The 787 represents a shift in design from hydraulic and mechanical components to an increased number of electrical systems. This configuration is expected to contribute to significant operational enhancements and result in lower maintenance costs. The 787's MPD and grouping of tasks into light and base checks is examined here.

787 MPD analysis & check planning

The 787 Dreamliner first entered service in October 2011, starting with the 787-8. The 787-9 entered service in 2014, while the -10 is due to enter service in 2017. Key customers that operate the type include British Airways (BA), Virgin Atlantic, Qatar Airways, Air New Zealand and Air India. The fleet is powered by two engine options: the General Electric (GE) GEnx-1B, and the Rolls Royce (RR) Trent 1000. These 'new-generation' engines are designed to promote lower fuel emissions and increase overall efficiency *(see Aircraft Commerce, Acquiring maintenance for new generation engines, February/March 2015, page 34).*

The purpose of the 787 family is to provide an ultra-long-range, 205-330-seat widebody with lower cash operating costs than previous-generation aircraft. To meet these requirements in an aircraft of comparable size to mid- and long-range aircraft, such as the 767 family, significant design characteristics have been implemented. The 787 is an example of a new generation aircraft *(see Aircraft Commerce, The 787's on-board fault diagnosis & line maintenance capabilities, page 53-61, issue 101).*

The 787 is described as an electronic aircraft, because many of its mechanical and hydro-mechanical components have been replaced with electrical components. Some components are software rather than hardware.

One key feature of the 787 family's architecture is the removal of the bleed air system, which was used to control cabin temperature and pressure via a relatively heavy on-board system of pre-coolers, valves and ducts. Removing it achieves a significant weight saving for the aircraft. A variable frequency starter generator (VFSG) system is now used instead of the bleed air system, so the Dreamliner has a mainly electrical system in place of the hydraulic and pneumatic systems widely found on legacy aircraft.

These differences suggest a large change in the aircraft's maintenance requirements. The absence of the bleed air system (and the associated zonal and system maintenance tasks) means that focus must now be on the electrical system components, such as the VFSG.

The replacement of many system components with electrical components and software means that many of the system maintenance tasks that were required for older generation aircraft are not required on the 787.

The early revisions of the 787's maintenance planning document (MPD) promote a maintenance schedule or programme that is focused on system-based, rather than structural-based, task demands. At this stage there are relatively few structural tasks in the MPD. The MPD is still new, so it is expected that the number of tasks structures programme will increase in the future.

Due to its inherent electrical capabilities, the 787 also generates large volumes of aircraft health monitoring (AHM) and engine health monitoring (EHM) data, compared to older types. The aircraft can pick up these large data volumes, and alert flight and line maintenance crew to them, which suggests that potentially more problems or faults will be detected as they actually arise, and therefore rectified early, rather than being detected at a stage where the fault could become problematic for the aircraft.

The large volumes of health monitoring data generated by the 787 will further lead to prognostics. This will be analysis of system and component health data to predict system and component malfunction. A large portion of the aircraft's maintenance may later be performed on an as-required basis.

Industry utilisation

According to recent databases, there are 410 passenger-configured 787-8s in operation. A further 730 787-8s, -9s and -10s are on firm order.

The average age of those in operation is close to two years, with annual utilisation close to 3,500 flight hours (FH) and 640 flight cycles (FC). This suggests an average flight time per sector of five hours and 27 minutes for the 787-8, and an FH:FC ratio of 5.45:1.00 across the fleet.

This rate of utilisation is used as a basis for planning and scheduling maintenance checks for an aircraft performing mid- to long-haul routes in this article.

MPD

The MPD was first issued at service entry. The latest changes to the MPD were implemented in May 2016.

It is important to note that even the earliest operational 787s, which were initially phased in by the first operators during 2011 and 2012, have yet to approach any large routine base check events. Air France Industries KLM Engineering & Maintenance (AFI KLM E&M), for instance, has only completed a few A checks to date.

Provisions or estimates for man-hours (MH) for performance of tasks are listed in the main body of the MPD. The MH for gaining access for maintenance tasks are in section AA of the PDF copy of the MPD, while preparation times are usually determined independently by operators. Including preparation time in the MPD is

The 7687 fleet has achieved an average annual utilisation of 3,500FH and 640FC. By comparison, MPD intervals for light or A checks are 1,000FH, and are 12,000FH, 6,000FC and 3YE, whichever comes first for the base checks.

more of an Airbus than a Boeing concept.

Despite this, operators and maintenance, repair and overhaul (MRO) providers are likely to apply a 'reality factor' to these elements of MPD labour to estimate the actual required MH for these tasks as realistically as possible.

"In general, the 787 has a usage parameter-based MPD," says Andre van der Harst, engineering unit manager at KLM E&M. "This means every task has its own interval, expressed in calendar time, FC, FH or a combination of two or three of these parameters. This is in contrast with the historical set-up of tasks with the same interval being grouped into a letter check in the maintenance review board (MRB) of legacy aircraft types."

"The 787 maintenance programme is basically drawn from the MPD, airworthiness limitations (AWLs), and certification maintenance requirements (CMRs). The maintenance programme also has items, such as airworthiness directives (ADs), repetitive service bulletins (SBs), and operator required items added," adds Peter Cooper, planning manager at Civil Aviation Services. "The MPD itself is published in two formats: PDF, which contains a number of sections and appendices, and Excel. The PDF version takes precedence. Often, for example with preceding aircraft types, revisions to an MPD occur about every four months."

The MPD for the 787 is published in three sections: systems and engines, structures, and zonal tasks. There are a total of 1,008 tasks in the MPD for the 787-8 and -9 as follows: 573 in the systems section; 154 in the structures section, and 281 in the zonal section.

This compares to more than 900 tasks in the structures section of the 767's MPD alone, and more than 800 tasks in the structures section of the 777's MPD.

These large numbers of structures tasks, compared to the 787, are partly explained by the 767 and 777 having more variants and engine types. There will be more structural differences, and therefore tasks, between a larger number of variants. Another difference is that the 787 is a young type, and high-interval structural tasks have yet to be added. The 787 has also been built with composite materials, so some tasks in legacy aircraft maintenance programmes will not exist in its MPD, and others will be merged.

