There are 1,100 E-Jets in operation, with the oldest aircraft now 13 years old. These will have completed their first base check cycles and heavy base checks. The E-Jets have a complex MPD, resulting in most base checks having large numbers of deep access tasks.

E-Jets airframe & base maintenance analysis

The four main variants of the Embraer E-Jet family entered service in 2002-2006, so the oldest aircraft are now 13 years old. There are more than 1,100 aircraft in active service. There are no set utilisation or age limits for a base checks in the E-Jets' maintenance programme, but there are large groups of tasks which mean one of the heaviest base checks will come due at an age of nine to 10 years.

The oldest aircraft will have therefore been through their heaviest base checks, but most of the fleet has not.

The Embraer E-Jets have relatively simple maintenance programmes with no pre-defined checks. There are about 1,500 tasks in E-170's and -175's maintenance planning document (MPD), which have flight hour (FH), flight cycle (FC) and calendar intervals. Unlike many aircraft types, the majority of tasks have a single interval criteria, while 146 have dual interval criteria.

Airlines and operators are free to organise tasks in the MPD into maintenance programmes that fit with their operating schedules. The E-Jets' MPD and airframe maintenance programme are examined with respect to the number of tasks at each interval, how the tasks might be grouped and arranged into light and base airframe checks, the types of task and content in each check, and the possible labour and material inputs for each level of check.

Fleet profile

The E-Jet family has been successful both as a regional feeder and small-sized airliner. There are 183 E-170s and 291 E-175s in active service. Main operators in North America are all regional feeder carriers, including: Compass Airlines (44 aircraft), Mesa Airlines (30), Republic Airways (106), Shuttle America (67) and Skywest (38), all providing regional feeder services for Alaska Airlines, American Airlines, Delta Airlines, and United Airlines. Sky Regional Airlines operates 15 E-175s for Air Canada.

Outside of North America operators providing regional and feeder services include Aeromexico Connect (9), BA CityFlyer (6), Egyptair Express (12), Air France regional subsidiary HOP!, Finnair regional feeder Nordic Regional (2), Japan Airlines subsidiary J-Air (13), and Alitalia Express (14).

A few airlines use the E-170 and E-175 to provide optimum capacity: Saudia (15), Flybe (11) and LOT (12).

Despite the E-190's larger size, it is used as a regional feeder by some of its operators. These include Aermexico Connect (30), BA CityFlyer (11), HOP! (10), KLM Cityhopper (28), Lufthansa Cityline (9), Nordic Regional (12) and Republic Airlines (5).

A larger number of airlines use the E-190 as a mainline jet. These include Air Canada (45), American Airlines (20), Austral Lineas Aereas (22), Azul (22), China Southern (20), Copa (26), jetBlue (60), Kenya Airways (15), Tianjin Airlines (46) and Virgin Australia (18).

The E-195 is the largest of the four variants, and so is mainly used as a mainline jet. This includes operations by Azul (61), Air Dolomiti (10), Air Europa (11), Flybe (10) and LOT (6). Lufthansa Cityline operates as a regional subsidiary for Lufthansa with a fleet of 24.

The largest fleet is operated by Republic Airways, with 21 E-170s, 85 E-175s and five E-190s. The second largest is Shuttle America with 51 E-170s and 16 E-175s. jetBlue operates 60 E-190s.

The airlines with the oldest fleets are Republic Airlines and Shuttle America, with the largest number of E-170s. Aeromexico, HOP! and LOT have similarly-aged fleets.

Aircraft utilisation

The global E-Jet fleet is operated and similarly by most operators. The E-170, E-175 and E-190 have average annual rates of utilisation of 2,350-2,550FH and 1,760-1,850FC. Average FH:FC ratios are 1.30-1.43 for the three fleets.

The E-195 is operated at slightly higher rates of 2,700FH, but at shorter average FC times of 1.26FH per FC, and so accumulate about 2,150FC per year. A typical utilisation rate is about 2,500FH per year, slightly over 200FH per month. An average FH:FC ratio of 1.30 equates to an average FC utilisation of 1,800.

The rates of utilisation by some operators are more varied than the typical or average rates. Annual utilisation is just over 1,800FH for BA CityFlyer's fleet, and about 2,000FH for Aeromexico Connect's, Egyptair Express's and J-Air's fleets. At the other extreme, Shuttle America averages about 2,800FH per year with its E-170s.

Azul in Brazil has the highest rate of utilisation, achieving about 3,300FH per year with its E-195s. This is with an average FH:FC ratio of 1.35.

The possible grouping of maintenance tasks in this analysis are based on aircraft utilisation of 200FH and 150FC per month, equal to 2,400FH and 1,800FC per year and an FH:FC ratio of 1.30.

MPD development

The E-170's/-175's MPD has 1,519 tasks. There are three groups that have interval criteria of FH, FC and calendar time. There are 686 tasks with a FH interval, 460 tasks with an FC interval, and 373 tasks with a calendar interval.

Not every task in the MPD applies to every aircraft in the fleet. An example of this is where one task applies to certain line numbers, but not to others. Another

'HALFWAY' CHECK & BASE CHECK SCHEDULE FOR E-JETS

Base check	FH interval	Equivalent FC interval	Equivalent MO interval
HALFWAY 1	3,750	2,900	19
Bas-1/C1	7,500	5,800	38
HALFWAY 2	11,250	8,700	57
Bas-2/C2	15,000	11,600	75
HALFWAY 3	18,750	14,500	94
Bas-3/C3	22,500	17,400	113
HALFWAY 4	26,250	20,400	132
Bas-4/C4	30,000	23,200	150
HALFWAY 5	33,750	26,100	169
Bas-5/C5	37,500	29,000	188
HALFWAY 6	41,250	31,900	207
Bas-6/C6	45,000	34,800	225
HALFWAY 7	48,750	37,700	244
Bas-7/C7	51,500	39,600	263

is where one task applies to aircraft that have not undergone a particular modification, while another task only applies to aircraft that have. The number of tasks that will apply to each aircraft can, therefore, be 100 or 200 fewer than the total of 1,519 listed in the MPD, but there will be additional customer tasks that are listed in an operator's approved maintenance programme (AMP).

"The E-190/-195 have about 50 more tasks in the MPD than the E-170/-175. The content of the two MPDs also differs between the two main types," says Valter Fernandes, operations executive vice president at TAP Brazil.

