capability and several other factors, when organising the 737NG's maintenance to best suit them. For example, two tasks may have different intervals, which if performed separately would require two different checks for completion. If these were combined, the interval of one task would not be fully utilised, but its combination with the other task may reduce repeated access and shorten downtime. This would, however, raise the peak in labour requirements. Another carrier may find it more convenient to have a larger number of smaller checks.

Most operators have arranged all minor and major check tasks to coincide with phases of utilisation. A phase is a given interval and each task is performed at this interval or an exact multiple of this interval. The highest phase is for items with the highest initial interval, and marks the end of the maintenance cycle.

EXAMPLES OF 737NG MAINTENANCE PROGRAMMES

Operator/maintenance facility	ATC Lasham	Sabena Technics	easyJet/ FLS Aerospace	KLM Engineering & Maintenance
Basic Phase & A1 check Interval (FH/FC/months)	500/350/2.0	500FH/1.5 months	500FH	500FH
No of Phases in maintenance cycle	48	80	80	48
Highest A check	A12	A9	A24	A24
Highest A check interval	12 phases 6,000FH/24 months	9 phases 4,500FH/13.5 months	24 phases 12,000FH/1.5 months	24 phases 12,000FH/48 months
C1 check interval	8 phases 4,000FH/16 months	10 phases 5,000FH/15 months	10 phases 5,000FH/18 months	12 phases 6,000FH/24 months
Highest C check	C6	C8	C8	C4
Highest C check interval	48 phases 24,000FH/96 months	80 phases 40,000FH/120 months	80 phases 40,000FH/144 months	48 phases 24,000FH/96 months

The phase interval may, for example, be 60 days, 500FH and 350FC. Different maintenance programmes will have different phase intervals, which will be optimised by each operator in relation to aircraft utilisation and average flight cycle time.

The intervals of all tasks are arranged so that they coincide with every phase and none fall in between phases. The group of items that come due at each phase are grouped as a check or several checks.

There are two sub-groups of tasks: minor check items, often referred to as 'A' check tasks; and major check items, often referred to as 'C' check tasks by most airlines.

Minor check tasks have intervals equal to the phase interval or a multiple of up to six of the phase interval.

Major check tasks have an initial interval and repeat interval of at least six to eight phases and items with the longest initial intervals will be up to 45 or 48 phases. These items will be grouped by most operators to form a heavy check. Their completion at the last phase will complete the heavy maintenance cycle, which is then repeated.

Tasks that have intervals less than a phase interval are grouped into line maintenance checks, such as pre-flight, daily or weekly checks.

Maintenance programmes

"We manage aircraft with a schedule based on a phase interval of 60 days, 500FH and 350FC," says John Hilton, planning superintendent at ATC Lasham, United Kingdom. This phase interval is good for an aircraft operating about 3,000FH per year and at an average cycle time of 1.5FH per FC. "This phase interval is the interval for the 1A check items and the highest A check multiple is the sixth (6A) performed at 3,000FH, equal to 12 months. We have arranged tasks into five A check multiples: the 1A, 2A, 3A, 4A and 6A items. This means the A check cycle starts with the A1 check, which has the 1A tasks, and is followed by the A2 check, which includes the 1A and 2A tasks. The cycle is completed at the A12 check, since this is the phase when all A check multiples coincide. This is equal to an interval of 6,000FH, 4,200FC and 720 days; almost two years."

As an example of the programme for major check tasks, C check tasks have a basic interval of eight phases, equal to 4,000FH, 2,800FC and 16 months. There are 1C, 2C, 3C, 4C and 6C check multiples with corresponding initial phase and FH intervals *(see table, this page)*. The C6 check therefore has an initial interval at the 48th phase, which is 24,000FH, 16,800FC and 96 months (eight years). This is equal to four cycles of A12 checks. The major check cycle is then completed at the 48th phase.