The 787 will have new structures tasks added to its MPD as it gains experience. This is first because supplemental structural inspection document (SSID) tasks will be issued, as a result of in-service reports and findings from airlines, and fatigue testing by Boeing.

A second factor will be that the 787 may have sampling tasks added to its MPD. These will have relatively short intervals for the sample aircraft, and longer initial intervals for the remaining aircraft in the fleet.

A third factor is that as the 787 progresses through service, airworthiness directives (ADs) and service bulletins (SBs) are issued, and will then generate new MPD task numbers.

The third 787 family variant, the -10, has not yet flown, so it is not referenced in the MPD. Engine-related tasks in the MPD will be specific to the engine used and expressed accordingly in the engine inspection tasks.

Maintenance patterns

Traditionally, an aircraft's MPD would adopt specific intervals for each task. This did not allow too much flexibility for airlines and MROs to fully optimise an aircraft's operational demands versus its maintenance commitments. For younger aircraft types, however, more than one interval parameter is given to each task, operating under a 'whichever comes first' (WCF) precedent that allows airlines to customise their fleets' maintenance programmes *(see A320 maintenance analysis, Aircraft Commerce April/May 2016, page 50).*

"Because of several usage or interval parameters for each maintenance task, there is no 'one size fits all' solution," explains der Harst. "The MPD allows operators to tailor the programme to their needs. This is a challenge, since there is a lot of engineering involved to find the optimal solution for an operator. In the past the pre-packaged letter check programmes were easier to implement. The programmes were less flexible when it came to planning checks". Tasks are now grouped into checks according to their multiple intervals and the aircraft's rate of utilisation.

"For the 787, the light check tends to have an interval ranging from 1,000FH to 2,000FH," continues der Harst. "The tasks that could be considered as those forming the base check, have a target interval from Boeing of three years. Depending on how the operator groups the tasks, an interval of 18 or 24 months is also possible. Overall, the first heavy base check is targeted at 12 years, with large groups of tasks coming due about every three years."

"Rather than letter checks, we group the 787's maintenance tasks into phase checks (line checks) and base (hangar) checks," says Lee Burgess, head of engineering at Monarch Aircraft Engineering. "As expected, longer task intervals are the main difference with new generation aircraft. For light checks, airlines can adopt the phase check system (1,000FH) or perform any tasks that come due at multiples of this interval. This is because each task will have its own individual interval given to it, rather than a letter check parameter."

The MPD provides an indication for a pattern of light or 'A' checks, and a

The 787's MPD is relatively light on number of tasks. The structures programme is particularly light in the number of inspections. This is likely to increase as fatigue-related and ageing-related tasks get added to the maintenance programme.

pattern for base or 'C' checks. The basic light or 'A' check interval is 1,000FH. There is no particular cycle of 'A' checks, but there are small and large groups of tasks with intervals that are multiples of up to eight times the basic interval. That is, 8,000FH *(see table, page 52)*. The several groups of tasks will form A checks in blocks. Checks will thus differ in size.

There are also smaller numbers of tasks with different intervals to a multiple of 1,000FH. These are regarded as out-of-phase (OOP) tasks.

The MPD indicates a basic interval for a base or 'C' check of 12,000FH, 6,000FC and 3YE, WCF. There are several groups of tasks in the structural, zonal and system programmes of the MPD with intervals that are multiples of this basic interval *(see tables, page 47 & 50)*. The MPD indicates a base check cycle of four checks. Generically referred to as 'C' checks, the fourth check in the cycle, the C4 check, includes deep access tasks, and so is a heavy check. The C4 check has an interval of 48,000FH, 24,000FC and 12YE.

Given typical rates of utilisation, the base 3YE will be reached first, and this will be equal to about 10,500FH and 1,920FC. For the C4 check, the 12YE will be reached first, and this will be equal to about 42,000FH and 7,700FC. Average utilisation of maintenance intervals by many operators is about 85% of the calendar intervals.

Components

Rotable components are tracked by serial numbers so that they can be monitored by the operator or maintenance organisation.

Rotable components are often the most integral parts to an aircraft's structure and operational viability, and include the landing gear, batteries, avionics and flight control components. "Engines, auxiliary power units (APUs), pressure containers (such as fire extinguishers and oxygen bottles), electrical components, pneumatic components, and certain actuators are other examples of rotables," says Cooper. Their nature means that rotables can be both hard-timed and monitored on-condition, with an expectation either to inspect and replace, or overhaul after a certain interval outlined in an MPD. "Hard-timed component tasks will often form the OOP tasks seen by operators in the MPD," adds Cooper.

"Boeing provides about 850 unique part-numbers for the 787-8 in its aircraft readiness log," says der Harst. "About 80% of these are monitored on-condition and the remaining 20% are hard-timed."

Structural tasks

The structural tasks section of the 787 MPD is relatively small, totalling 154 airframe and engine-orientated tasks. As described, the number of structural tasks is likely to increase in the future. This compares to the 767 which has about 950 structures tasks in its MPD *(see Assessing the 767's ageing maintenance, Aircraft Commerce, Issue 81, April/May 2012, page 38)*. The 777 has 845 structural tasks listed in its MPD *(see Assessing the 777's long-term base maintenance costs, Aircraft Commerce, issue 87, April/May 2013, page 28)*.

Since the aircraft has a composite fuselage, which separates it from older aircraft types, it is expected at this stage that the structural demands would be less than previously seen on metal composite-based fuselages. The structural demands will be further determined, however, through in-service behaviour and the MPD will be adapted accordingly.

"Inspections in the structural generated tasks have the following frequencies," begins Cooper, "with all threshold and repeat intervals being identical for each task in the current edition of the MPD.

"There are 13 items arising at either 3 years (YE) or 6,000FC, WCF. Then there is an intermediate airframe task that falls at either 8,000FC or 4YE, WCF *(see table, page 47)*. The next two items occur at either 6YE or 12,000FC, WCF. 27 tasks come due at either 12,000FC or 6YE, while nine items are due at either 12YE or 24,000FC," continues Cooper. "Last, there are 94 items arising at 24,000FC or 12YE, WCF. This is the first big structural check that comes due in the 787's maintenance cycle."