There are several reasons for the difference in MPDs. One difference is partly because Embraer designed the E-195 first with 100 fuselage frames, while it developed the E-170/-175 as shortened variants by removing some fuselage frames. This led to some design changes on the E-170/-175, especially in the centre fuselage and wing-fuselage join.

The E-170/-175 are also older. Findings from airframe checks often lead to additional or different kinds of tasks, and escalated or shortened intervals.

"Moreover, the fundamental difference is that the E-170/-175 and the E-190/-195 maintenance review boards (MRBs) for the two main types were developed separately, rather than derived from the same basic design," explains Raymond Topin, executive vice president engineering & maintenance at HOP Regional. "The E-170/-175 was designed first, and the E-190/-195 was a complete re-assessment, so there was a big difference in assessing maintenance significant items (MSI) when the E-190/-195's MPD was developed. So, while an MSI led to an operational task being developed for the E-170/-175, the same MSI led to a functional task being developed on the E-190/-195. Embraer is now trying to converge the two MPDs, so that they have fewer differences.

"The main differences between the E-170/-175 and the E-190/-195 are the design of the main landing gear (MLG) legs, the architecture of the flaps, the part numbers in the wings, and the engines. The E-190/-195 has differently configured and higher-rated variants of the General Electric CF34," adds Topin.

FH tasks

The FH tasks have intervals of 100FH to 40,000FH. The FH-denominated tasks are mainly system inspection tasks. There are 39 different task intervals between these two extremes, but there are 11 large groups of tasks at particular intervals.

There is a large group of tasks that forms the basis of the first base check. The base check pattern outlined in the MPD has an interval of 7,500FH for the first base check. This known as the Bas-1 check, or could be referred to as the C1 check *(see table, this page)*. This was escalated from an interval of 6,000FH.

At least 100 of these checks would have had to be performed on the first aircraft in the fleet, before enough result analysis had been completed, before an escalation to 7,500FH is permitted.

The MPD had many tasks with multiples of 6,000FH that were grouped into a pattern or cycle of four base checks. The cycle of four checks would the Bas-1/C1, Bas-2/C2, Bas-3/C3 and Bas-4/C4 checks, and originally had intervals of 6,000FH, 12,000FH, 18,000FH and 24,000FH.

Intervals of the checks are gradually being escalated to a cycle with a full interval of 30,000FH *(see table, this page)*.

The first main group was escalated to 7,500FH, and then the second was escalated to 15,000FH in February 2015. "The aim is to escalate the third group from 18,000FH to 22,500FH in early 2016," says Topin. "The fourth group currently at 24,000FH should be escalated to 30,000FH, to allow the four checks in the cycle to have a full interval of 30,000FH. This will not be before about 100 of the fourth base checks have been performed, however. These will provide the data samples and analysis required to make the escalation possible."

Based on an FH:FC ratio of 1.3:1 and an annual utilisation of 2,400FH and 1,800FC, the 7,500FH interval is equal to 5,800FC and 38MO *(see table, this page)*.

The Bas-2/C2 check has an interval of 15,000FH, which is equal to 11,600FC and 75MO. The Bas-3/C3 check interval of 22,500FH is equal to 17,400FC and 112.5MO *(see table, page 42)*. The Bas-4/C4 check has an interval of 30,000FH, which is equal to 23,200FC and 150FC *(see table, this page)*.

"Most E-Jet operators use these intervals for the basis of their base check cycles," says Fernandes. "There is the possibility that an airline can remain with the original base check programme of four checks at 6,000FH intervals until all four checks have been escalated to a multiple of 7,500FH, and the full cycle interval is at 30,000FH. The operator would then have to put the aircraft through a bridging programme."

The four base checks of the first base check cycle and first three checks of the second base check cycle, with their FH, FC and calendar intervals in months (MO) are shown *(see table, this page)*. The Bas-7/C7 check is significant since it has an interval close to 40,000FC. A large group of heavy tasks comes due at 40,000FC, marking a point at which the aircraft's maintenance requirements make it uneconomic to operate.

In addition to the main base checks, there are also 'halfway' checks at every 3,750FH, that are performed every 3,750FH between the base checks.

The E-170/-175 and E-190/-195 have several structural differences, and the MRBs for the two were developed separately. As a consequence the two MPDs have different numbers of tasks, and different types of task for maintenance significant items.

The design philosophy behind the E-Jet seems to have featured smaller and frequent light checks with system tasks and short downtimes to keep the aircraft operational. The MPD has the heavier tasks in large groups that would be performed in the base checks.

Light tasks

Tasks with intervals shorter than 7,500FH may therefore be grouped into a pattern of lighter checks. The first large group of tasks are 30 inspections with an interval of 750FH. This is followed by nine tasks at 1,500FH, 14 tasks at 3,000FH, a larger group of 48 tasks at 3,750FH, and 14 tasks at 6,000FH. All of these groups have intervals that are multiples of 750FH. These tasks are all relatively light in terms of access and require a relatively short downtime.

Tasks with intervals shorter than 7,500FH are arranged by many airlines into what are generically termed 'A' checks. There are several groups of FH tasks with intervals that are multiples of the 375FH interval of the 1A tasks. Some airlines have a cycle of A or 'half A' checks every 375FH.

The highest multiple is 24A tasks at 9,000FH, and so a check cycle is 24 checks with the A24 check at 9,000FH.

Some light tasks with shorter intervals are left-hand of the aircraft, and others are right-hand tasks. Some airlines split these between A checks to get an equalised pattern and grouping of tasks.

Most A checks are relatively light, and can be completed in an overnight shift, causing minimal disruption.

Base check tasks

In addition to the main base check task groups, there is a group of 47 tasks at 3,750FH. This group has some big tasks requiring the removal of panels for access. The downtime for the check is about two and a half days. The check is therefore treated separately to the A check task groups.

Even though the interval is 10 times the A check interval, it is not treated like the A10 check or the tenth check in the cycle. A checks are not performed exactly every 375FH. The actual achieved interval will be shorter, so the A10 check will be performed several hundred FH before 3,750FH. The group of 47 tasks at 3,750FH is therefore not in phase with the A check cycle. The group of tasks is therefore treated like a mini base or C check, and could be generically referred to as 'halfway check'. This is because it comes due halfway between the base checks *(see table, this page)*.

