The CRJ-100/-200 has a complex maintenance programme. The aircraft has three A check task groups and three C check task groups, all with different basic intervals. This makes check planning complex, with the result that tasks are performed early and checks are uneven in size.

CRJ-100/-200 airframe maintenance cost analysis

The CRJ-100 has become a popular aircraft since entering service in late 1992. There are now more than 930 CRJ-100s/-200s in operation with 68 airlines. The oldest aircraft are mature in maintenance terms, having been through their first series of heavy checks. The airframe-related maintenance costs of the CRJ-100/-200 are examined here.

CRJ-100/-200 in service

The CRJ-100 was acquired in large numbers by regional airlines, affiliated with the US majors, in North America in the early 1990s as a replacement for 35- to 50-seat turboprops, on the assumption that jets were more appealing to passengers and therefore had the potential to generate higher passenger revenues. Many of the aircraft are operated on hub feeder route networks on flight cycle (FC) times averaging about 70 minutes. A few are also operated on some point-to-point or hub bypass routes with relatively weak traffic demands, because their size makes them suitable for low traffic densities.

The CRJ-100/-200 has also had some success in Europe, even though this is a relatively high-cost environment in which to operate, and is less suitable than North America for 50-seat jets. Typical rates of annual utilisation are 2,000-2,300 flight hours (FH) and 2,000FC, with an average cycle time of 60-70 minutes. The analysis of airframe maintenance costs is based on these annual operating parameters.

These average FC times and annual rates of utilisation have a large influence on maintenance check planning, particularly because the CRJ-100/-200 have three sets of base check tasks.

Maintenance programme

The CRJ-100/-200 have a complex maintenance programme compared to modern generation jetliners. The maintenance programme is based around A-type checks that have three groups of tasks, and base checks that also comprise three sets of different tasks.

"The CRJ-100/-200 have a maintenance requirements manual (MR), rather than a maintenance planning document (MUD)," explains Steve Fisher, business development manager at Climber Air Maintenance Centre. "The MR is in two parts, and creates check intervals. Part one of the MR relates to systems, structures, zonal inspections and the corrosion prevention and control programme (CPCP). Part two relates to airworthiness requirements, powerplants and fuel systems. There is also the maintenance planning manual (MPM), which lists the inspections in detail." There have so far been 18 revisions to the maintenance programme.

Airframe maintenance can generally be divided into three groups: line and light maintenance; A checks; and base checks. "There are no actual line and light checks specified in the MR, although many operators decide to add pre-flight and daily checks into their maintenance programme," says Fisher. "The smallest check in the programme is a service check, with an interval of three days. The next largest is a 'routine' check every 100FH," explains Fisher.

The CRJ-100/-200 operate with annual utilisations of 2,000-2,300FH per year. This has a bearing on maintenance planing because there are three groups of base check tasks. These have intervals in multiples of 5,000FH, 4,000FH and 12 months.

CRJ-100/-200 A CHECK ROUTINE INSPECTION TASKS

Inspection task group	Interval FH	MH for routine inspection
1A	500	50
2A	1,000	80
3A	1,500	50
4A	2,000	95
5A	2,500	80
APU 1	300	2
APU 2	700	2
APU 3	1,200	2
APU 4	1,500	2
APU 5	1,800	2
APU 6	3,000	2
Out-of-phase tasks	400	3

CRJ-100/-200 C CHECK ROUTINE INSPECTION TASKS

Inspection task group	Maintenance programme interval	MH for routine inspection
1C	5,000FH	210
2C	10,000FH	280
3C	15,000FH	60
4C	20,000FH	26
5C	25,000FH	3
Gp 1 OOP	3,000FH	1
Gp 2 OOP	4,000FH	70
Gp 3 OOP	8,000FH	40
Gp 4 OOP	12,000FH	2
Gp 5 OOP	16,000FH	50
Gp 6 OOP	24,000FH	80
12-month calendar	12 months	20
18-month calendar	18 months	1
24-month calendar	24 months	40
36-month calendar	36 months	7
48-month calendar	48 months	240
60-month calendar	60 months	10
72-month calendar	72 months	890
96-month calendar	96 months	780
120-month calendar	120 months	64
144-month calendar	144 months	2
180-month calendar	180 months	5

A check tasks

Above these line and light checks are checks that can be generically referred to as A checks. "The original interval was 400FH, but this was then escalated to 500FH in April 2007," says Fisher. "There are five multiples of the basic A check tasks: the 1A items to be performed every 500FH; the 2A items every 1,000FH; the 3A tasks every 1,500FH; the 4A tasks every 2,000FH; and the 5A tasks every 2,500FH *(see first table, this page)*. Performed as block checks, all of the task multiples do not actually get in phase until the A60 check, so there is not really an A check cycle. This means that the grouping of the A check tasks into A checks is continuous rather than cyclical."