Most C check tasks are then repeated at the same intervals during subsequent C check cycles, while others have an initial interval of the 48th phase, and then repeat intervals of 16, 24, 32 and 48 phases. Those with repeat intervals of 16, 24 and 48 phases will all become due again at the end of the second cycle and second heavy check (at 96 phases), while those with a repeat interval of 32 phases will not become due at the second heavy check, but be performed 16 phases (24 months) earlier at the 80th phase.

Another example of maintenance programme organisation is given by Sabena Technics. "We operate a maintenance schedule with 80 phases in the maintenance cycle," says Guy Schepers, director of engineering at Sabena Technics. "Each phase has an interval of 500FH and 45 days for the aircraft we manage for a charter airline. These aircraft accumulate about 4,000FH and 1,800FC per year, and so have an average cycle time of 2.2FH. They therefore reach their 500FH limit in about 45 days, but only accumulate about 225FC in that period. The 500FH interval is reached in about 45 days. Any A check task expressed in FC will be fitted into the relevant A check multiple or phase by means of conversion. For example, if something has an interval of 500FC, it will be equal to 1,100FH so should be included in every second phase, with the 2A items.

"We then have a basic 1C interval of 5,000FH, equal to 10 phases, which is about every 15 months. We have eight C check multiples, the highest being the C8 check at the 80th phase or 120 months (10 years)," explains Schepers. "This means that the 1C, 2C, 4C and 8C items all come due at the C8 check, making it the heaviest. The 3C, 5C, 6C and 7C items do not come due at the C8 check. This also means the group of tasks in

Each 737NG operator has its own maintenance programme, and KLM has simplified its C check system to a cycle of four checks, each with an interval of 6,000FH and 24 months, with a heavy check every eight years.

each C check package is different throughout the life of the aircraft. Alternatively, to simplify maintenance planning, the operator may decide to zero the maintenance programme at the C8 check or 80th phase to keep the contents of the C check packages in each cycle almost identical. This means the 3C, 5C, 6C and 7C items would have to be performed again at the C8 check after they have already been performed in earlier checks. Alternatively, they could be given new intervals of 2C and 4C so as to simplify maintenance planning by coinciding with C2, C4, C6 and C8 checks. This is a compromise between planning efficiency and long-term maintenance costs."

A similar programme is that used to manage easyJet's 737-700 fleet. "There are natural groups of tasks in the 737NG's maintenance programme, and there are 80 phases in the programme with A checks every 500FH; the basic phase interval. Because there are multiple A check items all A checks are different," says Dave Waller, group manager of business development at FLS Aerospace. "The basic C check interval is 10 phases, and so there is a system of C1-8 checks, with the C8 being performed at the 80th phase. The phase 10 interval is 5,000FH, about 17-18 months, and so the C8 check will come due about every 12 years."

KLM's maintenance programme is optimised for the operation. Its aircraft accumulate 2,900-3,000FH per annum.

"We have arranged our maintenance schedule into two independent A and C check cycles," explains Ton de Geest, project engineer maintenance programmes at KLM Engineering & Maintenance. "Our basic 1A task interval is 500FH, and any items with intervals less than this are performed during line maintenance. All tasks with intervals of 500-5,000FH are performed in A checks, while those with intervals longer than 5,000FH are grouped in C checks.

"The A check cycle is completed at 24 phases, or after 24 A checks. There are multiples of 1A check tasks, that is 2A, 4A and other items, but we have equalised our A checks. We have also escalated our 1A task interval to 550FH, and so have also escalated 2A tasks to 1,100FH and other tasks accordingly," continues de Geest.

KLM's 1C check interval was 5,000FH and 18 months, whichever arose first. The aircraft accumulate about 4,350FH over 18 months, meaning they are unable to completely utilise the 5,000FH interval.

KLM has therefore had its calendar limit escalated to 24 months, during which it will accumulate about 5,800FH. It therefore reaches the 5,000FH interval after about 21 months. It also had its FH interval raised from 5,000 to 6,000, which just about coincides with 24 months, considering its rate of utilisation.