The 3,750FH interval for this check is equal to 2,900FC and 19MO at the rates of utilisation used in this analysis. The A checks are also out of phase with this halfway check, and so the two are managed separately.

There are several large groups of FH base check tasks. The group of base tasks with an interval of 7,500FH has 265 inspection tasks, the 12,000FH group of tasks has 15, the 15,000FH group has 114, the 18,000FH group has 42, the 22,500FH group has seven, the 24,000FH group has 24, the 30,000FH group has five, and the 40,000FH group has 10 *(see table, page 44)*.

1C tasks

The interval for 265 of the tasks in the 6,000FH group was extended to 7,500FH. This group is the core of the tasks that form the C1 check, and so became the Base 1 (Bas-1) check interval. The tasks could be generically referred to as the '1C' tasks. They will be performed for the first time at the C1 check, and every C check thereafter.

The other large groups of tasks with FC and calendar intervals are grouped into a particular base check according to how the different FH, FC and calendar groups fall due in relation to each other.

The 7,500FH tasks include 28 that affect the passenger doors. These require relatively deep access, and include lubrication and checking of the locking mechanism of passenger doors. There are also a large number of similar tasks relating to the cargo doors. The 28 tasks also include several zonal inspections in the wing-fuselage fairing, and engine pylons and cowling doors. The 1C tasks at 7,500FH are relatively light, however, and few panels have to be opened to gain access. Areas that do have to be opened are on the outside of the aircraft, for example, for fuselage inspections.

Some tasks were left or 'dropped out' and remained at 6,000FH. This has resulted in the MPD task groups with the different intervals described. These could be included in either an A, since they are at a multiple of 750FH. "These tasks need to be anticipated, and either performed out-of-phase with the base check cycle, or with smaller scheduled checks," says Fernandes.

In addition to the tasks at 7,500FH, there are also smaller numbers of tasks with intervals of 8,000FH, 9,500FH, 10,000FH, 12,000FH, 12,600FH, 13,000FH and 13,750FH. These are likely to be brought forward and included in the C1 check, together with the 1C tasks and the tasks at the 3,750FH interval that comprise the halfway check.

The MPD MH for each group of tasks are also listed *(see table, page 44)*. The task groups with particularly deep access requirements and the nature of the deep access required are highlighted *(see table, page 44)*.

The group of 1C tasks is carried out every 7,500FH, together with the 47 tasks comprising the halfway check, and totals 299 tasks. The group has 260MH listed in the MPD, including 197 MH for the 265 1C tasks, 33MH for the 47 halfway check tasks, and 21MH for the 15 tasks at 12,000MH *(see table, this page)*.

MAIN FH TASK GROUPS FOR THE E-170/-175

Task group	No. of tasks	FH interval	MPD MH	Deep access requirements
1C	47	3,750	33	
	265	7,500	197	28 tasks: various passenger & cargo door inspections, outer fuselage inspections
	4	8,000	3	
	1	9,500	1	
	10	10,000	4	
	15	12,000	21	
	2	12,600	1	
	1	13,000	1	
	1	13,750	0	
2C	114	15,000	128	36 tasks: several deep fuselage structural inspections - require removal of interior furnishings
	2	20,000	1	
3C	42	18,000 (to be 22,500)	57	46 tasks: wing main box, fuel tank, fuselage structure & cargo compartment
	7	22,500	1	
	6	25,000	4	
	2	26,000	1	
4C	24	24,000 (to be 30,000)	41	18 tasks: Fuselage doors, panels, side & top structure
	5	30,000	1	
	8	36,000	8	8 tasks: Deep fuselage & aircraft structure
5C	10	40,000	5	

MAIN FC TASK GROUPS FOR THE E-170/-175

Task group	No. of tasks	Initial FC interval	MPD MH	Deep access requirements
1C	37	6,250-10,197	44	Cargo doors, fuselage structures, aft bulkhead & fuselage, & wing main box
2C	35	11,979-17,299	59	Wing main box, rear fuselage frames, passenger door cutouts, stabiliser fittings, & wing stub spar
3C	179	17,840-22,000	370	Door latches & structures, centre fuselage, aft & forward bulkheads, wing box & spars, & horizontal stabiliser, fuselage structures & windows
4C	34	23,440-27,500	92	Wing structures, fuselage structures & skins, wing skin panels
5C	16	29,202-33,000	71	Forward bulkhead & wing structures
6C	16	35,794-38,648	35	Passenger door cutouts, internal fuselage structures
7C	125	40,000	242	Engine mounts, internal wing structures, fuselage structures, doors, forward & aft bulkheads

2C tasks

Almost 130 tasks at 12,000FH formed the basis of the Base 2 (Bas-2) or 'C2' check. Most of these were escalated to 15,000FH in February 2015, while 15 tasks have remained at 12,000FH. The 114 15,000FH tasks are the core of the Bas-2 check. The 12,000FH and 15,000FH tasks could be generically referred to as the 2C tasks, because other groups of tasks will also be performed in the C2 check. These 2C tasks will be first performed at the C2 check, and then every second C check thereafter; being the C4 and C6 check.

The 15 tasks in the 12,000FH group have two zonal inspections relating to the engine pylon and wing lower skin panel. These are likely to be grouped with the 1C tasks.

There are 36 tasks with a 15,000FH interval that involve inspections and tasks that delve deep into major structures *(see table, this page)*. "These include several inspections in the wing stub areas and behind the sidewall panels, in the area of the fuel tanks, the fuselage bulkheads and related areas and structures, the centre fuselage structure, and the wing flap mechanisms," says Topin. "There are also several tasks relating to the fuselage floor, and top and side structure. These all require the removal of the galleys and lavatories, as well as other interior items and furnishings. The whole interior has to be removed to allow these inspections, which uses a large number of MH to complete. Having gained this deep access, it makes sense to include as many other deep access tasks as possible to avoid duplicating downtime and access MH. The actual timing of the Bas-2 or C2 check with these tasks is four to six years, depending on annual utilisation."

There are also two tasks at 20,000FH, which could be grouped with the 2C tasks *(see table, this page)*.