In addition to these core structural tasks, there are eight additional tasks listed that relate to engine change *(see table, page 47)*. Four of them apply to aircraft fitted with the GEnx, and the other four are related to the RR Trent 1000. 2.5MH are allotted as inspection time per engine, involving internal detailed inspection of engine mounts and nacelle structure at engine removal.

Looking a little closer at inspection requirements at each interval, the following tasks can be examined in detail.

6,000FC/3YE tasks are all airframe tasks that apply to each 787 type and variant. These are light access tasks involving external detailed inspection of door cutout structures and door stops, plus special inspections of vertical fin root bolts. 5.5 inspection MH are listed in the MPD, which does not include access and preparation time. Given the current industry utilisation average of 640FC, for the purposes of this investigation one can assume that the 3YE interval will be reached first for most 787 operators.

The single task at 8,000FC/4YE is an airframe inspection relating to a special detailed investigation of the wing leading edge slat 6 and 7. Total inspection MH are referenced as 1.5 in the MPD. Again, given the expected 'normal' usage of the 787, it is likely that the 4YE interval will be reached before the aircraft

787-8 AND -9 STRUCTURAL AND ZONAL TASKS - MPD REVISION

Initial threshold & repeat interval	Airframe tasks All types	Tasks only relate to -8	Tasks only relate to -9	Trent 1000 tasks	GEnx tasks	Total MPD tasks	Inspection MH	Access Requirements
STRUCTURAL TASKS								
6,000FC/3YE	13					**13**	5.55	Door cutout structures,door stops. Vertical fin root bolts
8,000FC/4YE	1					**1**	1.50	Wing leading edge slat 6 & 7
12,000FC/6YE	23	3	1			**27**	19.65	MLG, tail & fuselage support structure
6YE/12,000FC	1	1				**2**	5.40	Wing fasteners
12YE/24,000FC	3	6				**9**	76.40	Fuel tank and nacelle fasteners
24,000FC/12YE	77	11	6			**94**	129.59	Deep access of cabin interior
ENGINE CHANGE				4	4	**8**	2.4 Per Eng	Engine mounts & nacelle structure at removal
Total structural tasks	**118**	**21**	**7**	**4**	**4**	**154**		
ZONAL TASKS								
6 MO	6					**6**	1.60	Visual of LDG & wheel wells (gear doors open)
4,000FH				4	4	**8**	3.80	Engine nacelle plus thrust reversers
6,000FH				10	10	**20**	15.00	Engine inspection
3YE	55			14	14	**83**	42.30	Access panel removal across fuselage & wings
6YE	67	2				**69**	50.05	Cargo floor panels & body fairing removal
12YE	69	7	7			**83**	69.30	Passenger,cargo, main deck and flightdeck panel removal. Fuel tank access.
24YE	10	1	1			**12**	23.00	Cabin & vertical stabiliser areas, panels and insulation blankets
Total zonal tasks	**207**	**10**	**8**	**28**	**28**	**281**		

accumulates 8,000FC.

Almost 26MH are listed in the MPD to perform the tasks that fall at 12000FC/6YE. These include 24 airframe tasks that apply to all 787 types, four airframe tasks solely for the -8, and one task for the -9. These are the first deep access demands that appear in the structural section of the MPD, a variety of internal and external detailed inspections requiring numerous panel removals throughout the fuselage. These inspections focus on the main landing gear (MLG), and tail and fuselage support structures. There is also a light access demand for an external detailed inspection of specific wing fasteners.

It is important to note that, without a 'reality' or multiplication factor used by maintenance planning engineers at this stage, the MH estimates listed in the MPD do not indicate the actual labour required by maintenance shops to perform the inspections. The 26MH referenced above from the MPD, for example, may need a multiplication factor of 1.5, 2 or even 4 to account for actual MH required to perform the routine tasks. The inexperience of a maintenance provider (due to the new aircraft type), or time to locate new parts as and when needed, may also mean that tasks use more MH.

As highlighted, the 787 MPD is structured so that the first in-depth structural inspection (requiring excessive downtime), which would form a core part of the first heavy check, falls at 12YE. 24,000FC is the alternative parameter, WCF. This is expressed in the MPD in two different ways, giving operators the flexibility of grouping tasks. There are tasks stated in the MPD at 12YE/24,000FC, and tasks expressed at 24,000FC/12YE. Given average annual utilisation rates of 3,400FH and 640FC, it can again be assumed that the 12YE interval will be reached first for both these groups of tasks.

For these two intervals parameters, there are 80 airframe structural tasks applicable to all types of 787 *(see table, this page)*. 17 tasks are then relevant only to the -8, and 6 tasks to the -9. In total,

The majority of 787s are relatively young. They have consequently not yet been through a base check, which is first due at a calendar interval of three years.

nearly 210MH are referenced as inspection time required in the MPD. The deep access requirements include internal detailed inspection of fuel tank and nacelle fasteners, alongside internal and external detailed inspections requiring deep access of the cabin. Such requirements will involve galley, seat and carpet removals to all the appropriate panels to be removed. It is reasonable to assume that this will require substantial additional preparation and access times.

Zonal tasks

There are 281 zonal tasks in the 787's MPD *(see table, page 47)*. Each interval is identified by a single parameter, rather than the FC/YE WCF referenced in the structural section. The parameters mentioned in the zonal section are month (MO), FH and YE.

"Much like the structural tasks, all tasks referenced in the zonal section have the same threshold and repeat intervals," describes Burgess. "That is, 6YE tasks have a threshold of 6YE and a repeat of 6YE, and 12YE tasks have a threshold of 12YE and a repeat interval of 12YE."

The first interval is 6MO, for which there are six tasks *(see table, page 47)*. These all relate to airframe inspections and require about 2MH of inspection time. These tasks include external general visual inspection from the ground of landing gears and wheel wells with gear doors open.