"There are just four phases in the C check cycle and our highest C check is the C4, which is equivalent to eight years for a 24 month C check interval. There are 1C, 2C, 3C and 4C tasks," explains de Geest. "The 24 month gap between C checks is convenient, since we can always schedule C checks during the less busy winter months. There is also a separate group of zonal tasks in the MPD which have had their interval escalated to 24 months, which allowed the C check escalation from 18 months. Our first aircraft has reached the C3 check. The 3C items first come due at the C3 check and then again at the C6 check. We are trying to escalate these items to the 4C interval, and if we cannot we will de-escalate them to the 2C interval to simplify the maintenance programme."

Several North American operators have similar maintenance programmes to those used for the easyJet or KLM fleets. "Typically programmes are C checks about every 18 months and a heavy maintenance visit (HMV) every 8-10 years," explains Steve Salvione, director of sale administration at Goodrich Aviation Technical Services. "Some customised programmes equalise the HMV items into the C checks. Some airlines are seeking to extend the C check interval to 24 months. A C check cycle of eight checks is operated with the C8 at about 12 years, although the actual achieved C check interval may be nearer to 14 months. So the HMV is actually being performed at about nine years. If the C check interval is extended to 24 months the HMV will then come due about once every 14 years. This may require HMV tasks to be phased into earlier C checks in the C check cycle."

Line maintenance

Besides the different ways operators organise A and C checks, there are also different ways to organise line checks. There are pre-flight and daily check tasks for all aircraft, which constitute pre-flight

The 737NG is operated by several US carriers, and many of these have a maintenance programme of a C check every 18 months, and a full C check cycle of eight checks, with the heavy check being performed about every 10 years.

and daily checks. Other line checks are devised by different airlines.

"In addition to pre-flight and daily checks, we also have service checks performed every four days, weekly checks and line checks in between A checks, that is every 250FH," says Julien Bulambo, central planning engineer at Sabena Technics.

Other carriers have more simplified schedules. One example is just pre-flight and daily checks preceding A checks. Pre-flight checks can be performed by flight crews at outstations and may only consume up to 1.0MH and $15 in materials and consumables. Daily checks, often done at night, may use about 8MH and $45 in materials and consumables.

A checks vary in size in most airlines, but one operator with an A check cycle being terminated at the A24 check reports an average of 135MH and $3,500 in materials and consumables per A check across the A check cycle.

In this case, a total of about 16,000MH and $230,000 in materials and consumables are consumed in all line checks in the A check cycle up to the A24 check. This is equal to a labour consumption of about 1.4MH, which charged at $70 per MH equals $98 per FH. Cost of materials and consumables is $22 per FH for all line checks. The total for all light and line checks is thus $120 per FH.

C & heavy checks

C check tasks consist of mainly system and structural items. The MH used are a combination of routine MH required for the tasks, the non-routine MH that arise out of the inspections, and several other items. These will include deferred defects, airworthiness directives (ADs), service bulletins (SBs) and modifications, general cabin cleaning and maintenance, interior refurbishment and stripping and painting.

The routine MH in each check will naturally depend on the operator's maintenance programme, but are generally been low compared to the 737-300/-400/-500 series and A320 family.

Sabena Technics, for example, which has a programme of C1 to C8 checks, estimates: 770MH for routine inspections in the C1 check; 960MH for the C2; 850MH for the C3; 1,150MH for the C4; 770MH for the C5; 1,200MH for the C6; 800 for the C7; and 2,220 for the C8. "This compares to 8,000-10,000MH for routine tasks in the heavy C check on the 737-300/-400," explains Johan Nys, customer support engineer base maintenance at Sabena Technics. "The non-routine ratio is also low for the 737NG, especially when it is still young. It starts at about 0.35 at the C1 check and rises by about 0.1 every C check, so reaches about 1.1 at the C8 check. The total of routine and non-routine for the C8 check is therefore about 4,550MH. The total for the lighter C checks is 1,000-2,220MH, depending on the C check.

"Lighter C checks require another 200MH for interior cleaning, and another 500MH for SBs and modifications. This takes the total MH for these lighter C checks to 1,740-3,000MH," says Nys. "The C8 check requires 800MH for interior refurbishment, another 1,000MH for SBs and modifications, and 1,200MH for stripping and painting. This will take the total MH use to about 7,600 for the C8 check."