3C tasks

The third main group of 42 tasks has an interval of 18,000FH. Another seven have already been escalated to 22,500FH, a three-times multiple of 7,500FH. Most of the rest of the 18,000FH tasks should get escalated to 22,500FH in February 2016, allowing these tasks to be in phase with the tasks at 7,500FH. Together they conveniently form the basis of the Bas-3 or 'C3' check, so the 22,500FH tasks could be referred to as the 3C tasks. They will first be performed at the C3 check and again at the C6 check.

At 18,000FH, 40 out of 42 tasks require deep access. These include the wing main box, the fuel tank, deep parts of the fuselage, the cargo compartment, and various structures in the flightdeck. Although these tasks require physical external and visual inspections of the fuel tank and surrounding area, accessing it is relatively easy because panels can be opened in the underside of the aircraft behind the landing gear bay.

There are seven tasks at 22,500FH, but four of these require inspections of the passenger door structures. As well as the tasks at 18,000FH and 22,500FH in the 3C group of tasks, there are six tasks at 25,000FH and two at 26,000FH which could all be grouped together and performed at every third C check. Two tasks at 25,000FH require deep access.

There are 57 tasks that have a total labour requirement of 63MH in the MPD in the 3C group. The group includes 46 deep access tasks *(see table, this page)*.

The MPD for the E-Jets has tasks with FH, FC and calendar intervals. There are several large groups of tasks for each type of interval, and this complicates base check planning. A large number of deep access tasks that come due every second base check require the removal of the entire cabin interior.

4C tasks

The fourth main group of 24 tasks at 24,000FH is expected to be escalated to 30,000FH in 2017. This group of tasks could be referred to as the 4C tasks. This would put them in phase with the 7,500FH and 15,000FH tasks, so the three groups would conveniently form the core of the Bas-4 or 'C4' tasks. The 4C tasks would be performed for the first time at the C4 check and then again at the C8 check.

Of the 24 tasks at 24,000FH, 18 require deep access, including inspections of: various EWIS components; fuselage doors; panels; side structure; and top structure. This group of tasks includes some internal fuselage inspections, which require the removal of some interior items and opening of panels.

There are also two groups of five and eight tasks at 30,000FH and 36,000FH. These are EWIS-related inspections that involve inspections deep in the fuselage and aircraft structure, but few additional MH would be needed to gain access for these task, if they were included in a check with C2 tasks. These are also likely to be grouped with the 4C tasks.

This group of 37 tasks has a total labour requirement of 50MH in the MPD. The group includes 26 deep access tasks *(see table, page 44)*.

5C tasks

There are 10 tasks with an interval of 40,000FH, all related to inspections of the slat and flap mechanisms. These would come due for the first time at the C5 check, and so be referred to as the 5C tasks. This would be the first check of the second base check cycle, with an MPD labour requirement of 5MH *(see table, page 44)*. The C5 check has an interval of 37,500FH, 29,000FC and 188MO *(see table, page 42)*.

The base check cycle would continue at the same intervals. The FH intervals and equal FC and MO intervals up to the C7 check are summarised *(see table, page 42)*. The C7 check has an interval that is equivalent to about 22 years of operation.

FC tasks

The FC tasks have 70 different intervals, ranging from 600FC to 40,000FC, and a total of 460 tasks.

The FC group has a relatively large number of tasks with dual interval criteria. There are 120 tasks which also have a dual FH interval. For all 120 inspections the ratio between the MPD FH and FC intervals of these tasks is 1.33. The actual interval used will be the one reached first.

In this particular analysis where aircraft are examined at an FH:FC ratio of 1.30:1, the FC and FH intervals will be reached at almost exactly the same time. "The FC tasks are usually performed at the same time as the FH tasks, in accordance with the operator's FH:FC ratio," says Fernandes.

The two large groups of tasks are at 20,000FC and 40,000FC, which have 146 and 125 inspections.

600-22,000FC

Besides the two large groups of 20,000FC and 40,000FC tasks, there are another 125 FC tasks at 50 different intervals between 600FC and 22,000FC. There are also 20 tasks between 600FC and 5,500FC that are more likely to be performed during lighter checks.

The remaining 105 tasks are between 6,250FC and 22,000FC. The large number of intervals, and small number of tasks at each interval, makes it difficult to plan these as groups into base checks. This inevitably means many will have to be brought forward, so their full interval will not be fully utilised. They are more likely to be included in the C1, C2 and C3 base checks before the C4 check. The actual check they are included in depends on the aircraft's overall FH:FC ratio.

Tasks that fall due between the C1 and C2 check intervals are assumed to be brought forward to the 1C interval of 5,800FC. These are 37 tasks with initial intervals of 6,250-10,197FC *(see table, page 44)*. This includes three deep access tasks.

The 35 FC tasks that fall due between 11,979FC and 17,299FC are assumed to be brought forward to the 2C interval of 11,600FC *(see table, page 44)*. This includes 11 deep access tasks.

Tasks between 17,840FC and 22,000FC are assumed to be brought forward to the 3C interval *(see table, page 44)*. Besides the large group of 20,000FC tasks, there are another 32 in this interval range, including 30 deep access tasks, that would be included in the 3C group.

There are 44 tasks with intervals between 6,250FC and 22,000FC that need deep access for routine inspections. Deep access tasks with FC intervals include inspections of the cargo and passenger door structures and locking mechanisms, the forward and aft pressure bulkheads, structures relating to the flap and slat mechanisms, the fuselage structure and window cutouts, the vertical and horizontal stabilisers, the main wing box, and the wing structure. These deep access tasks are mainly GVI, DET and special detailed inspection (SDI) tasks. SDI tasks require use of the NDT manual for instruction. Some of the tasks are in fact just visual inspections. Many SDI tasks require deep access.

FC tasks are external, so they can be performed relatively easily. Many of the FC tasks with lower intervals will get included with the C1 or C2 checks. Check planners should aim to combine the C1 and C2 checks with as many of the FC tasks as possible to minimise access. Combining task groups to avoid repeat access and downtime would mean bringing many tasks forward and not utilising a large portion of their interval. Most of the tasks at 18,000FC are deep access, and involve opening up a lot of the interior. Some of the inspections are in the tail cone. Two tasks are deep internal inspections in the centre of the fuselage. These require removal of much of the interior, so planners try to combine these with the C2. They are more likely, however, to be included in the C3 check because of their interval.