The next requirement falls at 4,000FH. Given the expected annual utilisation of 3,400FH, one can assume that these inspections will come due every year to 14 months. Eight tasks come in at 4,000FH and relate to the engine fitted; there are four tasks for Trent 1000 engines, and four for GEnx engines. 3.8 inspection MH are referenced in the document, with each engine requiring an external general visual inspection of left and right engine nacelles plus thrust reversers.

The next set of tasks comes due at 6,000FH. These are again, engine-related – with 10 items attributed to Trent 1000-equipped aircraft and 10 for those powered by the GEnx. A total of 15MH is allotted as inspection time in the MPD, which concerns an external general visual inspection of both engines, plus thrust reversers. Again, given the average annual utilisation of 3,400FH, one can assume these will come due every 24-30 months.

The rest of the Zonal tasks all have longer intervals expressed in terms of YE. There are 83 tasks connected to a 3YE interval, divided as 55 airframe tasks applicable to all 787 variants, and 28 engine-related tasks *(see table, page 47)*. These 28 tasks are split between Trent 1000 and GEnx engines.

Nearly 45 inspection MH are outlined, mainly pertaining to internal and external inspections across the fuselage and wings, requiring access panel removal. Again, it should be stressed that no access or preparation time is allocated in the 787 MPD at this stage.

Further zonal tasks fall at 6YE, 12YE and 24YE intervals. 69 tasks fall at the 6YE interval, 67 of which are relevant to every 787 aircraft, while the remaining two tasks only relate to the -8. About 50 MH are advised for inspection to cover these 6YE tasks, which include a mixture of light and deep access requirements *(see table, page 47)*. Cargo floor panel and body fairing removal is required for deep access detailed inspection, while a general visual assessment is needed both internally and externally for the fuselage and wing areas.

83 tasks are set out for the 12YE interval, alongside 70MH of MPD inspection time *(see table, page 47)*. Excessive panel removal is required throughout the tasks, including panel removal of the passenger, cargo, main deck and flight deck floors, alongside fuel tank inspections. It would be expected, therefore, that significant access and preparation time will need to be added to this MH estimation, something that will become more apparent as operators and maintenance providers gain more experience with the 787 family and start carrying out 12YE inspections. This is a maintenance event that is still a long way away from occurring on operational 787s.

Finally, 24YE zonal tasks are still relatively small in number, and may well develop in size as the fleet ages and findings are reported. There are 12 items in total, all of which are airframe-related, and the MPD estimate for inspections is 23MH *(see table, page 47)*. 10 tasks apply to the whole fleet, while the remaining two tasks are split between the -8 and -9. The purpose of these 24YE tasks is to inspect cabin and vertical stabiliser areas, requiring panel and insulation blanket removal.

System tasks

System tasks represent most of the task requirements for the 787's airframe, with 537 tasks spread out across a series of intervals and parameters *(see table, page 50)*. Inspection times listed in the MPD for these tasks total about 600MH, discounting access and preparation time.

"There are 95 different intervals for the system tasks," says Cooper. These can be divided into three groups according to interval parameter. These are FH tasks, FC & calendar tasks, and calendar tasks.

Once again, repeat intervals match the initial threshold, which in theory, simplifies the maintenance planning process for the 787's ageing maintenance (as a task passes its initial threshold). It should be noted, however, that the 787 MPD will evolve countless times as the fleet ages, and completes its first, second and third base check cycles. Repeat intervals may, therefore, be revised, and

787-8/-9 SYSTEM PROGRAMME TASKS - MPD REVISION

Initial threshold & repeat interval	Airframe tasks All types	Tasks only relate to -8	Tasks only relate to -9	Trent 1000 tasks	GEnx tasks	Total MPD tasks	Inspection MH	Access Requirements
FH tasks								
500FH-4,000FH	22			7	7	**36**	20.99	
2,000FH/12MO	2					**2**	1.30	
6,000FH/18MO	6					**6**	4.50	
6,000FH-8,000FH	23			6		**29**	15.52	Numerous GVI panel access
8,000FH/3,650FC	1					**1**	1.00	
9,000FH/1,000FC (repeat interval 4,500FH/1,000FC)				6		**6**	7.20	
12,000FH	24	4	1	4	6	**39**	28.83	
12,000FH/3,560FC	1					**1**	2.00	
12,000FH/6,000FC/3YE				14	14	**28**	2.8 per Engine	Numerous GVI panel access
14,000FH-18,000FH	4					**4**	2.40	
24,000FH	31			5	5	**41**	41.26	Numerous GVI panel access
30,000FH-36,000FH	6			2		**8**	4.60	
40,000FH	1					**1**	8.00	HSTA restoration
48,000FH	11					**11**	11.10	
FC & calendar tasks								
100FC-1,000FC	13			4	6	**23**	15.60	Engine Borescope inspection
2,000FC/12MO-18Mo	4					**4**	4.70	
4,000FC/2YE	1					**1**	0.20	
5,000FC-6,000FC	4			4	4	**12**	8.40	
6,000FC/3YE	14			2	2	**18**	11.20	
10,000FC-12,000FC	1			4		**5**	3.00	Eng fan blade removal
12,000FC/6YE	5					**5**	4.20	
16,000FC	3					**3**	18.75	
24,000FC/12YE	7					**7**	82.55	Landing gear restoration
50,000FC/20YE	1					**1**	8.00	HSTA secondary load path access
Calendar tasks								
2YE (rpt 1YE or 2YE)	3					**3**	10.00	
2YE	10					**10**	5.35	
3YE	47	2				**49**	147.95	GVI panel access
4YE	2					**2**	0.40	
5YE	5					**5**	6.10	
6YE	20					**20**	19.35	Cargo bays (deep access)
7YE	7	2				**9**	15.80	
8YE (repeat interval 2YE)	1					**1**	0.33	
9YE	4	2				**6**	8.25	GVI panel access
10YE	9					**9**	8.50	
12YE	23	1			1	**24**	32.70	Internal fuselage & wings
150MO	1					**1**	1.00	
15YE	3					**3**	1.50	Discard specific oxygen system
20YE	2					**2**	5.80	
Engine change/APU change	2			10	6	**18**	7.80	Engine inspections & APU change
Life limit/Ven Rec/Note	11		1	2	12	**26**	10.00	LLP restorations & checks (OEM dependant)
Life Limit - ENG & APU components	1			20	16	**37**		Engine removal for heavy SV
Life Limit - MLG & NLG components	2					**2**		Tasks for LDG overhaul
Shop Visit	1					**1**	1.00	components during restoration
Total tasks:						**521**		

A small portion of tasks in the 787's MPD are engine type-related. Most engine-related tasks are in the system programme.

either shortened or extended depending on the 787's actual long-term performance.