The first of the larger checks is the A4 check, with 1A, 2A and 4A tasks. The next largest is the A8, followed by the A12. According to Fisher the 1A and 3A routine tasks both require about 50 man hours (MH) to complete, the 2A and 5A routine tasks are both among the largest groups, requiring about 80MH, and the 4A tasks are the largest using about 95MH. The A4 check is the largest, with the routine tasks combining to require about 225MH.

There are also other small checks, of items such as the auxiliary power unit (APU). There are groups of one or two tasks which are concerned with items such as oil and detectors. These have repetitive intervals of 300FH, 750FH, 1,200FH, 1,500FH, 1,800FH, 3,000FH and 3,500FH, and all use 2MH for the routine tasks.

"The CRJ-100/-200 also has a hard-time removal interval for the APU," explains Gregory Olivier, maintenance planning manager at Sabena Technics DNR. "This is an interval of 3,500 APU hours, and about 30MH are required to remove and install a replacement unit. This action is usually included in a base check.

"The small APU tasks come due at regular intervals in multiples of 100MH after the initial thresholds of the tasks have been reached," continues Olivier.

These are either in phase with A checks or smaller line and ramp checks, and so can be scheduled accordingly.

The third group of A check tasks comprises a small group of airframe inspections that come due every 400FH. These are out of phase (OOP) with the 500FH multiple tasks. Consideration has to be given, however, to probable utilisation of the 500FH A check interval. A checks are likely to be performed every 400FH, meaning that the 400FH tasks could be included in the A checks. If the actual A check interval can be extended to beyond 400FH, the 400FH tasks could then be included in one of the 'routine' line checks that are performed every 100FH.

C check tasks

Like the A checks, there are three groups of C check task inspections which have different interval phases. The first of these are the main C check inspections which have intervals that are multiples of 5,000FH. The first group, the 1C tasks, has an interval of 5,000FH and requires about 210MH *(see table, page 56)*.

The 2C tasks have an interval of 10,000FH and use about 280MH. The 3C tasks have an interval of 15,000FH and use about 60MH. The 4C tasks are the smallest group and only use about 26MH. These come due every 20,000FH *(see table, page 56)*.

The 5C tasks are minimal, only requiring about 3MH, and come due every 25,000FH.

The second group of C check tasks are OOP items with FH intervals that are mainly multiples of 4,000FH. There are six groups, many of the tasks in which are structural inspections.

The first group comes due every 3,000FH, but only uses about 1MH. This group is small, and is often added to the A checks.

The second group is one of the largest, using about 70MH, and comes due every 4,000FH *(see second table, this page)*. The third group comes due every 8,000FH, and uses about 40MH. The fourth has an interval of 12,000FH, but

BASE CHECK TASK GROUPING

Base check	C check tasks	OOP C check tasks	Calendar tasks	Routine MH
24-month	1C	Gp 2	12 mth & 24mth	340
48-month	1C + 2C	Gp2 & Gp 3	12 mth, 24 mth, 48 mth & 60 mth	658
72-month	1C & 3C	Gp1, Gp 2 & Gp 4	12 mth, 24 mth, 36 mth & 72 mth	1,300
96-month	1C & 2C	Gp2, Gp 3 & Gp 5	12 mth, 24 mth, 48 mth, 60 mth & 96 mth	1,800
120-month	1C & 4C	Gp 2	12 mth, 24 mth & 120 mth	430
144-month	1C, 2C, 3C & 5C	Gp 1, Gp 2, Gp 3, Gp 4 & Gp 6	12 mth, 24 mth, 36 mth, 48 mth, 60 mth, 72 mth & 144 mth	1,955
168-month	1C	Gp 2	12 mth, 24 mth, 36mth & 180 mth	352
192-month	1C	Gp2, Gp 3 & Gp 5	12 mth, 24 mth, 48 mth & 96 mth	1,480
204-month	2C		12 mth, 36 mth & 60 mth	317

only uses about 2MH. The fifth group has an interval of 16,000FH and uses about 50MH. The sixth group is the largest, but does not come due until 24,000FH. This uses about 80MH.

The third main group of inspections has calendar intervals that are mainly multiples of one year, and there are 11 different groups of inspection tasks. The 12-month tasks consume about 20MH. This is a relatively small labour requirement. The tasks also have easy access, so they are often included in the A checks.

The tasks that come due every 18 months only require about 1MH. Like the 12-month tasks, these have easy access and are often included in the A checks.

The 36-month tasks only use about 7MH, require easy access, and are often included in the A checks.

The remaining seven groups of inspections come due every four, five, six, eight, 10, 12 and 15 years. These are summarised *(see second table, page 54)* but the largest are the four-year, six-year and eight-year groups, each of which uses 240MH, 890MH and 780MH for routine inspections.

Check planning

Planning A and C checks is complicated because each type of check has three groups of inspection tasks.