20,000FC tasks

There are 147 tasks at 20,000FC, including 87 that require deep access for task completion, making the tasks at the interval particularly relevant to base check planning. These are all related to the same areas of the aircraft as the deep access tasks with shorter intervals. These are all GVI, SDI and DET tasks. The SDI tasks require the deepest access, and so add the largest number of MH.

The FC interval is equivalent to about 26,000FH. It is preferable to combine the 20,000FC tasks with 2C tasks at 15,000FH to minimise repeating access. The Bas-4/C4 check that includes a repeat of the 15,000FH tasks in its workscope, and the 20,000FC tasks that will be a part of the C3 check, means that the C2, C3 and C4 checks are all likely to be heavy checks with a high level of access MH.

Many of the tasks with an initial interval of 20,000FC have shorter repeat intervals. There are 88 tasks with repeat intervals of 3,700-18,212FC. Many of these have deep access requirements, so base maintenance will get increasingly heavier once the 20,000FC tasks have been performed for the first time. This can mean that the C checks will get really heavy after these 20,000FC tasks have been performed for the first time, because they consume a large number of access MH. The repeat intervals for many of the FC tasks are relatively short because the rate of fatigue in the aircraft's structure accelerates.

There are also 59 tasks with the standard repeat interval of 20,000FC, which will complicate planning after this group of 147 tasks has been performed for the first time. Ideally, all tasks with short repeat intervals will be escalated to 20,000FC.

The total number of MPD tasks included in the 3C group is therefore 179. These have an MPD labour requirement of 370MH *(see table, page 44)*.

23,440-38,900FC tasks

There are another 66 tasks with 40 different initial intervals between 23,440FC and 38,900FC. The large number of intervals makes it hard to plan these tasks separately into main base checks, especially because of the deep access requirements. The intervals of these tasks means that many are likely to be brought forward and grouped together with the 4C, 5C and 6C tasks.

The 34 tasks with initial intervals of 23,440-27,500FC are brought forward to the 4C interval of 23,200FC *(see table, page 44)*. These have an 92MH in the MPD. This includes 20 deep access tasks.

The 16 tasks with intervals of 29,202-33,000FC are brought forward to the 5C interval at 33,988FC. This includes three deep access tasks with an MPD labour requirement of 71MH *(see table, page 44)*.

The 16 tasks with intervals of 35,794-38,900FC are brought forward to the 6C interval at 34,800FC. This includes nine deep access tasks with an MPD labour requirement of 35MH *(see table, page 44)*. The deep access tasks are DET, GVI and SDI inspections.

40,000FC tasks

The second large group of tasks comprises 125 inspections at an initial interval of 40,000FC, equal to about 52,000FH. There 95 tasks in this group with an initial interval of 40,000FC that require deep access tasks. All are DET, GVI and SDI tasks.

The 40,000FC tasks will come due at about 22 years. This raises the question of whether operators will perform this large group of tasks to keep the aircraft operational for up to another nine or 10 years before the next large groups of FH tasks and 20,000FC tasks come due.

Many of the inspections require deep access, so maintenance planners may try to combine them with one of the heavy C checks in the second base check cycle, such as the C2 or C4 when the galleys and lavatories are removed. The way to plan checks is to look at the access requirements of the big tasks groups, and then try to combine their interval in the most optimal way possible.

There are, however, 77 tasks with an initial interval of 40,000FC which have repeat intervals between 5,448FC and 38,000FC. The number of tasks in each repeat interval group is small, and only up to 18 in the case of one group. It is unlikely, however, that most of these will have to be performed a second time. The short repeat interval of these deep access tasks means that the aircraft's maintenance requirements increase more steeply after the 40,000FC tasks have been performed for the first time than after the 20,000FC tasks have been performed for the first time. This could make the aircraft uneconomic to operate after it has had the 40,000FC tasks performed.

There are 42 tasks with an initial and repeat interval of 40,000FC. These will only ever be performed once in the aircraft's operational lifetime.

MAIN CALENDAR TASK GROUPS FOR THE E-170/-175

Task group	No. of tasks	MO interval	MPD MH	Deep access requirements
1C	25	36-60	24	4 tasks: Fuselage floor-frame attachments
2C	118	72-108	319	117 tasks: Cargo doors, passenger door structures, fuselage, rear bulkhead, engine pylons, wing box, fuselage skin panels
3C	175	120-144	593	134 tasks: Passenger door structures, rear fuselage skin & tail cone, centre & forward fuselage skin, wing box spars & ribs, ailerons, engine mounts & horizontal stabiliser
4C/5C	12	180	4	

Calendar tasks

There are a relatively small number of different intervals for the calendar tasks in the MPD. These range from two days (DY) to 180MO.

The 373 tasks can be split into two groups. The first group of 43 tasks have intervals between 2DY and 24MO, so they will be included in line and light checks. There are 16 tasks in this group with a 14DY interval that also have a second interval of 120FH. In the case of aircraft completing 200FH per month, the 14DY interval will be reached first.

The base or 'C1' check interval of 7,500FH is equal to a calendar time of about 38 months. The 330 calendar tasks with intervals from 36MO to 180MO will therefore be grouped into the various base or 'C' checks according to their

BASE CHECK TASK GROUPING & BASE CHECK PATTERN

BASE CHECK	FH INTERVAL	FC INTERVAL	FH TASK GROUPS	FC TASK GROUPS	MO TASK GROUPS	TOTAL TASKS	NO. OF DEEP ACCESS TASKS	TOTAL MPD MH
Bas-1/C1	7,500	5,800	1C	1C	1C	361	35	328
Bas-2/C2	15,000	11,600	1C + 2C	2C + REPEAT TASKS	1C + 2C	675	164	828
Bas-3/C3	22,500	17,400	1C + 3C	3C + REPEAT TASKS	1C + REPEAT TASKS	805	297	1,317
Bas-4/C4	30,000	23,200	1C + 2C + 4C	4C + REPEAT TASKS	4C + REPEAT TASKS	802	46	1,023
Bas-5/C5	37,500	29,000	1C + 5C	5C + REPEAT TASKS	REPEAT TASKS	522	3	509
Bas-6/C6	45,000	34,800	1C + 2C + 3C	6C + REPEAT TASKS	REPEAT TASKS	979	9	1,720
Bas7/C7	51,500	39,600	1C	7C + REPEAT TASKS	REPEAT TASKS	571	95	678

interval. There are 13 different intervals for these 330 tasks. Few of the tasks have repeat intervals that are different to their initial intervals. This simplifies planning of these tasks into later checks after they have been performed for the first time.

