**The 787 has been designed with the extensive use of carbon fibre. One benefit is to reduce the number of system, structural and zonal airframe inspection tasks it requires. Analysis of the MPD examines the number of tasks due in checks, and the possible number of labour MH required.**

# 787 MPD & airframe maintenance requirements

The 787 was partially launched on the basis of being able to offer lower maintenance costs. Some predictions put the savings up to 20%, with 8% coming from the new engines. Others estimated a saving of 30% against a comparable product. This is a result of improved aircraft schedule reliability and the reduced length of time an aircraft is out of service for maintenance.

Boeing has about 60 customers from six continents that have placed orders for more than 1,000 aircraft. About 118 have been built. The first aircraft entered service in late 2011.

The stretched 787-10 is still under development. The 787-8 and -9 use either General Electric (GE) GEnx-Series or Rolls-Royce (RR) Trent 1000-Series engines, and have 240-380 seats, depending on cabin layout. The 787 is intended to replace similar size aircraft, such as the 767, A330 and A340.

This article focuses on the 787's maintenance planning document (MPD), and how design changes have resulted in theoretically lower airframe-related maintenance costs. As has been well publicised, the 787 has replaced the proven metal airframe technology with an unprecedented extensive use of carbon fibre. This eliminates many maintenance tasks related to structural and zonal maintenance. This is carbon fibre is less susceptible than metal to corrosion and fatigue damage.

Maintenance and tasks intervals have also been extended on structural inspections, because of a new, more damage-tolerant material that reduces repair costs: the airframe comprises composite barrel sections, instead of the multiple aluminium sheets which use a large number of fasteners. The weight savings from this new construction, together with improved aerodynamics, work to reduce fuel burn.

The redevelopment and reinvention of aircraft systems has led to fewer complex parts, which also assists in weight reduction for fuel burn savings and lower maintenance costs. For example, conventional hydraulically activated brakes with extensive piping, fuses, and control valves have been replaced by electrical control devices. This has been described as new 'electrical architecture' by the industry.

The 787's engines also use this electric architecture for numerous systems, and incorporate bleedless architecture, for example on the engine pneumatic system.

## MPD development

The 787's MPD is designed with the now well developed and tested maintenance steering group 3 (MSG-3) principles. This has a basic breakdown of systems inspections, structures inspections, and zonal inspections. The MSG-3 MPD follows task interval criteria of flight hour (FH), flight cycle (FC) and calendar time. Unlike the previous MSG-2 logic of heavy calendar interval inspections broken down into A, C and D checks, this MSG-3 MPD logic is driven by aircraft utilisation.

Maintenance inputs depend on whether aircraft are used on long- or short-haul operations. The MPD itself describes the frequency of tasks in terms of 'usage parameter and frequency'.

The 787 MPD provides operators with the maintenance planning information to customise their schedule to suit their operation. Operators also have to schedule additional maintenance items such as airworthiness directives (AD) and service bulletins (SB).

The 787's MPD has a significantly smaller number of scheduled maintenance tasks than previous generation aircraft. For example, the 787's MPD has about 940 tasks compared to a 767's or 777's MPD, which each have 1,300-1,400 tasks.

While more tasks will be added to the 787's MPD over time, this is still a striking reduction compared to older types, due partly to combining inspections into a single task card.

MPD numbers are converted to a task card that contains the inspection requirements in detail, along with mechanic and inspector certification areas. The task cards also provide drawings to assist the engineers with inspection detail.

It is important to note that the man-hours (MH) specified in the MPD are regarded as base figures to which a 'reality' factor should be applied. Extra MH have to be added to source equipment, set up inspection staging, and gain access to inspection areas. Many MROs and operators can multiply the MPD MH by a factor of 2.0 to 2.5 to give a realistic figure to plan labour requirements.

Although the 787's MPD does not have pre-defined checks, an 'A' check could be classed as having a 1,000FH interval. A guide for the first base check or 'C' check would be 12,000FH and 36 months.

The guide for the larger structural 'D' check or heavy maintenance visit (HMV) would be 36,000FH or 12 years (YR). As the aircraft cycles though the checks, therefore, the second base check would have any repeat inspection tasks along with the newly reached threshold tasks.

Because the 787 is designed to be flown on extended range twin-engine operations (ETOPS), and to fly tracks where it can be up to 330 minutes from a suitable airport in the event of an engine failure, additional maintenance requirements are needed for all airlines that operate their aircraft on ETOPS missions.

To control this maintenance, the MPD references a supplemental 'ETOPS' Guide Volume 1 manual 'Configuration


*Due mainly to the 787's extensive use of composite materials, its MPD has about 940 maintenance inspection tasks. This compares to 1,300-1,400 tasks in the 767's & 777's MPD. The 787's task intervals are also longer than the intervals of equivalent tasks in older aircraft types' maintenance programmes.*

Maintenance and Procedures' (CMP). This CMP document includes ETOPS parts list information and other specific assistance for operators. Because this operational set-up needs more attention to maintenance handling and spares of an approved ETOPS standard, a small cost increase will be offset by the operational advantages of flying on a more direct route.