Regardless of this, most system checks have alternative intervals allocated to them, which makes planning and integrating these tasks more complex. There are several parameters involved: MO, YE, FH and FC *(see table, page 50)*.

Many of the system tasks are OOP, so they do not coincide with a base check. It is assumed for the purpose of this article that most FH and FC tasks that are OOP will be brought forward to the nearest larger A check or a base check. There are also a small number of tasks with a short interval, which are performed frequently, such as a daily tyre pressure check. Larger task groups are described here.

FH tasks

There are 22 airframe tasks and 14 engine-related tasks between 500FH and 4,000FH. These all have single FH intervals attached. A total of 21MH are attributed for inspection in the MPD *(see table, page 50)*.

There are two tasks with intervals set at either 2,000FH or 12MO, WCF. There are a further six items that have intervals at 6,000FH or 18MO, WCF. The inspection MH for these in the MPD total about 4.50MH.

A further 29 airframe and engine tasks come due between 6,000FH and 8,000FH. These tasks require significant inspection panel access, and so will take over 15.50MH to perform, according to the MPD *(see table, page 50)*.

At either 8,000FH or 3,650FC, WCF, one airframe task is due that requires 1MH of inspection time. If the aircraft is powered by Trent 1000 engines, a further six tasks are due at either 9,000FH or 1,000FC, WCF. These six tasks have a slightly different repeat interval of 4,500FH or 1,000FC, WCF, which comes into effect after the initial inspection has been performed. The MPD references about 7MH of inspection time for these Trent 1000 tasks.

At 12,000FH, which is one of the interval parameters for the base check, there is a larger group of tasks, 39 airframe and engine-related items in total. 30MH to perform the inspections is estimated in the planning document.

There are a further 28 engine-related tasks at either 12,000FH, 6,000FC or 3YE, WCF, which one can assume would also come due at the same time as the 39 tasks at 12,000FH. These tasks require about 3 hours per engine to carry out inspections *(see table, page 50)*.

There are about 80 tasks which have intervals shorter than the base check interval of 12,000FH/6,000FC/3YE. These can be incorporated into various A checks, according to their intervals. Some of these tasks may be incorporated into later base checks as the aircraft accumulates FH and FC through its years of operation.

The remaining FH-dependent tasks listed in the MPD come due between 14,000FH and 48,000FH in the system tasks section. Four airframe tasks come due between 14,000FH and 18,000FH *(see table page 50)*.

At 24,000FH, which could fall in line with the second base check, 41 tasks are listed. Ten of these tasks are engine-related and depend on engine type. In total 41MH are allotted as inspection time in the MPD for these tasks.

Between 30,000FH and 36,000FH another eight tasks come due. Two of these are performed if the aircraft has Trent 1000 engines. These tasks are relatively minor and require about 5MH.

The horizontal stabiliser actuator (HSTA) requires restoration at 40,000FH. This is referenced in the MPD as requiring about 8MH to inspect.

40,000FH equates to about 12YE assuming industry figures, which is a long time to predict to stay on-wing. This task, therefore, may have its interval revised if findings arise ahead of this interval.

The last FH tasks fall at 48,000FH. These consist of 11 airframe tasks *(see table, page 50)*.

FC & calendar tasks

There are 79 tasks that are FC and/or calendar driven, WCF. There are 23 tasks between 100FC and 1,000FC, 10 of which are engine-related and mainly consist of borescope inspection tasks *(see table, page 50)*. There are four tasks that fall due at 2,000FC. These have alternative intervals of either 12MO or 18MO attached to them and inspection requirements of 5MH.

18 tasks are due at either 6,000FC or 3YE, WCF. This again should coincide with the first base check, assuming industry average utilisation. 14 of these tasks are applicable to both -8s and -9s.

As the FCs accumulate, more deep access tasks appear in the systems section, since operational wear and tear, as well as airframe fatigue, starts to be monitored.

Landing gear removal for overhaul is required at 24,000FC or 12YE, WCF.

At 50,000FC or 20YE, WCF, the HSTA secondary load path access inspection is due, historically a large task. At 50,000FC or 20YE the MPD suggests a long interval for this item before inspection is performed.

Calendar tasks

Remaining system tasks are calendar timed, with YE frequencies *(see table, page 50)*. Every 2YE, 10 airframe tasks fall, with 5.50MH suggested for inspection. At 3YE – the base check interval – 47 additional airframe tasks are referenced. The MPD offers 150MH as a guideline inspection time for these.

There are a further 20 airframe tasks are listed in the MPD at six years *(see table, page 50)*. These would come due every second base check. Deep internal

787 MPD FREQUENT INTERVAL OR 'A' CHECK TASKS (1,000FH & 200FC/4Mo) BASED ON AVERAGE FLEET UTILISATION

Line Checks	Interval & Repeat threshold	Airframe tasks (all types)	Number of Trent 1000 tasks	Number of GEnx tasks	Total No. of MPD tasks	Inspection MH (MPD)
'A' check task groupings						
1A Tasks: 1,000FH/200FC & 4MO						
	1,000FH	8	2	2	12	4.85
	200FC	1			1	0.50
	250FC		2		2	0.60
	3MO/400FC	1			1	0.20
	5MO/800FC	4			4	2.00
				Total	20	8.15
2A Tasks: 2,000FH/400FC & 8MO						
	2,000FH/12MO	2			2	1.30
	2,000FH	2	2	2	6	1.76
	500FC		2		2	0.60
	600FC	4		4	8	7.70
				Total	18	11.36
3A Tasks: 3,000FH/600FC & 12MO						
	3,000FH-3,500FH	2			2	1.25
	12MO/1YE	5			5	4.30
				Total	7	5.55
OOP tasks to be included on line inputs or nearest 'A' check						
	6MO	8			8	2.35
	1,500FH		5	5	10	8.48
2nd & 3rd 'A' check cycle inclusions before and between base checks at 3YE						
	1,000FC	2		2	4	3.80
	2,000FC / 12MO or 18MO	4			4	4.70
	4,000FH	6	4	4	14	8.05
	6,000FH	13	4		17	8.95
	7,500FH		2		2	1.0010
	8,000FH	10			10	5.57
	13MO	1			1	0.20
	18MO	1			1	0.10
	6,000FH/18MO	6	10	10	26	19.50
	24MO	3			3	3.00
	2YE	13			13	15.35
	8,000FH/3650FC	1			1	1.00
	4,000FC/2YE	1			1	0.20
	9,000FH/1,000FC		6		6	7.20
				Total	103	78.62

access to cargo bays and general inspection via access panels are required in these tasks *(see table, page 50)*.

