**The oldest 737NGs have completed their first base maintenance check cycles. Analysis of the maintenance requirements and inputs reveals that Boeing has achieved its objective of providing the aircraft with a maintenance cost advantage over the 737 Classics.**

# Analysing the 737NG's first base checks

The first 737NGs were delivered in late 1997 and early 1998, so they have reached eight or nine years of age. This corresponds with the calendar limit on some of the aircraft's base maintenance tasks, so the oldest aircraft have therefore completed their first base maintenance cycles and first heavy checks. The number of heavy checks for 737NGs is due to increase in late 2006 and 2007, following increased deliveries later in 1998 and 1999.

The 737NG fleet currently totals 1,800 aircraft, with another 800 on order, including more than 300 that were ordered in the first half of 2006. A successor to the 737NG is therefore unlikely to enter service before 2012-2013. Moreover, the fleet is expected to reach 4,000 units by 2014, thereby making the 737NG one of the most important aircraft types in the narrowbody base maintenance market.

The advent of the first heavy checks on 737NGs makes it appropriate to examine the aircraft's first base maintenance cycle and man-hour (MH) and material inputs.

## Maintenance programme

The 737NG's maintenance programme has been developed with maintenance steering group (MSG) 3 philosophy, and has all tasks arranged into multiples of a phase interval. This allows operators to group maintenance tasks into packages to form maintenance checks in the way that is most efficient for them, rather than having tasks grouped into checks that are pre-defined by the maintenance planning document (MPD).

The basic phase interval for maintenance tasks on the 737NG is 500 flight hours (FH). A tasks have an initial inspection interval and repeat inspection interval of this basic phase interval.

Tasks that must be performed every phase interval at 500FH are usually referred to as a Phase (P1) check, or generically as an A check, by operators and maintenance providers.

The interval is expressed on each task card by FH, flight cycles (FC) and calendar periods, a combination of two of these criteria or all three. This means that when tasks are grouped to form a maintenance check, the check may have an interval that is dictated by FH, FC and calendar periods. This must be considered in relation to rates of aircraft utilisation.

The freedom for airlines to group tasks into checks as they wish allows them to take into consideration aircraft downtime, access for maintenance, manpower and availability of resources. It also permits maximum utilisation of task intervals. Some operators may decide to perform block checks, while others may prefer to have equalised maintenance in an attempt to make checks of a similar size or to shorten downtime and maximise utilisation.

Maintenance tasks with the highest multiple of the basic phase interval come at the end of the maintenance cycle.

Minor check tasks have intervals of up to six times the P1 interval, but base maintenance tasks have initial and repeat intervals of at least six times the P1 interval. The longest initial intervals are 48 or even 80 times the P1 interval. Different operators can have maintenance cycles with intervals of 24,000FH (48 times 500FH) or 40,000FH (80 times 500FH). Tasks with these highest intervals can be grouped to form a heavy check.

Base checks are formed by grouping tasks with intervals of eight, 10 or 12 times the P1 interval. Tasks with intervals of 4,000FH, 5,000FH or 6,000FH would be referred to as P8, P10 and P12 checks. Tasks that are grouped in this way are often generically referred to as a C check. Some tasks have multiples of two or three times these intervals, and so have intervals of 8,000FH, 10,000FH or 12,000FH, performed at the P16, P20 or P24 checks.

The ability to group tasks into tailored checks means that maintenance programmes vary between operators, although similar programmes have evolved. Operators that choose a programme with the highest interval at the P48 check have a base cycle with an interval of 24,000FH, while those with a P80 check have a base cycle interval of 40,000FH.

## Maintenance planning

Operators that have a maintenance programme with a P48 check can have a base check interval of eight phases (P8), and so have six base checks in the base maintenance cycle. These will be P8, P16, P24, P32, P40 and P48 checks, often referred to as C1, C2, C3, C4, C5 and C6 checks. The P8 check will have an interval of 4,000FH and up to 18 months. The maintenance cycle will therefore have an interval of 24,000FH and nine years.

ATC Lasham in the United Kingdom is a maintenance provider that now has experience of the full base maintenance cycle on the 737NG. It provides maintenance for aircraft that are operated on a maintenance programme comprising a base check interval of 4,000FH and 16 months, P8 checks, and six base checks in the cycle. The maintenance programme has an interval of 24,000FH and 96 months (eight years), so going up to the P48 check. This programme is based on an aircraft utilisation of 250FH per month, or 3,000FH per year. Some low-cost carriers, however, have a higher rate of utilisation than this.