The 787 MPD MSG-3 logic incorporates a corrosion prevention and control programme (CPCP), electrical wiring interconnect system (EWIS), enhanced zonal analysis procedures (EZAP), and lightning/high intensity radiated fields (L/HIRF) inspections into the base document. These items in the past have been separated or been major revisions to the older aircraft MPDs.

## Systems tasks

The MPD systems section has tasks specified in six different intervals: FH, FC, Calendar, FH/FC, FH/Calendar and FC/Calendar. The initial and repeat intervals in the system programme are equal, with a few exceptions.

There are 531 tasks in this chapter, starting from the frequent daily inspection, going up to 50,000FC/20YR tasks. These tasks include visual checks (VCK), general visual inspections (GVI), detailed inspections (DET), functional checks (FNC), operational checks (OPC), restoration (RST) and discard (DIS) checks.

The Systems groups of tasks are summarised *(see table, page 40)*.

### FH tasks

There are 161 pure FH-based tasks. The 200FH to 48,000FH tasks will need to be grouped into line and base checks in accordance with each operator's flying schedule.

The 36 tasks from 200FH to 4,000FH, which will fall due before the first base check, contain aircraft system operational checks, filter changes and fluid servicing with minimal access requirements. This could be done under 'A' check scheduling.

The 32 tasks from 6,000FH to 8,000FH contain lubrication tasks, more filter changes (including cabin air system and numerous function checks), and oil servicing with minimal access needed.

The 37 tasks from the 12,000FH group contains checks on the environmental system, aircraft static systems, seats, flight control and engines.

The three tasks from 14,000FH-18,000FH contain inspection requirements on the leading edge slat skew/loss system, operational checks of the rudder trim switch and a functional check of the cabin speakers.

The 37 tasks in the 24,000FH group contain some more extensive access requirements. This is because many of the functional checks required are off aircraft, like thrust reverser and flight control hydraulic fuses, numerous equipment cooling system checks and fuselage positive pressure relief valve functional checks.

The eight tasks at 30,000-36,000FH contain only minor access requirements for fuel filter changes (Trent 1000 engine), fire system checks, and alternate control checks on the stabiliser trim.

The eight tasks in the 48,000FH group are GVI, OPC and FNC tests of various systems valves and override mechanisms, with minimal access requirements.

### FC tasks

There are just 25 pure FC-based tasks. Intervals range from 100FC to 16,000FC and will need to be grouped into line and base checks in accordance with each operator's flying schedule.

The 10 tasks from the 100FC to 1,000FC group contain light-access system visual checks, like water trap inspections on sense lines. For the GEnx engine there are borescope inspection tasks, which refer to the airworthiness limitations (AWL) section of the engine manual for a shorter interval option to be considered.

The eight tasks from the 5,000-6,000FC group contain inspection and operational requirements of the battery system and thrust reversers.

The five tasks from the 10,000-12,000FC group contain the Trent 1000 fan blade lubrication and restoration tasks, along with head up display (HUD) desiccant changes.

The two tasks from the 16,000FC group are FNC tasks of the horizontal stabiliser trim actuator, and inspections of the inboard and outboard flap support points for excessive wear.

### Calendar tasks

There are 143 calendar tasks in the systems section. Of these, 13 have intervals less than 24 months (MO) and include the minor but frequent daily, seven-day and 14FC checks that focus on the wheels, brakes, and main and auxiliary power unit (APU) battery enclosure vent burst disc indicators.

The 12 two-year interval tasks, of which some have a 1YR repeat interval, include light lube and operational checks of aircraft systems.

The one task from the 4YR group is on the emergency lighting operational system.

The nine tasks from the 7YR and eight tasks from the 9YR group mainly consist of L/HIRF inspections, and