The largest groups of tasks have intervals of 72MO, 96MO and 120MO, which have 39, 76 and 168 tasks. These three large groups are corrosion prevention control programme (CPCP) inspections. These tasks account for most of the deep access tasks in the FC group of inspections.

The tasks that could be regarded as 1C calendar tasks therefore have intervals between 36MO and 60MO *(see table, page 47)*. There are 25 tasks with a labour requirement of 24MH in the MPD, including four deep access tasks.

There are 118 tasks with intervals between 72MO and 108MO, which have 319MH listed in the MPD. All are deep access tasks. These could be regarded as 2C tasks, and be performed together with the 2C FH tasks.

All 39 72MO tasks need deep access, and involve inspections of the cabin doors, fuselage structure, engine pylons, stabiliser and wings. These are all GVI, SDI and DET tasks. The passenger door tasks have light access requirements. The access gained for the C2 tasks means that little or no additional access will be required for the 72-month tasks. “Despite the 72MO interval, we actually carried out the tasks in our Bas-1/C1 checks,” says Topin. “We included them in the C1 to avoid an intermediate check between the C1 and C2. Our annual utilisation is about 2,000FH, so the Bas checks come due about every 45 months, meaning that the Bas-2 check would be at 90 months.”

The 90MO, 96MO and 108MO tasks would also be grouped with the 2C tasks.

All 76 tasks at the 96MO interval require deep access to complete the inspections. They affect the fuselage structure, wings, passenger doors, and engine pylons. These are DET and GVI tasks. “Like the 2C tasks, the 96MO tasks include inspections that require the removal of items such as the interior, landing gears, and some flight control surfaces,” says Topin.

If they are included in the C3 check, the access required for the 20,000FC tasks will minimise additional access MH required for the 96MO tasks. If included in the C2 check, the access for the 96MO tasks will be minimised by the 15,000FH tasks. “We included the 96MO tasks in the Bas-2 checks to save spending MH on additional access, since the 2C FH tasks already require removal of the interior,” says Topin. “The FH escalations of Bas checks, and the groups of tasks that need deep access but have different intervals, mean that compromises have to be made in grouping tasks into base checks.”

The 168 tasks at 120MO, together with the seven at 132MO, 136MO and 144MO, would comprise a 3C task group, being brought forward to the 112MO interval. This group of 175 tasks has a particularly large labour input, since there are 593MH in the MPD. Moreover, 134 of the tasks require deep access to perform them.

The 120MO group of tasks is large, and 132 of the 168 tasks require deep access. They relate the structure of the wings, fuselage and stabiliser. As with all other deep access FC and calendar tasks, the deep access tasks at this interval are DET, GVI and SDI tasks. “These have similar deep access implications as the 2C tasks,” says Topin. Access MH required will be minimised if the tasks are included in either the C3 or C4 check.

The highest interval for calendar tasks is 180MO, so it could be performed for the first time at the C4 check at 180 months or at the C5 check since it is unlikely to be performed at its full interval of 188MO. There are 12 tasks, all of which relate to emergency equipment, and do not need deep access. They have an MPD labour requirement of 4MH.

Base check task groups

The main groups of FH, FC and calendar tasks have been described. Tasks are grouped into checks by analysing the access requirements of each major group first, and then grouping them appropriately.

The grouping of tasks into base checks is complicated by the large number of repeat intervals of the many groups of FC tasks. An example is the 146 tasks with an initial interval of 20,000FC, which are included in the 3C tasks when performed for the first time.

This group can be sub-divided into 16 groups that have different repeat intervals, ranging from 2,000FC to 18,000FC. The tasks with repeat intervals of 2,000-5,500FC would be included in lighter checks after being performed for the first time. The tasks with repeat intervals of 6,000-11,000FC would be repeated at every base check, the tasks with repeat intervals of 12,000-17,000FC would be performed at every second base check, and the tasks with repeat intervals of 18,000FC would be performed at every third base check.

Similarly, the calendar tasks with initial intervals of 96MO are sub-divided into groups with repeat intervals of 40MO, 64MO, 78MO, 82MO, 86MO, 88MO and 90MO. These will fall due at different base checks after being performed for the first time at the C2 check at about 75 months.

As described, the base checks are the C1 at 7,500FH, the C2 at 15,000FH, the C3 and 22,500FH and the C4 at 30,000FH *(see table, page 44)* on the basis of the large groups of FH tasks. These have equivalent FC intervals of about 5,800FC, 11,600FC, 17,400FC and 23,200FC. “The Bas-1/C1 is relatively light, and has a downtime of

There are several large groups of FC and calendar tasks. This ultimately results in three out of four checks in the base check cycle having heavy workscopes, with large numbers of deep access tasks.

about eight days," says Topin. "The Bas-2 is actually the biggest check in the cycle, since the galleys and all of the cabin interior have to be removed. The E-170/-175 and the E-190/-195 also comes into a lot of structural SBs that have to be performed after the aircraft has accumulated 5,000FC. These SBs are strengthening improvements in the wing structure. Topin explains that they are highly recommended, but are not mandatory. They should be done to avoid some major structural repairs in later checks. The number of SBs and structural modifications that has to be performed depends on the maturity of the aircraft. Later production aircraft will have had modifications incorporated on the production line, while older ones will need the largest number of modifications. As aircraft get close to a total time of 20,000FC it is common for them to use about 1,000MH for these structural modifications.

"When these structural SBs are added to all the other tasks in the Bas-2/C2, the check takes 21-28 days to complete," continues Topin. "A lot of MH can be used in the same area when the structural SBs are included."

The 47 FH tasks of the halfway checks at every 3,750FH are performed midway between the base checks. They are therefore at 3,750FH, 11,250FH, 18,750FH and 26,250FH *(see table, page 44)*. The same group of tasks is also included in the 1C group of FH tasks in the main base checks when they come due *(see table, page 44)*.

The main groups of FH, FC and calendar base check tasks and their related MPD MH described are summarised *(see table, page 48)*. The maximum number of MPD tasks, the number of deep access tasks, and related MPD MH are stated here. This number of tasks and MPD MH do not apply to every aircraft in the fleet. The actual maintenance requirement for each aircraft will be less than shown.