Airlines that have maintenance cycles with a P80 check will complete the base maintenance cycle at 40,000FH. These base maintenance cycles can have intervals of 10 or 12 years. The base check will be the P10 check (C1 check), with an interval of 5,000FH. Eight checks will complete the cycle at the P80 check (C8).

"We manage the maintenance for several operators and have extended the intervals for the base checks from 5,000FH to 6,000FH, but there were still some safety-critical items with an interval of 5,000FH that caused some difficulties in maintenance planning," explains Matthew Stewart, base planning manager at SR Technics. "The maintenance programme operated on the basis of a phase interval of 500FH, a base check with an interval of 10 phases (P10) and interval of 5,000FH, and a heavy check at the eighth base check (P80) at 40,000FH.

"The aircraft actually does 450FH between A checks, so the tenth phase (P10) check is done at 4,500FH," adds Stewart. "We can fully utilise the C check interval by doing the P10 minor check at 4,500FH, and combining the P11 minor check with the base check at 5,000FH.

"The MPD goes up to a P80 check, with an interval of 40,000FH, which is not reached until about 12 years. There are problems when base check intervals are escalated, since it puts some tasks out of phase with the initial and repeat intervals of others," explains Stewart. "This can mean that the initial thresholds of some tasks are not well utilised, which can cause problems with lessors over maintenance reserves. It is easier to separate tasks with 500FH intervals from base check items, and escalate base checks from 5,000FH to 6,000FH. This can save a C check every 30,000FH. The base maintenance cycle would then be completed at 48,000FH (eight times 6,000FH)."

Others may have a base check interval of 12 phases (P12), and so will have a base check interval of 6,000FH and up to 18 months. The base maintenance cycle will have six base checks, and an interval of 36,000FH and nine years. The base checks will be the P12, P24, P36, P48, P60 and P72 checks. These would be referred to as the C1 to C6 checks.

Turkish Airlines operates a fleet of 32 737-800s. The first was delivered in 1998, and the airline still has aircraft due for delivery. "We have a maintenance programme with a C check interval of 6,000FH and 18 months, and have six C checks in the base check cycle," explains Erhan Ozcan, manager of production planning and control at Turkish Technic. "The oldest aircraft have been through their C5 checks and are due their C6 checks in September 2007, nine years after delivery. The C6 check can be regarded as the biggest check, but we do not yet have any experience of doing this.

"The aircraft accumulate 3,500-4,000FH per year, and we manage to reach about 5,850FH between checks in the 18-month interval," says Ozcan.

Operators with the earliest delivered aircraft and a maintenance programme of 48 phases, will therefore have completed, or be due, their first heavy checks before the end of 2007.

## Base check contents

The full content of base checks has to be considered when assessing all of the inputs for base maintenance.

The main items are the routine inspections and non-routine rectifications that arise as a result. The number of routine tasks and the MH required to complete them are relatively light for the 737NG when compared to the 737-300/-400/-500 series.

There are four 737NG variants: the -600, the -700, the -800 and the -900. Stewart explains that despite the differences in the size of these four aircraft, there is little difference between them in terms of the number of MH required for routine inspections and non-routine rectifications.

"The number of routine tasks will increase a little as the aircraft go through each base maintenance cycle," says Ozcan. "This will raise the number of MH for routine inspections by a small amount, but the number of MH used for non-routine work will increase by a larger amount."

"Airworthiness directives (ADs), SBs, modifications and engineering orders (EOs) must be added to the basic work package," says Stewart. The content of these can vary widely between subsequent checks on the same, as well as different, aircraft. ADs and SBs often only affect blocks of line numbers, and can be included on the production line, while others do not have to be incorporated immediately after being issued.

The removal and installation of some rotable components must also be carried out. "The majority of rotables are removed and maintained on an on-condition basis," explains Ozcan. "The 737NG has about 900 rotable components, of which about 200 are hard-time components with fixed removal intervals for maintenance, accounted for by 70 different part numbers. These parts include the flight controls, emergency equipment, pneumatics and hydraulics. They are removed during base checks, repaired in back shops, and then reinstalled on the aircraft. The removal and installation of these components also consumes some MH."