## 787-8/9 SYSTEM PROGRAMME MPD TASKS

| Intial threshold | Repeat interval | Number of tasks | Deep access tasks | Light access tasks |
|---|---|---|---|---|
| Daily-7DY-14FC | Daily-7DY-14FC | 4 | | |
| 3 MO - 6 MO | 3 MO - 6 MO | 3 | | |
| 12 MO - 24 MO | 12 MO - 24 MO | 6 | | |
| 200FH - 4,000FH | 200FH - 4,000FH | 36 | | |
| 6,000FH - 8,000FH | 6,000FH - 8,000FH | 32 | Numerous general inspection panel access | |
| 12,000FH | 12,000FH | 37 | Numerous general inspection panel access | |
| 14,000FH - 18,000FH | 14,000FH - 18,000FH | 3 | | |
| 24,000FH | 24,000FH | 37 | Numerous general inspection panel access | |
| 30,000FH - 36,000FH | 30,000FH - 36,000FH | 8 | | |
| 48,000FH | 48,000FH | 8 | | |
| 100FC - 1,000FC | 100FC - 1,000FC | 10 | | Engine boroscope inspections |
| 5,000FC - 6,000FC | 5,000FC - 6,000FC | 8 | | |
| 10,000FC - 12,000FC | 10,000FC - 12,000FC | 5 | | Fan blade removals |
| 16,000FC | 16,000FC | 2 | | |
| 2-YEAR | 1-YEAR/2-YEAR | 12 | | |
| 3-YEAR | 3-YEAR/6-YEAR | 46 | | Numerous general inspection panel access |
| 4-YEAR | 4-YEAR | 1 | | |
| 6-YEAR | 6-YEAR | 21 | Deep internal access to cargo bays and general inspection access panels | |
| 7-YEAR | 7-YEAR | 9 | | |
| 9-YEAR | 9-YEAR | 8 | Numerous general inspection panel access | |
| 10-YEAR | 10-YEAR | 1 | | |
| 12-YEAR | 12-YEAR | 32 | Extensive internal access to fuselage and wings | |
| 200FC - 1,000FC/2 MO - 6 MO | 200FC - 1,000FC/2 MO - 6 MO | 10 | | |
| 2,000FC/12 MO - 18 MO | 2,000FC/12 MO - 18 MO | 4 | | |
| 2,000FH/12 MO | 2,000FH/12 MO | 1 | | |
| 4,000FC/2-YEAR | 4,000FC/2-YEAR | 1 | | |
| 6,000FH/18 MO | 6,000FH/18 MO | 3 | | |
| 6,000FC/3-YEAR | 6,000FC/3-YEAR | 18 | Numerous general inspection panel access | |
| 8,000FH/3,650FC | 8,000FH/3,650FC | 1 | | |
| 9,000FH/1,000FC | 4,500FH/1,000FC | 6 | | |
| 12,000FC/6-YEAR | 12,000FC/6-YEAR | 5 | | |
| 12,000FH/36 MO | 12,000FH/36 MO | 3 | | |
| 12,000FH/3,560FC | 12,000FH/3,560FC | 1 | | |
| 12,000FH/6,000FC/3-YEAR | 12,000FH/6,000FC/3-YEAR | 28 | Numerous general inspection panel access | |
| 16,000FC/8-YEAR | 16,000FC/8-YEAR | 1 | | |
| 18,000FH/8,000FC | 18,000FH/8,000FC | 1 | | |
| 24,000FC/12-YEAR | 24,000FC/12-YEAR | 7 | Possible landing gear restorations | |
| 5-YEAR/10,000FC | 5-YEAR/10,000FC | 1 | | |
| 50,000FC/20-YEAR | 50,000FC/20-YEAR | 1 | | |
| ENG CNG/APU CNG | ENG CNG/APU CNG | 17 | Inspections at engine and APU change | |
| LIF LIM/VEN REC/NOTE | LIF LIM/VEN REC/NOTE | 92 | Time limited component restorations and checks in accordance with vendor time constraints on components | |
| SHP VST | SHP VST | 1 | Functional check at component off aircraft during restoration | |

## 787-8/9 STRUCTURAL PROGRAMME MPD TASKS

| Intial threshold | Repeat interval | Number of tasks | Deep access tasks | Light access tasks |
|---|---|---|---|---|
| 6,000FC/3-YEAR | 6,000FC/3-YEAR | 13 | | External detailed in general of door cutout structures and door stops plus special inspections of vertical fin root bolts |
| 8,000FC/4-YEAR | 8,000FC/4-YEAR | 1 | | Special detailed inspection of wing leading edge slat 6 and 7 |
| 12,000FC/6-YEAR | 12,000FC/6-YEAR | 26 | Internal and external detailed inspections requiring numerous panel removals. Inspections focus on MLG, tail and fuselage support structure | |
| 6-YEAR/12,000FC | 6-YEAR/12,000FC | 1 | | External detailed inspection of specific wing fasteners |
| 12-YEAR/24,000FC | 12-YEAR/24,000FC | 6 | Internal detailed inspection of fuel tank and nacelle fasteners. | |
| 24,000FC/12-YEAR | 24,000FC/12-YEAR | 86 | Internal and external detailed inspections including deep access of the interior of the cabin | |
| ENG CNG | ENG CNG | 8 | Internal detailed inspection of engine mounts and nacelle structure at engine removal | |

bonding jumper checks in areas of minor access requirements.

The one task at 10YR requires the overhaul of the flightdeck door decompression panel opening mechanism.

Tasks that can be grouped at base check level are the 3YR repeat (46 tasks), 6YR repeat (21 tasks) and 12YR repeat (12 tasks).

The bulk of the 3YR tasks are GVI of the APU compartment, nacelle areas, and wing leading and trailing edge inspections with the panels open. Other tasks in this group that require less access are inspections and operational checks of items such as attendant and passenger seats, along with checks of cabin safety equipment. Major component restorations include the primary and secondary air-conditioning pack heat exchanges and the power electronics control system.

The 6YR checks focus on cargo bay and electronic bay condition, including cleanliness below floor panels. These require floor panels to be raised.

The 12YR tasks have functional and detailed inspection checks of current (electrical) return network installations for bond degradation throughout the cargo bays, along with trailing edges.

Restoration (the term used for the cleaning of combustible material from the components) of the cargo bays, flight compartment and areas under the main passenger compartment furnishings is required. This interval also includes detailed inspections of the fuel tank systems. This is the first stage of the aircraft's service at which extensive internal furnishings like galleys and toilets will have to be removed for detailed inspections. This is four to six years later than older-generation aircraft types.