These MH consumptions will therefore take total MH consumption for the C1 to C8 cycle to about 24,000MH. This is over an interval of 80 phases or 40,000FH. Actual interval achieved by most operators is about 90% of check interval, so the C8 interval may be in the region of 36,000FH; thus MH consumption will therefore be equal to 0.6MH per FH.

Another illustration of MHs used in the C check cycle is for aircraft operated with a C check cycle of C1 to C6 checks performed every eight phases and 4,000FH. MH for routine inspections are similar in magnitude to those experienced by Sabena Technics. C1 checks, for example, only consume about 744MH for routine inspections, and C2 to C5 checks have similar requirements, with a peak of about 1,100MH for the C3 check. The heaviest check, the C6, may use about 5,300MH for routine tasks. The defect ratio for this maintenance programme is slightly higher, starting at about 0.5 for the C1 but will still be about 1.0 for the C6 check. This will take the sub-total for routine and non-routine inspections to about 1,150-2,100MH for the C1 to C5 checks, and up to about 10,500MH for the C6 check. Interior cleaning will consume 200-400MH for the C1 to C5 checks, while interior refurbishment during the C6 check will use about 1,500MH.

The incorporation of SBs and modifications in C1 to C5 checks will use between 450MH and 800MH, while the C6 check may consume as much as 4,500MH. Stripping and painting at the heavy check will use about 1,200MH.

This will take total MH for the C1 to C5 checks to between 1,700MH for the C1 check and 3,100MH for the C3 check. The C6 check will consume in the region of 17,500MH. Total MH used for the C checks over the first C check cycle will be about 29,000MH. This will be over an interval of 24,000FH, although the actual interval used will be about 22,000FH. MH consumption will thus be in the region of 1.3MH per FH.

Material consumption in each check partially depends on the actual tasks in each check, but is also related to the MH consumed and the routine to non-routine ratio. Aircraft operated with a C1-C6 C check maintenance programme will consume about $30,000 of materials and consumables in the C1 check, but this will rise to about $75,000 in the C2 and increase up to $125,000 in the C3 check. The smaller C4 check will use about $85,000 and the C5 $70,000. The C6 heavy check, which includes interior refurbishment will use about $450,000 in materials and consumables. The total material expenditure for the C check cycle will therefore be in the region of $835,000.

This is equal to a rate of $39 of materials and consumables per FH of the C check cycle, and in the region of $30/MH used.

Aircraft operated by US carriers, whose maintenance programme includes a C check interval of 18 months and C check cycle terminating at the C8 check at an interval of 36,000FH, have demonstrated a similar rate of MH consumption.

"Total MH use for routine inspections, non-routine defects, interior cleaning and incorporation of modifications will be in the region of 1,100MH for the C1 check," says Salvione. "The non-routine ratio for new aircraft has been 0.2-0.3 at the C1 check. The MH used at the C2 check will rise to about 1,500MH, and reach 1,800-2,200 for the C3 and C4 checks. The non-routine ratio has climbed to about 0.6 for aircraft that have reached this check.

"The C5, C6 and C7 checks will use 2,400-3,000MH, and are expected to have non-routine ratios of 0.6-0.7MH. The heavy C8 check will be 22,000-23,000 for routine inspections, non-routine tasks and defects, interior refurbishment and modifications. Non-routine ratio may rise to about 0.8 to 0.9 by this check, which compares to 0.9-1.1 for the 737 Classic. About another 1,000MH will be required for stripping and painting, taking the total for this check to about 23,000MH," continues Salvione.

The C1-C8 check cycle will be about 38,000MH over an interval of 36,000FH. This is equal to an MH consumption rate of 1.05MH per FH.

Aircraft operated on this type of maintenance programme can be expected to use about $25,000 for the C1 check, rising to $75,000-85,000 for the C2 and C3 checks, and increasing to a mid-cycle peak of $125,000 for the C4 check, and also for the C6 check. The C5 and C7 checks will use about $70,000 each, while the C8 heavy check can be expected to use $450,000-500,000. The aircraft is expected to use in the region of $1 million of materials and consumables in the first C check cycle. Over the 36,000FH interval, this is equal to $33 per FH and $26 per MH used.