Base checks also include customer requests. "Airlines often ask for their aircraft to be cleared of outstanding items and all maintenance tasks, except for line and ramp items, up to the next phase check," explains Stewart. "This means that airlines will ask us to clear all deferred defects, perform out-of-phase tasks, incorporate any modifications or SBs that otherwise require additional downtime, and even carry out some interior work or cleaning."

Out-of-phase items often relate to components that have hard-times for removal that are not a multiple of the basic phase interval.

The other major elements of base checks include: interior cleaning and general maintenance; the periodic refurbishment of galleys, toilets and


*The 737NG benefits from having an efficient maintenance programme that has long intervals between base checks, as well as low routine maintenance requirements compared to older generation aircraft of a similar size.*

panels; and stripping and repainting the aircraft. The size of the workscope is also the choice of the airline in accordance with its marketing requirements, so the number of MH and materials used will vary between carriers.

Interior refurbishment has become out of phase with the heavy check on modern aircraft, and different parts of the refurbishment process are performed over different C checks.

## Base MH check inputs

The majority of MH used in each check will be accounted for by routine inspections and non-routine rectifications. The number of MH used for routine and non-routine work will of course vary depending on the length of the base check cycle that each operator has selected for its aircraft. The MH used per FH over the base check cycle interval, however, should be similar for aircraft in the 737NG fleet in the first base maintenance cycle.

The rate of MH expenditure per FH for all maintenance tasks in the first base check cycle should also be similar for aircraft in the 737NG fleet. This rate will naturally increase as aircraft age.

All 737NG operators have experienced the low number of MH required to complete routine tasks compared to the 737-300/-400/-500 series. Stewart explains that this is due to several factors, including the flexibility of the 737NG's maintenance programme, which avoids a lot of repeated access, unlike older generation aircraft. It has also been built to be maintenance friendly and avoid unnecessary MH.

"In our maintenance programme of eight C checks over an interval of 40,000FH," says Stewart, "the C1 and C3 use 700-800MH for routine tasks, the C2 1,100MH, the C4 2,500MH, the C5 1,500MH, the C6 1,300MH, the C7 1,600MH and the C8 2,200MH." This totals 12,000MH *(see table, page 52)*, and is equal to a rate of 0.30MH per FH over the base check cycle.

"The non-routine ratio is slow to start with on the C1 and C2 checks at about 40-45%, but gradually rises to 50% for the C3 and C4, and then to 65% for the C5, 75% for the C6, 85% for the C7 and up to 90-100% for the C8," continues Stewart. "This means that the number of MH used for non-routine maintenance is about 300MH for the C1, but climbs to 400-500MH for the C2 and C3 checks, then to 1,000-1,100 for the C4, C5 and C6 checks, and up to 2,000MH for the C8 checks. Total MH for non-routine maintenance in the first base check cycle is about 7,500, and the total number of MH required for routine and non-routine maintenance for all eight checks is 19,500-20,000." This is equal to a rate of 0.50MH per FH, if the full 40,000FH interval of the base check is used *(see table, page 52)*. This will increase slightly if 37,000-38,000FH of the interval is utilised.

Ozcan says that a similar rate of MH per FH have been required for routine tasks over the first base maintenance cycle. "We have used an average of 980 for the C1 check, 1,060MH for the C2, up to 1,600 for the C3, 1,300 for the C4 and 2,500 for the C5. Although we have not yet performed a C6 check, we estimate that this will use 3,200MH," explains Ozcan. This is equal to a total of 10,700MH over the cycle, and 0.30MH per FH *(see table, page 52)*, which is the same level as experienced by SR Technics. "The non-routine ratio that we have experienced in the first base check cycle started at 50% in the C1 checks, rose to 70% in the C2 and C3 checks, and then increased to more than 100% in the C4 and C5 checks," continues Ozcan. "The number of MH required for non-routine tasks totalled about 7,100MH for these five checks. I estimate that routine and non-routine tasks in the C6 check will use about 6,750MH." This will take total MH for routine and non-routine maintenance in the first base check cycle to 21,500MH, which is equal to a rate of 0.60MH per FH *(see table, page 52)*.

ATC Lasham has recently completed full base check cycles for some 737-700s. So far it has seen that the C1 uses an average of 1,100MH, the C2 1,450MH, the C3 2,300MH, the C4 1,800MH, the C5 1,350MH and the C6 around 9,300MH. The non-routine ratio starts off at about 50% for the C1 check, but rises to 80-100% for the C6 check at the end of the cycle. The C6 is the heavy check, and uses about 4,700MH for the routine tasks and a similar number of MH for the non-routine rectifications. This totals about 17,700MH for routine and non-routine tasks for the six checks in the cycle, and is equal to an MH consumption rate of 0.74 per FH *(see table, page 52)*.