### Combination interval tasks

The 92 combination FC/FH/Calendar task intervals will come due at whichever interval is reached first. All the tasks will have to be scheduled into the maintenance cycle when due, and have no major access requirements beyond removal refit of inspection access panels. This is apart from the 24,000FC/12YR restoration of the main and nose landing gears. The 12YR life on the gears depends on reliability reports during service, and may be reduced.

The 10 tasks in 200-1,000FC and 2MO to 6MO repeat interval group, includes lubrication (including the landing gears), cleaning of landing gear struts, and GVI of cargo-handling systems.

The 18 tasks in the 6,000FC/3YR group contain lubrication tasks that include shock strut servicing checks, cargo bay and thrust reverser inspections with minor access requirements.

The 28 tasks in the 12,000FH/6,000FC/3YR group all require GVI, DVI and operational checks of thrust reverser components.

### Other tasks

The systems section of the MPD contains 17 engine and APU detailed inspection tasks to be carried out while these major components are removed for either defect rectification or scheduled engine change. These tasks call up the inspection of the support structure, linings, seals and heat shields, thrust links and mount lugs. They are split between the GEnx and Trent 1000 engine type along with the APU.

There are also system operational checks on disconnect functions, for example, on the variable frequency starter generator. Seven of these tasks have repeat FH or FC limits to inspect the areas at whichever interval comes first.

The 60 'life limit' and 'vendor recommended' tasks, along with those designated with the interval 'Note', all cover items such as lifed component and safety equipment that includes fire-extinguishing squibs and oxygen cylinders. The major life-limited items in this number are the main and nose landing gear (at intervals to be determined).

The single task that has a shop visit as its interval is for a crew oxygen system cylinder regulator pressure 'off airplane' test.

**787-8/9 ZONAL PROGRAMME MPD TASKS**

| Intial threshold | Repeat interval | Number of tasks | Deep access tasks | Light access tasks |
|---|---|---|---|---|
| 6 MO | 6 MO | 6 | | External general visual inspection from the ground of gears and wheel wells with gear doors open |
| 4,000FH | 4,000FH | 8 | | External general visual inspection of left and right engine nacelle plus thrust reversers |
| 6,000FH | 6,000FH | 21 | | External general visual inspection of left and right engine plus thrust reversers |
| 3-YEAR | 3-YEAR | 79 | Internal and external GV with access panel removal across the fuselage and wings for inspections | |
| 6-YEAR | 6-YEAR | 67 | Internal and external GV inspections with cargo floor panels and body fairing removal | Internal and external GV of fuselage and wing areas. |
| 12-YEAR | 12-YEAR | 76 | Internal and external GV inspections with passenger floor/cargo/main deck and flight deck panel removal plus fuel tank access | |
| 24-YEAR | 24-YEAR | 11 | Internal GV inspections of passenger cabin and vertical stabilizer areas with panels and insulation blankets displaced as required | |

The 22 'Note' interval items have a mix of tasks, such as operational checks of the slide/rafts that the operator has to schedule.

The 10 tasks refer to checks and restorations of safety equipment, such as seat belts and life jackets, recommended by the manufacturer.

## Structures tasks

The structures section of the MPD specifies 141 tasks in a combination of FC- and Calendar-based intervals. These inspection tasks are designed to detect, by visual or non-destructive inspection (NDI), structural defects resulting from stress, damage, disbond, fatigue and delamination.

The Structures group of tasks are summarised *(see table, page 41)*.

### FC/Calendar tasks

These combination interval tasks are a mix of FC- and calendar-based priorities. The tasks are to be carried out at whichever interval comes first.

There are 13 6,000FC/3YR tasks for the cargo and passenger compartment doors, door surrounds, and door stop fittings. There is also an inspection of the vertical stabiliser front-spar-to-rear-spar root attach tension bolts.

The single 8,000FC/4YR task is for the special detailed inspection (with a borescope or videoscope) of the wing leading-edge slat six and seven drainage holes and ribs.

The 26 tasks in the 12,000FC/6YR group focus on internal and external detailed inspections with removal of the access panel in the MLG, engine, tail and fuselage support structure. In addition, attention is paid to attach fittings, such as flight control actuators and jackscrew fittings and hinge structure.

There is a single 6YR/12,000FC task which has the reverse interval priority to the paragraph above. This is for the external inspection of the tops of the over countersunk fasteners on the upper and lower wing surface. This task is not derived via the MSG-3 analysis, however, and has been introduced into the maintenance programme as an AWL item, and added to the inspection programme due to flight safety analysis.

The six tasks in the 12YR/24,000FC group are also airworthiness limitation (AWL) tasks, for detailed inspections of sealing and fasteners, including high-tension bolts to the nacelles. Fuel tank access is required.

The 86 tasks in the 24,000FC/12YR group require the equivalent of a heavy structural inspection, with deep access to the passenger cabin, cargo bays, the vertical and horizontal stabiliser, and the wings.

This involves the displacement of interior furnishings, and removal of the ailerons and flaps. Detailed visual and NDI methods are used. Some of the tasks give alternative compliance operations which, if the right tooling is available, could reduce MH requirements. For example, a detailed visual inspection of the aft cargo compartment stringers at specific aircraft body stations could be performed instead from the outside of the fuselage surface using a technique approved by the 787 NDT manuals, and reduce costs.