At 10YE and 12YE other large groups of tasks come due: nine tasks at 10YE requiring 9.00MH for inspection, and 25 tasks at 12YE. One of these tasks is only for the GEnx engine, while the remaining airframe tasks require extensive external access to the fuselage and wings.

The longest YE interval system task is 20YE. Two airframe tasks that will take about 6MH to inspect come due at this point. The repeat interval for these tasks is also 20YE *(see table page 50)*.

A check tasks

A line check (also referred to as a 'phase' or 'A' check) is a group of relatively light tasks, often performed in a hangar. These checks have shorter intervals than base checks.

Excessive downtime is not expected.

The 787's first base check has an interval of 12,000FH, 6,000FC and 3YE, whichever interval is reached first. Aircraft are likely to reach either the 12,000FH or 3YE interval first, depending on annual rate of utilisation. The first C check will have about 232 MPD tasks.

"Boeing suggests a block or phased maintenance programme, based on a daily utilisation of 11FH or 5.5FC," explains Cooper. "This leads to the A check at 1,000FH/3MO and the C check at 12,000FH/36MO". There are no letter checks in the 787's MPD. For the purposes of illustration, however, it is best to refer to the line check as an A check. It should be assumed that the first A check, the 'A1', should consist of items that occur at 1,000FH, 3MO or an equivalent FC of about 500FC.

The A check can be due at three to four months, depending on aircraft utilisation and task interval utilisation if adopting a non-equalised, block maintenance planning programme. For example, current industry utilisation suggests that there will be an A check performed every three to three-and-a-half months. Therefore about three to four A checks would be performed each year. As letter checks have been replaced by the FH/FC and MSG-3 concept, checks can be adapted for each aircraft's needs. The calendar time acts as a backstop if the task requires a more rigid interval for replacement of hard-timed safety components. Other operators may choose to perform each task as it comes due, rather than adopt check packages. This again depends on operating habits and conditions.

The A1 check will also include items that fall outside of the 'A2' check interval. It follows that this should equate to about 2,000FH/8MO and 1,000FC. Any light access task items that are OOP and fall between the A1 and A2 checks will most likely be bought forward into the A1 line check to prevent another interim inspection.

This philosophy would continue through the 'A3' check (3,000FH, 12MO and 1,500FC, WCF) and so on. A series of between nine and 12 A checks will be performed up to the first base check.

"There are 30 items with a frequency of 1,000FH, 1,500FH, 3MO, 5MO, 200FC or 250FC. These could be considered as 1A tasks," according to Cooper. "Consequently there are 26 items with a frequency of 2,000FH, 6MO, 12MO, 500FC or 600FC that could be allotted as 2A tasks *(see table, page 52)*."

Assuming the 3A tasks would fall at either 3,000FH or 12MO, there are a further seven tasks that come due at these intervals *(see table, page 52)*. Inspection time for these is listed in the MPD at about 5.60MH.

In addition to the above tasks that fall due within the first year of operation, other OOP tasks will begin to come due in later A check cycles. These are estimated at about another 100 tasks and extra 80.00MH of inspection requirements *(see table, page 52)*.

Out-of-phase tasks

As previously mentioned, OOP tasks are those whose interval is likely to fall outside of the standard expected line or base check demands for an aircraft. Given the moveable, rather than rigid, structure to the 787's MPD, the performance of these OOP tasks will depend on an airline's operating habits. "As all tasks are usage parameters tasks, the number of OOP tasks in each check depends largely on the light and base check cycle set-up," maintains der Harst. "Depending on the available Part 145 capabilities and operators' requirements, OOP tasks can be addressed individually or combined with an A or a C check. An OOP task, depending on its interval, is most likely to be included in the A or C check that best fits its interval relative to the A or C check." It is often expected that, in order to handle the OOP tasks as conveniently as possible, planners will bring forward OOP tasks into a block maintenance package. This could be the line or base check, even though substantial time may be left in its interval ahead of the task. "It can be seen that most structural and zonal inspections fall in with the C check frequency of 3YE/12,000FH/6,000FC, WCF," says Cooper "but this is not quite so much the case for the system items. Items outside these frequencies may be treated as OOP within the operator's approved maintenance programme (AMP) and performed as they arise. Or, more likely, I anticipate that these OOP system items will be included in the next (suitable) check for the operator."

As an example of a group of OOP tasks, "there are 12 zonal GVI (general visual inspection) tasks at 6MO and at 4,000FH. 40-50% of system tasks, however, fall outside of the base check intervals," maintains Burgess.

The larger number of intervals available per task for the 787, alongside the redundancy of the letter check, has led to some airlines adopting 'equalised maintenance' as standard management. Equalised maintenance means that the operator spreads all tasks across smaller equal maintenance packages rather than the block line and base events that can have significant downtime.

It is early in the 787's operational lifetime, so operators are still determining how best to optimise usage with regard to long-term OOP task management.

Anticipated 787 base checks

Base checks will often include the following tasks: routine general, visual and detailed (special) inspections, non-routine and defect rectifications, ADs, SBs and modifications, component changes, OOPs, and cosmetic work, such as interior cleaning and refurbishment.