## Additional check inputs

The next largest element comprises ADs, SBs, modifications and EOs. "It is hard to put an average figure for this portion of base checks," explains Stewart. "An airline can expect to budget 300-450MH for each check, but the number used varies widely. The number of MH can also be much higher than this for at least one base check in the cycle, especially when big modifications are issued."

Turkish Airlines' aircraft have required more MH than this for EOs during the first base check cycle. "The number of MH required started at about 300 for the C1 check, but climbed to 630MH by the C3 check, and then reached 1,100 in each of the C4 and C5 checks. I expect it to be about this number for the C6 check," says Ozcan.

A conservative estimate for budgeting purposes would be for an average consumption of 900MH for each check in the base maintenance cycle. This would take MH for this portion of base maintenance to 5,500MH for maintenance cycles of six checks, while it would be as high as 6,000-7,000MH for aircraft on cycles of eight checks *(see table, page 52)*.

MH for the removal and reinstallation of hard-time rotable components are only about 20 per check *(see table, page 52)*.

The number of MH used in clearing defects and other customer requests depends on the aircraft's maintenance programme, and the airline's philosophy with respect to clearing deferred defects in line and A checks. "A budget of 120MH can be estimated for this element, although the actual MH required can clearly vary widely around this number," says Stewart.

## Interior work

Interior work comprises regular interior work and cleaning, and interior refurbishment. "Regular interior work, such as cleaning, carpet and seat cleaning, and general interior work, depends on the operator's requirements," says Stewart. "The wear and deterioration of the interior is in proportion to aircraft utilisation, low-cost airlines, which use their aircraft more extensively, therefore have to clean and refurbish more intensively. You also have to consider that the gap between base checks can be as long as 20 months, and airlines that want to maintain a high standard will have to do some interior work during line and A checks."

Turkish Airlines works on seat covers and cabin carpets every two to three months. "We remove, refurbish and reinstall seat covers once every two months, and during a C check. Fabric seat covers on a 737 require about 50MH for this process, while leather seat covers require about 100MH," explains Ozcan. "Fabric seats can be cleaned by machine, while leather seats have to cleaned manually. Leather seats, however, last longer and have more appeal for passengers. Carpets are cleaned on the same basis, and consume about 30MH. Seats are also removed, refurbished and reinstalled every C check. This uses about 500MH.

"Cabin interior cleaning is performed during A and C checks but the depth of cleaning is more intense during C checks," says Ozcan. "General cabin cleaning uses about 200MH in a C check. Sidewall panels are also removed, refurbished and reinstalled every C check, which uses about 200MH."

This indicates that it is possible to use about 1,000MH in each C check for interior work, cleaning and general refurbishment.

The interval between galley and toilet refurbishment also varies between operators, and Turkish Airlines has the policy of performing this action every fifth C check. "The removal, refurbishment and reinstallation of the galleys consumes about 400MH, and the same process for the toilets consumes about the same amount of labour," says Ozcan.

## Total MH inputs

The total MH inputs for C checks in the base check cycle, including regular interior work reaches about 29,000MH for all six checks for an aircraft with a maintenance programme going up to a P48 check. Aircraft on longer cycles of six checks going up to a P72 check will use in the region of 30,000MH, while aircraft on a system of eight C checks per cycle will consume slightly more at 30,000-32,000MH. These are not the total MH inputs for C checks, however, since hours for interior refurbishment and stripping and repainting still have to be added.

The cost of materials and consumables for the six checks in a programme going up to the P48 check