### Engine change tasks

There are eight MPD inspection cards related to engine mounts and pylon torque box areas (four for each engine type) that have intervals at 'ENG CNG' (engine change). These tasks are carried out when the engine is removed for replacement or defect rectification, for inspection of the mounts and structure around the mounts with engine removed.

**787 MPD FREQUENT INTERVAL OR "A" CHECK TASKS TO BE GROUPED PER OPERATORS SCHEDULE**

| Interval Threshold | Repeat Threshold | Additional Intervals | Tasks | Man hours |
|---|---|---|---|---|
| Daily - 3 MO | Daily - 3 MO | | 11 | 3.52 |
| 1,000FH | 1,000FH | | 11 | 5.35 |
| 1,500FH | 1,500FH | | 8 | 6.48 |
| 500FC | 500FC | | 2 | 0.6 |
| 2,000FH | 2,000FH | | 7 | 2.22 |
| 3,000FH | 3,000FH | | 1 | 0.5 |
| 600FC | 600FC | 4 MO | 3 | 1.5 |
| 800FC | 800FC | 5 MO | 4 | 2 |
| 800FC | 800FC | | 1 | 0.2 |
| 4,000FH | 4,000FH | | 12 | 7.22 |
| 1,000FC | 600FC | | 4 | 8 |
| 1,000FC | 1,000FC | 6 MO | 3 | 3.6 |
| 6,000FH/2,000FC/18 MO | 6,000FH/2,000FC/18 MO | 18 MO | 5 | 4.1 |
| 6,000FH | 6,000FH | | 42 | 27.46 |
| 7,500FH | 7,500FH | | 2 | 1 |
| 8,000FH | 8,000FH | | 10 | 5.57 |
| 9,000FH | 4,500FH | 1,000FC | 6 | 7.2 |
| 6 MO | 6 MO | | 8 | 2.35 |
| 12 MO/13 MO/2,000FC | 12 MO/13 MO/2,000FC | | 5 | 3 |
| 2-YEAR/24 MO/4,000FC | 2-YEAR/24 MO/4,000FC | | 16 | 15.45 |

## Zonal tasks

The zonal section of the MPD has 268 tasks specified in calendar time and FH. It consists of a programme of GVI for the general condition and security of systems and structural items contained in a specific zone. These in general are to be carried out within touching distance, unless otherwise stated in the inspection card generated by the MPD number once access is gained.

The Zonal groups of tasks are summarised *(see table, page 42)*.

### FC tasks

There are eight 4,000FH tasks related to inspections of both the GEnx and Trent1000 engine nacelle areas, which only require minor access.

As for the 6,000FH tasks, there are 21 which are engine-related inspection areas, including the thrust reversers and the engine itself with more panels open.

### Calendar tasks

The calendar-based tasks start with six 6MO tasks to inspect the main and nose landing gears with doors open.

The heavier zonal calendar-based tasks, both in quantity and MH content, are then required at 3YR, 6YR, 12YR and 24YR initial intervals, and with identical repeat intervals.

The 79 tasks in the 3YR group, which would ideally fall in line with the first base check, consist of internal and external GVIs over most of the aircraft. There are numerous access panel removal/refit requirements, but the removal of major structural items, such as interior furnishings or flight controls, is not needed.

The 67 tasks in the 6YR group cover internal and external GVIs of the fuselage and wing areas, with the heavier of the access requirements now being introduced into the cargo bays with the removal of floor panels.

The 76 tasks in the 12YR group include numerous passenger door, fuselage, wing and fin inspection tasks, with the deeper inspection levels now reaching the internal floor and fuel tank structure. Throughout the rest of the aircraft there are extensive GVIs down to structural level (all equipment removed). This requires getting down to structure under the insulation blankets that line the interior walls of the fuselage, and entry into the wing fuel tanks.

The 11 tasks in the 24YR group require extensive internal fuselage and stabiliser inspection with heavy access. Because this grouping of tasks would also be carried out with the 12YR repeat tasks, some access requirements will already met by other inspections.

### Additional & OOP tasks

As well as scheduling the system, structural and zonal MPD tasks, operators will have to include inspections developed as a result of safety analysis during the certification of the aircraft.

AWL tasks (both type- and line-number-specific), certification maintenance requirements (CMR), and special compliance items (SCIs), are listed in a separate document, and referred to in Section 9 of the MPD.

Every operator must incorporate these tasks to maintain compliance with the aircraft type certificate requirements. Also to be included are ALI and critical design configuration control limitation (CDCCL) inspections linked into SCI inspections, all resulting from safety analysis information. An example of such tasks is the continued monitoring of wiring through, and adjacent to, the fuel tanks, due to incidents of fuel vapours being ignited by sparks from wiring in poor condition.

Many of these tasks appear within the MPD sections, where the origin of the task appears in the description section, if not MSG-3 based.

Other out-of-phase (OOP) maintenance tasks will include the FC or FH and calendar items, whose intervals have been reached between line and base checks, and may include items where expiry dates have been reached on life limit and vendor-recommended intervals.