The first 787 did not go into operation until October 2011, so no operator has reached the first 6YE structural check yet, let alone the first

787 MPD BASE CHECK TASKS (12,000FH OR 3YE) BASED ON AVERAGE FLEET UTILISATION

Base Check	Interval & Repeat threshold	Airframe tasks (all types)	Tasks relate to -8	Tasks relate to -9	Trent tasks	GEnx tasks	Total No. of tasks	Number of insp MH (MPD)
1c tasks: Every base check & every 3YE								
	3YE	102	2		14	14	**132**	190.25
	6,000FC/3YE	27			2	2	**31**	16.75
	12,000FH/6,000FC/3YE				14	14	**28**	2.8 ENG
	12,000FH	24	4	1	4	6	**39**	28.83
	12,000FH/3560FC	1					**1**	2.00
						Total	**231**	**242.00**
OOP tasks to be included at nearest check								
	8,000FC/4YE	1					**1**	1.50
2C tasks: Every 2nd base check & every 6YE								
	6YE	87	2				**89**	69.40
	12,000FC/6YE	29	4	1			**34**	29.25
	24,000FH	31			5	5	**41**	41.26
						Total	**164**	**140.00**
OOP tasks to be included at nearest check								
	16,000FH	1					**1**	0.20
	18,000FH	2					**2**	2.00
	5YE	5					**5**	6.10
	7YE	7	2				**9**	15.80
						Total	**17**	**24.10**
3C tasks: Every 3rd base check & every 9YE								
	9YE	4	2				**6**	8.25
	10YE	9					**9**	8.50
OOP tasks to be included at nearest check								
	30,000FH-36,000FH	6			2		**8**	4.60
	40,000FH	1					**1**	8.00
	8YE	1					**1**	0.33
	5,000FC-6,000FC	4			4	4	**12**	8.40
						Total	**22**	**21.33**
4C tasks: Every 4th base check & every 12YE								
	12YE	92	8	7		1	**108**	102.00
	24,000FC/12YE	87	17	6			**110**	288.54
	48,000FH	11					**11**	11.10
	150MO	1					**1**	1.00
						Total	**230**	**402.64**
Additional tasks when required by manufacturer life limits								
	Engine change/APU	2			14	10	**26**	10.20
	Life Limit/Ven Rec/Note	11		1	2	12	**26**	10.00
Tasks in 2nd cycle of base checks (12YE to 24YE)								
	15YE	3					**3**	1.50
	10,000FC-12,000FC	1			4		**5**	3.00
	20YE	2					2	5.80
	16,000FC	3					**3**	18.75
	50,000FC/20YE	1					**1**	8.00
	24YE	10	1	1			**12**	23.00
First cycle of 'C' check packages at 12,000FH intervals / 3YE 787-8 with Trent 1000 engines								
	C1 (12,000FH/3YE)							233.00
	C2 (24,000FH/6YE)							370.00
	C3 (36,000FH/9YE)							250.00
	C4 (48,000FH/12YE)							770.00

Note*: Aircraft utilisation will affect base check scheduling and will vary per operator
Note**: MPD tasks carried out at overhaul/shop visits are not included
Note ***: Additional MH will be needed for the LDG removal & installation tasks

The base check cycle is losely defined in the MPD as being a cycle of four base checks. The fourth check has an MPD interval of 48,000FH, 24,000FC and 12YE, whichever is reached first.

major base check. Most airlines, like KLM, will have only seen line check routine maintenance so far.

"The number of checks in a cycle depends on whether the maintenance programme is set up into equalised, un-equalised, or smaller checks. So there can be a cycle ranging from two large checks, to four, or up to eight or even 16 smaller checks, if you divide the base checks intervals to less than three years," explains der Harst. "The first heavy base check should occur at about 12 years."

As described, the base check cycle for the 787 contains four C checks over a 12-year period. This is repeated over the 12- to 24-year period, which is the second base check cycle. It is expected that some ageing or structural monitoring tasks will begin to apply throughout this second cycle. It follows that the third base check cycle will happen in the 24- to 36-year period for the 787.

"The base checks have intervals of 12,000FH or 3YE and a mixture of both. That is, due at 12,000FH or 3YE, WCF," says Burgess. "This first base check may still be termed as a 'C1' by maintenance providers, which would contain the '1C' set of tasks. "The base check and '1C' task group interval is every 12,000FH or 3YE.

"The intervals for the '2C' and '4C' groups of tasks are 24,000FH/6YE, 48,000FH/12YE and 24YE, and they get progressively heavier and so on," he continues.

"The 48,000FH/12YE and 24YE are the more in-depth groups of tasks, with the 6YE tasks covering structure by GVIs as a zonal set of tasks," adds Burgess.

Typically, if adopting the more traditional 'non-equalised' approach to maintenance planning, operators will structure base checks accordingly.

The C1 check includes just the 1C set of tasks, which are those at either 12,000FH, 3YE or 6,000FC in the MPD *(see table, page 54)*. It also includes any OOP tasks with significant downtime potential, because their frequency is close to the parameters that are set for the base check.

For example, there is an airframe task that occurs at 8,000FC/4YE in the MPD that is likely to be brought forward into the first base check *(see table, page 54)*.

Adding up the tasks that meet the frequencies concerned for the C1 check, alongside the associated inspection times, suggests that the MPD lists the following for a C1 base check:

- 132 tasks that fall at 3YE;
- 31 tasks at 6,000FC/3YE;
- 28 tasks at 12,000FH/6,000FC/3YE;
- 39 tasks at 12,000FH; and
- 1 task at 12,000FH/3,560FC.

Including the OOP task referenced above, this totals 232 tasks connected to these intervals, with an advised inspection time given in the MPD of 243.43MH.

One must consider that throughout these estimations, while most of these tasks are airframe tasks that apply to both the 787-8 and -9, about 77 of these tasks are engine- or type-dependent.

The C2 check would as standard include these 1C task items, in addition to some 2C tasks with an expected interval of 24,000FH, 12,000FC or 6YE. Considering these frequencies, the following 2C tasks can be highlighted: 89 tasks at 6YR; 34 tasks at 12,000FC/6YE, WCF; and 41 tasks at 24,000FH.