**MAINTENANCE INPUTS FOR 1ST 737NG BASE MAINTENANCE CYCLE**

| Number of base checks | 6 | 6 | 8 |
|---|---|---|---|
| Base check | P8 | P12 | P10 |
| Base check interval-FH | 4,000 | 6,000 | 5,000 |
| Highest base check | P48 | P72 | P80 |
| Highest base check interval-FH | 24,000 | 36,000 | 40,000 |
| Utilised base check interval | 21,500 | 33,000 | 36,000 |
| Routine MH in base check cycle | 9,200 | 10,700 | 12,000 |
| Non-routine MH in base check cycle | 8,500 | 10,500 | 7,500 |
| Routine & non-routine MH in base check cycle | 17,700 | 21,500 | 19,500 |
| MH per FH | 0.74 | 0.60 | 0.50 |
| $ Materials & consumables | 400,000 | 420,000 | 450,000 |
| MH for EOs, ADs & SBs | 4,500 | 5,500 | 7,000 |
| MH for component changes | 120 | 120 | 160 |
| MH for defects & customer requests | 750 | 750 | 1,000 |
| MH for regular interior work & refurbishment | 6,000 | 7,000 | 11,000 |
| $ materials for interior refurbishments | 75,000 | 80,000-100,000 | 150,000 |
| Number of interior refurbishments | 1 | 1-1.5 | 2 |
| Number of repaints | 1 | 1-1.2 | 2 |
| MH for strip & paint | 1,400 | 1,400-1,600 | 3,000 |
| $ Materials for paint | 25,000 | 30,000 | 50,000 |
| Total MH for base maintenance cycle | 30,500 | 36,500 | 42,000 |
| Labour cost @ $50/MH | 1,525,000 | 1,900,000 | 2,100,000 |
| Total materials & consumables | 500,000 | 530,000 | 650,000 |
| Total cost-$ | 2,025,000 | 2,430,000 | 2,750,000 |
| Cost per FH | 90 | 74 | 75 |

will be about $40,000 for lower checks and increase in proportion with an increased consumption of MH. The heavier third, fourth and fifth checks (P24, P32 and P40) will use $50,000-60,000, and the C6 or P48 check will use about $150,000. This will take total materials to about $400,000 *(see table, this page).*

The cost of materials for aircraft on a six-check cycle ending with a P72 check will have material and consumable costs of about $50,000 for the lower checks, which will increase as the MH consumed rise with the check content to about $110,000 for the heavy check that uses in the region of 9,000MH. This will take total materials and consumables to $420,000 *(see table, this page).*

Material consumption will clearly be higher for aircraft with a cycle of eight C checks totalling about 32,000MH, and materials for the full cycle will be about $450,000 *(see table, this page).*

## Interior refurbishment

A full interior refurbishment might typically be required every five or six years. Each one will consume about 4,500MH and $75,000 in materials. An aircraft operating on a base cycle of eight checks per cycle would have two interior refurbishments per cycle, while aircraft on shorter cycles would have one of the equivalent of one and a half refurbishments per cycle *(see table, this page).*

Overall, interior work and refurbishment will utilise about 7,000MH in a six-check base maintenance cycle, and about 11,000MH in an eight-check base maintenance cycle *(see table, this page).*

Stripping and repainting is also an issue of choice for each operator. The requirement for a new paint scheme relates to aircraft utilisation, as well as periodic airline livery changes. Most airlines choose to strip and repaint their aircraft every five to eight years, and operators must also take into consideration the need for their facilities to meet environmental standards. This can often dictate that aircraft are stripped and repainted at specialist facilities, so it is therefore not possible for this work to be carried out during a base check. Ozcan says that about 1,400MH are used in the process and the cost of paint is $15,000-20,000.

## Total cycle inputs

The total MH and material costs described give indications of what the aircraft will require. The actual inputs will ultimately depend, however, on the intervals each operator has between checks, the non-routine ratio, MH required for EOs and the airline's interior refurbishment policy.

While the three maintenance programmes described have varying inputs, they are also similar in that the total cost is $75-90 per FH. Overall, the aircraft with longer maintenance programmes consume 1.1-1.2MH per FH, and those with shorter maintenance programmes 1.4MH per FH. The three programmes collectively demonstrate that the 737NG has lower base maintenance requirements than the A320 family. The A320 utilises at least 10,000MH more and has higher associated material costs than the 737NG in its first base check. Moreover, the A320 has a shorter cycle interval.

The 737NG has clearly benefited from a modern maintenance programme, the main advantage of which has been long check intervals.

This leaves the issue of what maintenance inputs the aircraft will require in its second base check cycle. Stewart explains that the aircraft will have a small increase in routine tasks in the second cycle, while bigger changes will come in the non-routine element of the checks. The non-routine ratio has been at about 50-100% for the first cycle, and Stewart expects this to climb to 100-120% for the lesser C checks and to reach about 130% for the heavy check at the end of the second cycle. This will increase the number of MH used in the base check cycle by 5,000-6,000. Additional MH may also be required if the burden of ADs, SBs and modifications grows. AC