## Check inputs

Via the MPD appendix C, where tasks are sorted by interval, Boeing has based utilisation of the 787 fleet at 10FH and 2.78FC per day for guide planning purposes. An alternative 'Block' or 'Phased' maintenance programme packaging is given in Appendix D of the MPD, based on an average utilisation of 11FH per day, and 5.5 FH per FC.

With this 'Phased' maintenance ratio of almost 6FH:1FC, maintenance can conveniently be scheduled at 'A' check intervals of 1,000FH, and base or 'C' check intervals of 12,000FH.

As a guide, the 'A' check basic phase interval would be 1,000FH, 180FC, and 90DY/3MO. The 'C' check basic phase interval would be 12,000FH, 2,160FC, and 1,080DY/36MO. This would ideally divide the maintenance into 11 'A' checks before the 12th one would come due, and be included in the 'C' check.

When the summarised systems, structures and zonal tasks are examined *(see tables, pages 40, 41 & 42)*, the extensive variations of thresholds and intervals do not fall so conveniently into an ideal block pattern. Their varying complexity means that, whatever the aircraft's utilisation, some tasks will need to be performed as standalone items or brought forward to a time of convenience to avoid over-running their intervals. This has to be managed by the operator's maintenance planning organisation, whether it is internal or external.

Given that most 787s will be used for long-haul operations, the aircraft are likely to be operated at a rate of 4,500-5,000FH per year. The aircraft will also potentially be used at an average FC time of 8-10FH, and so accumulate 450-600FC per year. They are therefore likely to reach the FH guide intervals for the base checks before they reach the calendar intervals, and to reach the structural check's calendar interval before they reach the FC interval.

The 787's main appeal is that it has fewer tasks in its MPD than the 767 and 777. The 787's design has therefore been effective in reducing the number of inspection tasks, and extending check intervals.

The largest reductions in base check tasks are in the second and fourth base checks, or 'C2' and 'C4' checks. These checks are due at six- and 12-year intervals, thanks to the reduction of structural inspection requirements which is a result of the composite material used instead of the aluminium.

There will still be a few structures tasks in the six-year, C2 check. These will only be external tasks, not heavy internal tasks. The big check will therefore be the C4 check, at the 24,000FC and 12-year interval.

Most tasks in the 787's MPD can easily be grouped to allow a base or 'C' check at intervals which are twice those of the 767 (every 18 months for most operators). The 787's base check intervals are also one-and-a-half to two times those of in-service aircraft like the A330 and 777.

**787 MPD HIGHER INTERVAL OR "C" CHECK TASKS TO BE GROUPED PER OPERATORS SCHEDULE**

| Interval Threshold | Repeat Threshold | Additional Intervals | Tasks | Man hours |
|---|---|---|---|---|
| 3,250FC | 1,625FC | | 1 | 3.5 |
| 6,000FC/3-YEAR | 6,000FC/3-YEAR | 3-YEAR | 153 | 146.65 |
| 12,000FH | 12,000FH | 36 MO | 3 | 6 |
| 12,000FH | 12,000FH | 6,000FC/3-YEAR | 67 | 31.18 |
| 14,000FH | 14,000FH | | 1 | 1 |
| 16,000FH | 16,000FH | | 1 | 0.2 |
| 18,000FH | 18,000FH | | 2 | 9.5 |
| 4-YEAR/8,000FC | 4-YEAR/8,000FC | | 2 | 2 |
| 24,000FH | 24,000FH | | 37 | 28.76 |
| 6-YEAR | 6-YEAR | | 89 | 65.6 |
| 7-YEAR | 7-YEAR | | 9 | 17.1 |
| 30,000FH | 30,000FH | | 3 | 0.9 |
| 6,000FC | 6,000FC | | 4 | 1.6 |
| 9-YEAR | 9-YEAR | | 8 | 11.5 |
| 10-YEAR | 10-YEAR | | 1 | 0.5 |
| 10,000FC | 10,000FC | | 4 | 2 |
| 12-YEAR | 12-YEAR | | 104 | 101.6 |
| 36,000FH | 36,000FH | | 4 | 3.45 |
| 12,000FC | 12,000FC | 6-YEAR | 31 | 22.55 |
| 12,000FC | 12,000FC | | 1 | 1 |
| 48,000FH | 48,000FH | | 8 | 9.6 |
| 16,000FC | 16,000FC | 8-YEAR | 1 | 0.75 |
| 16,000FC | 16,000FC | | 1 | 2 |
| 24-YEAR | 24-YEAR | | 11 | 21.5 |
| 24,000FC | 24,000FC | 12-YEAR | 93 | 198.67 |
| 50,000FC | 50,000FC | 20-YEAR | 1 | 8 |
| ENG/APU CNG/LIFE LIMIT/NOTE/SHP VISIT/VEN REC | | | 100 | 37.3 |

## 'A' check tasks

'A' check tasks in the MPD can be broken down into eight simple groups for visibility. These are summarised *(see table, page 44)*. Intervals vary from 1,000FH to 9,000FH, with the highest being equal to two years of operation. There are three task groups with calendar intervals, with the highest being two years. For the FC groups it is clear how the varying thresholds could be reached while still falling short of the first base check at the 3YR mark.