A320, 737NG & 757-200 HEAVY COMPONENT REPAIR COSTS

Aircraft type	737NG
FH:FC	1.5
Number main wheels	4
Main tyre retread interval-FC	200
Nose tyre retread interval-FC	135
Retread $/main tyre	300
Retread $/nose tyre	160
Number of retreads	4-5
New main tyre-$	1,000
New nose tyre-$	230
$/FC retread & replace	**11**
Main wheel inspection interval-FC	200
Nose wheel inspection interval-FC	135
Main wheel inspection-$	600
Main wheel overhaul-$	1,000
$/FC-Wheel repair	**21**
Number brakes	4
Brake repair interval-FC	800-1,300
Brake repair cost-$	13,000
$/FC-brake repair	**36-64**
Landing gear interval-years	9-10
Landing gear interval-FC	17,000-18,000
Exchange fee & repair cost-$	160,000
$/FC-landing gear repair	**10**
Thrust reverser repair interval-FC	12,000
Repair & exchange fee-$/unit	150,000
$/FC-thrust reverser repair	**25**
APU hours repair interval	6,000-8,000
FC APU repair interval	6,000-8,000
Shop visit cost-$	150,000-200,000
$/FC-APU shop visit	**22-30**
Total-$/FC	**125-161**
Total-$/FH	**86-110**

Heavy components

Besides airframe checks and line replaceable units (LRUs) which are maintained on an on-condition basis, heavy components form the remainder of the 737NG's maintenance items. This group includes wheels, tyres, brakes, landing gear, thrust reversers and the auxiliary power unit (APU). These are maintained on an on-condition basis, although they have 'soft' maintenance intervals (an approximate or average interval that allows minimum maintenance costs per FH).

Wheels are removed when tyre treads have worn down. The actual interval at which treads become worn depends on the severity of landing and braking, which in turn are affected by the weight of the aircraft at landing and treatment

737NG FAMILY FLIGHT HOUR AIRFRAME AND COMPONENT MAINTENANCE COSTS

Maintenance item	
FH/Year	3,000
FC/Year	2,000
FH:FC	1.5:1.0
Line & light maintenance	
MH/FH	1.4
MH $/FH @ $70/MH	98
Materials: $/FH	22
C & Heavy checks	
MH/FH	0.8-1.3
MH $/FH @ $50/MH	40-65
Materials: $/FH	40
Total line & C checks-$/FH	**200-225**
Heavy components-$/FH	**86-110**
LRUs & rotables-$/FH	
Rotable home base stock capital cost	25
Pooling fee	40
Maintenance, repair & management	110
Total for LRUs & rotables	**175**
TOTAL AIRFRAME & COMPONENTS-$/FH	**461-510**

by pilots. Tyres on smaller variants will have longer removal intervals than on larger variants, and in turn payload being carried will affect landing weight. "Typical intervals between removals for tyre remoulding are about 200FC for main wheels and 135FC for nose wheels," says Jean-Pierre Gielen, director of component services at Sabena Technics. "Intervals will be less for the -800/-900 compared to the -600/-700. Cost of remoulding tyres is about $300 for main wheels and $160 for nose wheels. Nose wheel tyres can be remoulded a maximum of 10 times, and main wheels up to six times. The actual number of remoulds is about half this, since tyres have to be scrapped if there is damage to the carcass under the tread to avoid shredding which would cause large-scale damage to the aircraft. New main wheel tyres cost about $1,000 and new nose wheel tyres about $230."

Main wheel tyres that have been remoulded four times and replaced at the fifth removal will therefore cost a total of about $2,200 for remoulding and replacing. This will be over an interval of about 1,000FC. Cost for all four main tyres will be equal to $9 per FC.

Nose wheel tyres remoulded five times and replaced at the sixth removal, after about 900FC, will have a total cost of about $1,000. This will be equal to $2,000 for both tyres and $2 per FC.