OOP tasks that could reasonably be included in the C2 check can be added. These could be an airframe task at 16,000FH, two tasks at 18,000FH, and 14 tasks that come due at 5YE and 7YE. This would mean a total of 181 2C tasks to be included in a C2 check, together with the 232 1C group of tasks. Additional inspection time given in the MPD is 164MH, to total 407 MPD MH.

A third base check, sometimes referred to as the 'C3' check, would consist of the 1C tasks again, in addition to those that meet the following intervals: 9YE, 36,000FH or 18,000FC. These could be termed the '3C' set of tasks.

There are also 15 additional tasks referenced at 9YE and 10YE in the MPD. These OOP tasks, which can be added to this check, include eight tasks that fall between 30,000FH and 36,000FH, and a single airframe task at 40,000FH. The MPD highlights about 40MH for the 3C and these 15 OOP tasks.

The final check in the first base check cycle, the 'C4' check, would likely occur at 12YE assuming normal utilisation. It would be expected that this check would include the 1C, 2C, and 4C set of tasks. In terms of 4C items, this would notably include the items listed in the MPD that come due at 12YE, 24,000FC/12YE, 48,000FH and 150MO.

There are 230 4C tasks and about 400 additional MPD MH that are separate to the other sets of tasks.

The above describes all tasks referenced in the MPD, regardless of relevance to type, or engine used, so some will not apply to all 787s in operation. For example, a 787-8 with GEnx engines will have marginally different task requirements to a 787-9 fitted with Trent 1000 engines.

Taking an example of a 787-8 aircraft fitted with the Trent 1000 engine, and assuming 'normal' utilisation with base checks at 12,000FH/3YE intervals, not all tasks listed in the MPD apply. The following total MPD inspection routine MH can therefore be derived:

- C1 check (1C tasks) at 12,000FH/3YE: 233MH
- C2 check (1C + 2C tasks) at 24,000FH/6YE: 370MH
- C3 check (1C + 3C tasks) at 36,000FH/9YE: 250MH
- C4 check (1C + 2C + 3C + 4C tasks) at 48,000FH/12YE: 770MH, not including landing gear removal and installation.

Labour MH quoted in the MPD for the 787's heavy check at 12YE is relatively light. Experience has yet to be gained before it is clear what multiplication factor should be applied to MPD MH to give an accurate estimate of actual MH to perform routine maintenance tasks. There is also too little experience to determine a probable non-routine ratio.

Some additional tasks have already begun to be added to the second base check cycle, which will occur between 12YE and 24YE. These come due at the following frequencies: 15YE, 20YE, 24YE and 50,000FC 20YE, WCF. These create about 26 extra tasks, alongside 60 additional inspection MH in the MPD.

The above approximations are based on industry average utilisation, and basic MPD task demands. It is not representative, therefore, of an operator's individual maintenance programme that may include discretionary maintenance tasks, such as additional inspections specific to that operator. It is also not representative of an equalised maintenance programme, or of an operator that experiences high utilisation of shorter/longer FH:FC ratios than seen in the 'industry utilisation' section. This may further be influenced by factors, such as operational climate (for example, a dry or salty atmosphere), or the type of usage seen by a cargo operator.

Deep access & fatigue tasks

Deep access tasks tend to focus on signs of fatigue and operational wear and tear as a type ages and progresses through its lifecycle stages. These tasks assess how the type is coping under long-term utilisation, and require extensive access and investigation, all of which will involve panel removal. The removal of interior items, such as galleys, lavatories or seating, for example, will take time to perform.

The first major deep access event occurs at the end of the first base check cycle. "The 12YE checks involve a lot of access, including removal of cabin ceiling, sidewall panels and stowage bins," explains Burgess, "The deeper access, however, is at 24YE with the insulation removal."

"Zonal and structural 12YE items require a deep strip of the cargo and passenger compartments," says Cooper. "For the cargo compartment, this means removing all linings, insulation, waste tanks, and certain passenger cabin floor panels.

"In the passenger compartment all sidewall panels, ceiling panels, insulation, overhead bins and certain cabin equipment, including galleys and monuments, need to be taken out ahead of the inspection tasks," adds Cooper.

As the aircraft ages it is expected that the number of MPD tasks related to fatigue and corrosion assessment will increase, although the infancy of the 787 means that these tasks do not yet feature prominently in the current MPD. "Structural groups of tasks will occur in the fatigue programme, alongside the 12YE and 24YE checks. These are not yet finalised, however, by Boeing," says der Harst.

Other considerations

Other considerations should be taken into account when planning and estimating work packages for 787s going into a check. One of these is an additional factor used by maintenance planners to provide a realistic overview of the actual MH to customers. This gives operators an idea of the actual amount of labour MH an A or base check would use. This accounts for access, preparation time, and non-routine findings such as corrosion, or unforeseen replacement of a component or LLP before scheduled expiration time. "Because most of the industry has only experienced a few line maintenance events, it is not yet known what 'real world' factors can be attributed to each single task item," says der Harst. "It depends heavily on the way the MH are defined internally by an operator. This means whether they include administration time or not, and whether factors such as access time are included on the task-card or as a separate item."

Only operators' experience and knowledge of how the 787 handles over several years and thousands of FCs in a variety of climates and operational conditions, in addition to the experience of maintenance providers, will provide reliable figures for this.

Another operator-driven item that has yet to emerge as a part of the overall maintenance programme for the 787 is cosmetic maintenance to the aircraft, as it continues to operate for an extended period of time. The different technologies used, such as the composite fuselage, should in theory improve longevity of the paint. This means an extended period of time for the customer before a touch-up, or full strip and repaint is addressed. "It is not known what the re-paint interval will be for the 787," finishes der Harst. "It will depend on the industry's experience with paint deterioration on a composite fuselage."

It is still too early in the 787's life cycle to fully appreciate the overall effect its enhancements will have from a maintenance planning perspective. It cannot yet be compared in terms of fatigue or ageing performance to counterparts, such as the 767. The 787 also does not yet benefit from MRO knowledge of common quirks or characteristics that may help to understand or prevent some maintenance issues arising. With the 787's high data collation and management capabilities, however, this knowledge may be acquired more quickly than previously seen in the industry. AC