The MPD MH, estimated by Boeing, are also quoted in the table. The 6,000FH tasks is clearly the largest group, resulting in 27.46MH on its own, plus the 15.7MH for tasks that come due at a similar time. If the lesser inspections are included at the same time, for example, the Daily to 3MO with 3.52MH, and the 1,000-1,500FH with 11.83MH, the result is about 58.51 Boeing MH for inspection and servicing tasks.

As well as routine inspections, there are non-routine defects, tasks added by the operator, aircraft cleaning, any access to be included and incorporation of airworthiness directives (ADs) and service bulletins (SBs) to consider. Taking the estimated 6,000FH for the heaviest 'A' check mentioned above, then the base Boeing 58.51 MH, using a mark-up factor of 2.0, equates to routine inspections that will use about 117MH. With 15MH for access requirements, and 10MH for general cleaning, the total comes to 142MH. These MH on a larger 'A' check grouping are relatively low for an aircraft of its size.

The type of defects found in A checks are often in-service damage, system leakages, and clearing technical log defects. These can potentially double the number of MH required.

If the 1,000FH multiple is used for an A check interval, the intervals of some task groups must be adjusted so that the 1,500FH tasks are brought forward to a 1,000FH interval. The 1,000FC tasks will be performed at the equivalent FH interval depending on the FH:FC ratio. The calendar tasks will have to be performed at the most appropriate 1,000FH multiple in relation to utilisation.

## Base check tasks

The base check task groups are also summarised as a guide to possible groupings *(see table, this page)*. They have been divided into nine main task groups.

Three of these groupings have FH intervals of 12,000FH, 24,000FH and 36,000FH. These would be the target intervals for the first three base checks.


*Task intervals in the 787's MPD are varied. Tasks can be grouped into 'A' and base or 'C' checks with intervals close to multiples of 1,000FH and 12,000FH/30-36 months.*

The other main groupings are the 3YR, 6YR, 12YR, 12,000FC and 24,000FC tasks. The actual interval and content of base checks is determined when these task groups come due in relation to each other. This is influenced by aircraft utilisation.

If the aircraft operates at 4,500 FH per year, then multiplying this by six years (interval for the second base check) gives 27,000FH before the 6YR tasks come due.

Looking at the largest of this FC grouping with 153 tasks, the 6,000FC/3YR group has an inspection MPD MH requirement of 146.65MH.

The largest quantity of FH tasks is for the 12,000FH list, which when included with the varying alternate intervals gives 70 tasks with 37.18 Boeing MH for the inspections.

The largest calendar quantity of tasks falls with the 89 6YR tasks at 65.6 Boeing MH, and the 104 12YR tasks at 101.6 Boeing MH.

The key to working out check sizes though, as with the 'A' checks, is to work out which OOP tasks to be included at the base check to clear the aircraft going forward. This will also include the lesser checks at the same time.

For example, the 12YR check (C4) could not be done without the 6YR items, since they will be required under their repeat interval.

With an average Boeing guide utilisation of 3,500FH and about 970FC per year, the MH for a C1 check at three years would be about (selecting relevant thresholds from the table, page 45) 200MH. Multiplying this by 2.0 for a reality factor gives a starting figure of 400MH. To then be included is access man hours, in this case a guide figure of 300 man hours. Together with a coverage of 20MH for routine 'A' check items the total starts to build in this case to 720MH for a base C1 check inspection and access figure.

Providing a defect allowance of 0.3:1 against the guide 720MH will add another 216MH to become a C check figure of 936MH.

It is clear that extra charges can quickly mount up. Boeing's guide figures do not even include time-expired component changes, additional cleaning requests, or passenger seat overhaul if the operator decides this may be the first opportune time to do detailed maintenance of the seats. So there are many considerations to think about when evaluating maintenance costs.

The same practice put through the heavy 12YR check would leave the base check size in the region of 400 Boeing MH. A realistic budgetary figure for check sizes is reached by allowing a multiplication factor of 2.0 for these inspections, plus an allowance of 1,800MH for access for the internal cabin component and flight control removals based on similar-sized aircraft, and giving all of these routine inspections a defect ratio of 0.6:1 at an early age. The 12YR check could therefore require 4,000-5,000MH. This does not include an allowance for any interior refurbishment, airline tasks or stripping and repainting.

If the target is to have a base check every 12,000FH and 36 months, and a heavy structural check, being the fourth in the cycle, at 24,000FC and 12 years, then the calendar target intervals for the base checks could only be fully utilised for aircraft operating at up to 4,000FH per year. Most long-haul operations already achieve higher rates of utilisation. For an aircraft operating at 4,800FH per year, the calendar tasks would have to be brought forward.

The 6YR and 7YR tasks would have to be brought forward and grouped together and performed at every second C check, which would be every five years/60 months to utilise downtime and common access requirements.

The 9YR tasks would be performed every 36,000FH or every seven-and-a-half years/90 months. The 24,000FC/12YR tasks could still be performed every 12 years, but the fourth base check would have been performed early at 10 years/120 months.