Total tyre remoulding and replacement cost will be about $11 per FC, equal to $8 per FH for aircraft operating an average cycle time of 1.5FH *(see table, this page)*.

Gielen explains that wheel rims are inspected when wheels are removed due to tyre wear. "An inspection is done at every removal until the sixth when a full overhaul is performed. This involves a complete strip, dimension check, valve check and bearing inspection."

Wheel inspections cost about $600, and overhauls about $1,000. The cost for each wheel is therefore $4,000 over an interval of about 1,200FC for main wheels and 800FC for nose wheels. This is equal to an overall cost of about $21/FC for all wheels, or about $14/FH *(see table, this page)*.

Brakes are checked during line checks, but wheels will be removed when brake discs are worn close to minimum allowable thickness. (The 737NG's brakes are steel). Again, removal is on an on-condition basis and intervals will be longer for smaller 737NG variants and those with gentler handling during landing, and carrying lighter payloads. "Intervals for brake removal will be 800-1,500FC, depending on landing weight and aircraft variant," explains Gielen. "An average repair cost is about $13,000." This takes cost per FC for each unit to $9-16, equal to $6-11 per FH for aircraft operating an average flight cycle time of 1.5FH *(see table, this page)*.

The landing gear interval on the 737NG is 18,000FC or 120 months, whichever is reached first. Aircraft operating on a typical pattern of 3,000FH and 2,000FC per year will reach the interval after about nine years. Charter airlines or those operating fewer annual cycles will utilise the full 10-year interval. At the other extreme, aircraft operating high -cycle operations of eight to 10 flights per day will reach this interval in just five to six years.

Landing gear repair in most cases will be paid for in three elements of exchange fees, fixed repair fee and additional costs. A typical market rate for all three of these is about $160,000.

An aircraft therefore achieving a utilisation of 3,000FH and 2,000FC per year will have an interval of about 25,500FH/17,000C between landing gear removals, which will be equal to a cost of $7/FH *(see table, this page)*.

Thrust reverser maintenance is an on-condition item. Intervals vary, but some airlines have established soft times in the region of 12,000-18,000FC. The actual interval would depend on the FH:FC ratio, aircraft variant, operating environment and weight of the aircraft, but intervals are longer than for older generation aircraft.

Repair costs vary widely from $50,000 to $180,000 per shipset, although the cost escalates quite fast once the unit starts to deteriorate and the composite structure delaminates. Quality of inspection and removal timing are therefore important in controlling costs.

A conservative budget for a higher cost of $150,000 per unit and removal every 12,000FC results in a cost of $25 per FC for both shipsets, or $17 per FH *(see table, this page)*. The actual rate per FH will vary widely in conjunction with the variation on removal intervals and shop visit costs.

The 737NG's auxiliary power unit (APU) is the GTCP 131-9B, similar to the model used on the A320 and MD-80. Most operations have an APU utilisation rate of one APU hour per FC. "Removal intervals for the APU can vary. A 4,000 APU hour interval is short, and 6,000-8,000 APU hours is more typical," says Gielen. "Most airlines send their APUs to Honeywell for repair, and shop visit costs vary between $150,000 and $200,000, although they tend to be lower for the first."

A typical cost for APU maintenance will thus be in the region of $22-30 per APU hour or per FC. This will be equal to $16-20 per FH.

The 737NG has so far demonstrated a lower consumption of MH in both line and base maintenance checks compared to its predecessor, the 737-300/-400/-500 family, and its main competitor; the A320 family. This has been achieved through its maintenance concept and programme and has also been designed to be maintenance friendly.

LRUs & Rotables

Line replaceable units (LRUs) and rotables are the remaining components that have to be considered. Airlines with large fleets can own, manage and repair their own inventories and incur the full costs associated with this. Airlines with smaller fleets and in-house maintenance facilities are likely to find it more economic to lease or finance at least some of their spare parts inventories, and also sub-contract the repair and management of all LRUs and rotables.