Each airline is likely to group and arrange tasks in different ways due to a variety of factors, however.

The 1C to 7C groups of FH, FC and calendar task can thus be arranged into block checks to form the main task groups in the first seven base checks, the C1 to C7 checks *(see table, page 48)*.

The overall effect of the grouping of FH, FC and MO tasks means that out of the eight checks in two base check cycles, only the Bas-1/C1 and Bas-5/C5 checks have relatively light access. The Bas-5/C5 check could require heavy and deep access, however, if the 180MO tasks are included. The 2C FH tasks and other groups mean that the C2 and C4 checks in the first cycle, and the C6 and C8 in the second cycle all require the removal and reinstallation of the interior.

The C3 check will require almost as much deep access as the C2, which is because of the large number of 3C FH and 3C FC tasks, especially at 20,000FC, that require deep access.

The C6 check will have a combination of 2C FH, 3C FH and 3FC task groups, all with deep access requirements.

In addition to the current MPD tasks, there is also the possibility that fatigue tasks will get added to the aircraft's maintenance programme following years of service and fatigue analysis. These are referred to differently by different airframe manufacturers, but usually end up with different FC or calendar tasks being added to the MPD.

Base check inputs

The main elements of base check inputs include aircraft preparation and routine inspections, non-routine defects and rectifications, changing of components and heavy components, cleaning, interior refurbishment, incorporations of SBs and ADs, and stripping and repainting. The MH and material inputs are for the E-170/-175, and not the E-190/-195.

Complete interior refurbishment is less likely on aircraft the size of E-Jets compared with widebodies. The main interior items will be repaired and refurbished on-condition or as required when they get removed during the heavier base checks.

Routine inspections

As described, the actual number of MPD inspection tasks and related MPD MH for each check will be less than shown in the table, because not every MPD task applies to every aircraft in the fleet. There will, however, be some additional customer- and interior-related tasks.

The MPD MH do not reflect the actual number of MH that will be needed to complete the check. Additional labour will first be required for aircraft docking and preparation. The MPD MH also assumes perfect conditions for carrying out each task, and takes no account of the access required. A multiplication factor is used by planning engineers to estimate the number of routine MH that will be required. When working on a new aircraft type, where planners and mechanics have no experience, a multiplication factor of up to 10 can be used for the very first aircraft.

Once experience has been gained and the learning curve for planners and mechanics has been fully reached, a factor of about 3.0 should be used for MPD tasks. A higher factor is recommended for access tasks, especially when panels and interior items have to be removed. About 1,000MH are required to remove and reinstall the interior, which is required during a Bas-2/C2 and Bas-4/C4 check. A smaller allowance of 600MH is used for the Bas-3/C3 check, which does not have such a deep acess

Although the workscopes of the four base checks are large, the intervals between each check are up to three years. This will help amortise maintenance inputs over a long FH interval.

requirement.

The routine and access MH required for the checks in the first base check cycle will therefore be about 1,300MH for the Bas-1/C1, 3,500MH for the Bas-2/C2, 4,550MH for the Bas-3/C3, and 4,100MH for the Bas-4/C4. The total labour for routine inspections and access will be about 13,400MH for the four checks of the first base check cycle *(see table, page 52)*.

The Bas-3/C3 check in this particular case has a particularly heavy burden of the 20,000FC and 120MO tasks. The Bas-2/C2 check has the burden of the 2C, 72MO and 96MO tasks; all of which require deep access.

The routine MH then become light again for the Bas-5/C5 check, while the Bas-6/C6 check has the 2C tasks; and various groups of repeat 20,000FC, 96MO and 120MO tasks. The Bas-7/C7 check is relatively light in terms of FH tasks, but it does have the 40,000FC tasks; as well some repeat tasks from the 20,000FC and 96MO groups. The higher access requirements for these tasks result in higher MH for routine inspections, despite the MPD MH in the Bas-7/C7 check being similar to the Bas-5/C5 check *(see table, page 48)*.

Non-routine rectification

The MH required for rectifying findings and defects clearly increases with successive base checks. It is also likely to be higher in checks that have large numbers of deep access tasks and extensive access requirements.

A non-routine ratio will therefore be about 0.5 for the Bas-1/C1 check. This will climb to 0.8 or 1.0 between the Bas-2/C2 and Bas-4/C4 checks. A consideration has to be given for the likely non-routine ratio that is applied to the access MH. Some non-routine is inevitable, since removing interior items will lead to findings.

The defect ratio generates about 640MH for non-routines and defects in the Bas-1/C1 check; rising to about 2,800MH for the Bas-2/C2 check, which is the first heavy and extensive check the aircraft will undergo. The Bas-3/C3 and Bas-4/C4 checks, which each have a heavy content and require a lot of access, will each use 3,600-4,100MH for non-routine rectifications *(see table, page 52)*.

The total non-routine labour for the four checks in the cycle is about 11,100MH in this case *(see table, page 52)*.

The sub-total for routine and non-routine portions of the base checks is thus about 24,500MH for the four checks in the cycle. While these inputs may seem high, they must be considered in relation to the long interval between base checks. This is almost three years.

Interior cleaning & refurbishment

Interior cleaning will be required during base checks, although it will only account for a small percentage of the total check content. An allowance of about 80MH should be made for a smaller base check, and 120-140MH for larger and more extensive base checks *(see table, page 52)*.

The interior furnishings will not be refurbished as extensively as widebody aircraft used for long-haul operations.

Some furnishings, such as seat covers and carpets, will need to be removed and cleaned during base checks, however.

The interior items, or most furnishings, will be removed during heavier base checks because of access requirements. This will produce findings, and result in some interior refurbishment work being required. The modular construction of the aircraft should simplify this process. A small allowance of 250MH should be made for the Bas-1/C1 check, while a larger allowance of 400-500MH should be made for the heavier Bas-2/C2 to Bas-4/C4 checks *(see table, page 52)*.

An allowance of 800-900MH for stripping and repainting the aircraft should be made. This is likely to be once every two or three base checks *(see table, page 52)*.