It may make sense for operators to bring the structural check (36,000FH/12YR check) forward and perform it at 120 months with the fourth base check. The base checks therefore have to be arranged as a series of four checks, and at an interval of 12,000FH and about two-and-a-half years/30 months.

The C4 check and structural tasks would be combined at about 48,000FH and 120 months. If the target interval of 36 months for the C check is to be reached, then the FH interval in the MPD would have to be extended to 14,000-15,000FH to suit most operators' probable rates of utilisation.

## Routine & non-routine

Since the fleet is still young, it is not possible for the maintenance costs and resultant savings to be fully examined, and analyse how the 787 compares against sister aircraft, such as the 767. Because the first 787 entered service in 2011, the first 3YR base check is imminent.

The extensive use of composite materials and carbon fibre means that the incidence of findings and defects is expected to be lower than on current generation aircraft. This will potentially result in a lower non-routine (defects) ratio, and also a slower rate of increase in the non-routine ratio as the aircraft gets older. The use of longer task and check intervals and fewer task cards overall means the 787 is expected to have lower airframe-related maintenance costs. This will depend on how the composite structures hold up over time with wear and tear, pressurisation loads and general in-service activities.

*The first 787 entered service in 2011, and consequently the first 3-year check is imminent.*

## Major ADs

As with all new model types, problems upon entry into service have led to several ADs being released relating to 787 flight safety concerns.

Of note, the major ADs are: AD 2012-24-07, for fuel leaks on engine fuel feed manifolds; AD 2013-15-07, for specific design emergency locator transmitter (ELT) battery checks; and AD 2013-08-12, for the modification of the aircraft battery system.

AD 2012-24-07 requires the inspection and correction of defects found on engine fuel feed manifold couplings. It also requires further inspections on engine fuel feed manifold rigid and full flexible couplings. These are required due to reported fuel leaks as a result of assembly issues.

Correct lock wiring of this system had to be inspected within seven days (lock wire installation), and 14 days (fuel manifold couplings) of the effective release of the AD (5th December 2012). Labour for this task were only in the region of 10MH.

AD 2013-15-07 is for the inspection of a fixed ELT installed on the 787, which is also installed on other model types. This was prompted by a fire on a stationary aircraft, which is believed to have been initiated by the ELT. This inspection requirement is only listed as taking 1MH. It involves an inspection of the condition and re-installation within 10 days of the release of the AD (26th July 2013), and rectification of defects before further flight.

AD 2013-08-12 (released April 2013) which supersedes an existing AD (2013-02-51), and requires the modification of the main and auxiliary battery system.

This AD has a labour requirement of 112MH for the work. A revision to the MPD introduces a requirement to replace the main and APU battery enclosure vent burst discs under a life limited parts requirement. Some of the costs would be covered under warranty, however.

These ADs only affect a small number of aircraft, because of the small number in service.

The latest development found on the 787-9 during flight tests are small hairline cracks in the wings, which has been attributed to an altered manufacturing process. It does not affect the in-service aircraft.

## Cabin refurbishment

Interior cleaning and on-condition repairs, along with interior refurbishment scheduling costs, are down to the operators' requirements, and standards. Base checks inputs provide the best opportunity for deep interior cleaning.

A MH allowance for a deep cleaning of the interior is 100-400MH, on a sliding scale in relation to what check size the aircraft is on, can be used. This would include a deep cleaning of leather seats, but not the removal and refit of cloth seat coverings for dry cleaning.

The outside wash can use up to 120MH, depending on the method and tooling used.

Opportunities for cabin refurbishment or re-design will be convenient at the six-year inputs. This is when the aircraft has its first reasonable downtime to refresh the interior if needed. It is up to the airline's planning department to take advantage of any access gained at system, structural or zonal tasks during a major refurbishment.

## Stripping & repainting

Stripping and repainting the aircraft will be at the operator's discretion. As a guide, repainting every six years at or after a major input can be used. A budget for labour is 2,500-3,000MH. Cost of paint varies with the complexity of the livery.

Boeing has developed new paint stripping techniques that make it possible to chemically strip the paint on the aircraft's composite airframe to eliminate the hand-sanding requirement and save time.

## Summary

Boeing offers an optional GoldCare support network for 787 operators at an agreed price per FH. This support was enhanced in 2010 with an EASA sub part M approval for its European market (for maintenance planning/managing). The financial advantage is that it apparently gives operators a comprehensive life-cycle-management service of engineering support, maintenance control, maintenance planning and material repair of the aircraft managed by Boeing.

Under Boeing's GoldCare scheme they will assist with all maintenance and parts support, tracking aircraft condition and configuration to help with scheduled reliability. On the commercial side, a 787 operated with manufacturer's support assists the remarketability of the aircraft.

The 787 should use significantly fewer MH for base checks than older generation types. This is due to the extended task intervals, and their less frequent intensive access requirements.

The aircraft is still young, however, and the maintenance planning tasks will grow and develop as information is gained from the active aircraft. Also fully unknown at this stage is the extent to which major ADs and SBs will come as a result of operation.

As the aircraft matures it will then be clearer, when routine and non-routine maintenance data can be compared over the same intervals against the older aircraft types, if the 787's design and MPD contributed to reducing its maintenance requirements.