To illustrate the costs relating to LRU/rotable ownership, management and repair, it is simplest to analyse the costs that airlines with smaller fleets are likely to pay for acquiring LRU inventories via a pool provided by a large supplier, and the repair and management fees for all units charged on a power-by-the-hour (PBH) basis.

Airlines will split their stock of LRUs and rotables between those that have to be held at a home base location to ensure a reliable service, and those that can be acquired from an inventory pool, because their absence would have less of a serious impact on schedule of operation.

The home base stock can either be owned or leased, possibly from the same supplier that provides access to the pool of remaining inventory. The size of home base stock for a fleet of 10 aircraft is about $7.3 million. The ownership cost for this inventory when depreciated over 15 years at an interest rate of 6% is equal to about $740,000 per year. This equates to $74,000 per aircraft, and about $25 per FH *(see table, page 32)*.

The PBH pool access fee for the remaining stock for a fleet of 10 aircraft will be in the region of $40 per FH.

Also, the repair and management fee for all LRUs and rotables will be $110 per FH for fleets of 10 aircraft. This takes total cost for LRU-related costs to $175 per FH *(see table, page 32)*.

Summary

The 737NG family clearly has a maintenance costs advantage over the A320 family *(see Airbus & Boeing narrowbodies: maintenance cost analysis, Aircraft Commerce, October/November 2002, page 23)* and the 737-300/-400/-500 *(see The 737-200 and -300/-400/-500 series: a guide to maintenance costs, January/February 1999, page 28)*. The main contributor to the 737NG's superiority is the lower rate of MH consumption in both the line and light check cycles and in the C and heavy check cycle. The 737NG may also have marginally lower costs relating to heavy components and LRU and rotables, although these will vary with operators.

Boeing's main objective with the 737NG was to achieve 15% lower maintenance costs than the 737 Classics. A large reduction in terms of MH used has certainly been achieved, and this is been mainly through lower MH consumption in light and base maintenance checks in the first maintenance cycle for both types. The difference in material and consumable consumption is also similar.

The main difference is in the C and heavy checks. Estimates are that the 737NG's consumption varies between 0.8 and 1.3 MH per FH and about $40 per FH for materials in the first maintenance cycle, when all checks are considered. This is based on estimates for MH used in higher C checks, because no aircraft have yet been through their first heavy check. A labour rate of $50 per MH brings this total to $80-105 per FH. In contrast, the 737-300/-400/-500 consumes 1.9-2.1 MH per FH for C and heavy checks in its first maintenance cycle and labour rate of $50 per MH and material consumption of about $50 per FH brings the total to $145-155 per FH, a higher cost of $40-50 per FH for the 737 Classics. This equates to a 40-50% lower cost per FH for the NG series, although the difference between total maintenance costs for the two families will not be as large when other elements of maintenance are accounted for.

The 737NG also has a lower labour and material consumption than the A320 family. The A320 family uses 1.4-1.8MH and $50 of materials per FH in its first maintenance cycle. This is a cost of $110-135 per FH; close to the 737 Classics.

The main contributors to the lower MH consumption are the 737NG's maintenance programme and low non-routine ratio. "The 737NG's MH consumption is light compared to earlier 737s and the A320 family because of the way the 737NG has been redesigned. It is both maintenance friendly and corrosion resistant," says Waller. "The 737NG has a maintenance steering group 3 (MSG3) programme, while the 737 Classic has a MSG2 programme. MSG3 means there is a reduction in the number of routine tasks, since inspections are effectively replaced by condition monitoring. Many tasks in the older 737s have become on-condition items in the 737NG, and some systems and components are also simpler. FLS Aerospace has seen the 15% reduction over the 737 Classics that was quoted by Boeing."

The 737NG's overall maintenance costs are $460-510 per FH *(see table, page 32)*, which compares to about $555 for the A320 family when operated on the same FH:FC ratio of 1.5 and annual rate of utilisation of 3,000FH. This equates to about $150,000 per aircraft per year, although engine related costs are not considered. Airframe and component maintenance costs for the 737 Classics are close to the A320 family. AC