Other small additions will be an allowance or budget for the removal and reinstallation of heavy components. This would be about 120MH for lighter C checks, and rise to 350MH for heavier checks where the removal of the landing gear *(see table, page 52)*, and other items such as the thrust reversers or APU for overhaul were included in the check workscope. The main landing gear removal interval is 30,000FC or 144MO, whichever is reached first. The 144MO interval will be reached first, and so the gear is likely to be removed at the Bas-4/C4 check.

SBs, ADs & modifications

As described, a large number of MH will be required for older aircraft with earlier serial numbers for non-mandatory structural modifications, covered by SBs, made to the wings. These will have to be included in the workscopes of the Bas-2/C2 or Bas-3/C3 checks of some aircraft, depending on their age, and will consume in the region of 1,000MH.

A smaller allowance for SBs should also be made for all other base checks. This takes into consideration the regular stream of SBs that are released by aircraft manufacturers, but which cannot be predicted.

Topin says that the E-Jets have had a few, relatively light, airworthiness directives (ADs). Topin explains that the number of ADs has progressively reduced as the production line has progressed; that is, E-170/-175s built from 2004 had

SUMMARY OF MH & MATERIAL INPUTS FOR EMBRAER E-JETS FOR 2 BASE CHECK CYCLES

check	FH interval	MPD MH	Access & Routine MH	Defect ratio	Non-routine MH	Sub-total MH	Interior clean MH	Interior refurb MH	ADs, SBs, & EOs MH	Heavy comp change MH	Strip & paint MH	Total MH	Total material costs-$
Bas-1/C1	7,500	328	1,300	0.5	640	1,926	80	250	200	120		2,600	61,000
Bas-2/C2	15,000	828	3,500	0.8	2,800	6,300	140	500	300	350		7,560	170,000
Bas-3/C3	22,500	1,317	4,550	0.8	3,650	8,200	120	400	300	300	900	10,200	250,000
Bas-4/C4	30,000	1,023	4,100	1.0	4,000	8,100	140	500	300	350		9,400	215,000
Total 1st base check			**13,400**		**11,100**	**24,500**	**480**	**1,650**	**1,100**	**1,100**	**900**	**30,000**	**693,000**
Bas-5/C5	37,500	509	1,800	0.6	1,100	2,900	80	250	200	150		3,600	86,000
Bas-6/C6	45,000	1,720	7,000	0.8	5,600	12,600	140	500	300	350	900	14,800	353,000
Bas-7/C7	52,500	678	3,000	0.9	2,70	5,600	120	400	300	300		6,8400	158,000

51 ADs issued against them, but aircraft delivered from 2006 have had 21 ADs issued and about two or three ADs issued each year. Similarly, E-190/-195s delivered from 2008 have had 27 ADs issued against them, at an average rate of four ADs per year. An allowance of 200-300MH will be used for smaller and regular SBs and ADs that get issued.

The total labour inputs for the four checks of the first base check cycle are therefore about 2,600MH for the Bas-1/C1. These rise to 7,600MH for the Bas-2/C2, 10,200MH for the Bas-3/C3, and 9,400MH for the Bas-4/C4 *(see table, this page)*. Total labour for the four checks in the cycle is thus about 29,900MH.

Cost of materials

Allowances should be made for materials costs, consumables and parts. An approximation can be made by using a ratio of $25 per MH for the routine and non-routine labour portions of the check, a small ratio of $5 per MH for access labour, an allowance of $50 per MH for the regular and non-major SBs and ADs, and $35 per MH for regular interior repairs and refurbishment.

In addition to these, there is also the cost of paint when the aircraft is re-painted. An allowance of $25,000 should be made for an aircraft of the size of the E-170/-175 *(see table, this page)*.

Total cost will thus be about $61,000 for the Bas-1/C1 check *(see table, this page)*. This will rise to about $170,000 for the Bas-2/C2, $250,000 for the Bas-3/C3 and $215,000 for the Bas-4/C4 checks *(see table, this page)*.

The total material cost for the four checks of the first base check cycle is therefore in the region of $693,000 *(see table, this page)*. This does not include, however, the additional costs of replacing a relatively small number of life-limited rotable components, and other rotable components that have to be removed during the base checks following functional and operational system tasks made in the checks. This cost should be covered in an overall rotable supply charge, which is regarded separately to airframe maintenance costs.

The cost of materials also does not include those parts and other items used in performing heavy ADs and SBs.

Rotable component support

E-Jet operators have several choices when it comes to sourcing, managing and repairing stocks of rotable components.

It may be economic for large operators to own their stock, and use their engineering departments to manage repairs and perform all the related tracking and certification procedures.

Operators with small- and medium-sized fleets can elect to have their rotable support managed through a third party specialist contact. Embraer supports a large number of E-Jet operators this way. Other providers include SR Technics, AAR and Spairliners.

Spairliners is a 50:50 joint venture between Air France Industries (AFI) and Lufthansa Technik. This joint venture was initially started in 2005 to provide rotable support for the A380, but its activities have been extended to include the Embraer E-Jets.

Spairliners holds about 20% of the market share for this type of E-Jets support, second only to Embraer. Spairliners supports 11 airlines that include Royal Air Maroc, Lufthansa Cityline, HOP!, Alitalia, KLM Cityhopper, Air Moldova, Air Dolomiti, and Kenya Airways.

The first element of Spairliners's product involves providing a homebase stock of essential rotables, in the region of $5-8 million of rotables for a fleet of about 10 aircraft. This stock typically includes high failure rate, 'no-go' items.

The second element involves the remaining components that are either low failure rate or 'go' items. Customers request these from a centrally located pool of stock. Several airlines have access to this stock. Stock held is increased only marginally when a new customer joins the pool, creating economies of scale.

The stock is held centrally by Spairliners at Paris Charles De Gaulle and Munich airports, in stores operated by AFI and Lufthansa Technik. Items are dispatched to customers on request, which is usually after two to four hours. Maximum flight time for shipments is about 13 hours, and so they are received by the airline within 24 hours. Despite this relatively short processing time for non-essential components, many airlines prefer to have pool stocks located on the same continent as their operations.

Overall, Spairliners holds about $120 million of E-Jet rotable inventory, which is enough to support about 150 aircraft.

The third element of the support service is for Spairliners to perform all repairs, transport, logistics, and all related management activities. A large portion of repairs are performed at AFI or Lufthansa Technik component shops, together with the relevant engineering some components are sub-contracted if AFI or Lufthansa Technik shops do not have the capability in-house. AC