Consideration should first be given to C or base checks. How the three main groups of tasks and their multiples come due can be examined, but this ultimately depends on rates of aircraft utilisation. The grouping of tasks can be analysed based on annual utilisations of 2,000FH.

If all base check tasks are first analysed at their actual intervals, it can be seen that the aircraft would require a large number of small checks, thereby increasing downtime. Maintenance would also be inefficient if access is repeated. Grouping tasks into a smaller number of larger checks inevitably results in loss of interval for some tasks.

Aircraft with annual utilisations of about 2,000FH can have checks in phases of 24 months. This means that tasks with multiples of 4,000FH and calendar items with interval multiples of 12 and 24 months and higher can be grouped together. Tasks with intervals that are multiples of 5,000FH would have to be brought forward and performed early.

As described, the 12- , 18- , and 36-month calendar tasks all use a relatively small number of MH, and are usually included in A checks. In the cases where they come due at the same time as large groups of other tasks they are included in base checks. Examples are the 24-month, 48-month and 72-month checks *(see table, this page)*.

This leaves the larger task groups, which have intervals of 48, 60, 72, 96, 120, 144 and 180 months. These are scheduled in the base checks.

Not all these tasks are able to use their full intervals, however. An example is the 60-month tasks. To avoid a small check at 60 months to perform only these tasks at five years, they are brought forward to the 48-month check *(see table, this page)*. They are then repeated at the 96-month check to avoid another small base check being required at 98 months.

The 180-month tasks are also brought forward to the 168-month check, again to avoid a small check being required at 180 months just to carry out these items *(see table, this page)*.

The second group of tasks includes those with interval multiples of 4,000FH. The first group of tasks (Group 1), with intervals of 3,000FH, only requires 1MH and can be scheduled in A checks. These tasks can also be scheduled into base checks when their interval coincides with a base check.

The fourth group (Group 4) of OOP tasks comes due every 12,000FH and only uses about 2MH. In this case they are scheduled with the 72-month and 144-month checks *(see table, this page)*.

The second, third and fifth groups (Group 2, Group 3 and Group 5), which come due every 4,000FH, 8,000FH and 16,000FH, can included in base checks *(see table, this page)*.

The third main group of tasks includes those with interval multiples of 5,000FH. The 4C tasks, with an interval of 20,000FH, can be performed at their actual interval at the 120-month check *(see table, this page)*. The 1C, 2C, 3C and 5C tasks have to be brought forward in multiples of 4,000FH, 8,000FH, 12,000FH and 24,000FH.

Once these three groups of tasks are grouped together, there are checks every 24 months *(see table, this page)*. The items included in each check and the total routine MH required are summarised. The first large check is the 72-month check, which requires about 1,300MH *(see table, this page)*. The next large check is the 96-month check which requires about 1,800MH. The 144-month check is the largest.

The alternative for aircraft with utilisations of 2,200-2,600FH per year would be bi-annual checks, but with 4,000FH multiple tasks brought forward and performed early. In this scenario the 5,000FH and calendar tasks would be grouped at their appropriate intervals in bi-annual checks.

A checks are relatively easy to plan, however, because the third group of OOP tasks that comes due every 400FH is small. The actual interval of the A check is also likely to be close to 400FH. These OOP tasks can therefore either be scheduled in one of the 'routine' checks at a 100FH interval, or in the A checks if the actual interval is less than 400FH.

The APU-related tasks, however, also come due in A checks or a 'routine' check that comes due in multiples of 100FH. The amount of routine labour for A checks is 50-186MH, depending on the size of the check.

The group 1 base check tasks come due every 3,000FH and use about 1MH. These can therefore be scheduled either every fifth or sixth A check, or in a 'routine' check.

The other main group of base check tasks that are scheduled with A or line checks are the 12- and sometimes 36-month calendar tasks. The 12-month tasks use about 20MH, and can be scheduled with every fourth or fifth A

The organisation of base check tasks into convenient groups according to rates of aircraft utilisation results in uneven sized checks. Most operators can organise a system of base checks with an approximate frequency of 24 months. Large checks occur at about six, eight and 12 years in some cases.

check. The 36-month tasks will add another 7MH when added once every 15-17 A checks. These tasks therefore increase the range of routine labour for most A checks to 50-130MH.

Check inputs

The total workpackages for A checks include routine inspections, non-routine rectifications, the clearing of deferred defects that have arisen during operation, some component changes and some interior cleaning work.

As a rule, the MH for routine inspections can be added to by another 50% for all additional tasks. This takes the total labour for these checks to 80-200MH, with an average of over 130MH. Labour charged at a generic rate of $70 per MH will take the cost of the labour portion to $5,600-14,000.

The cost of materials and consumables with these checks will be $2,000-4,500.

Base check workscopes will have similar items to A checks. "In addition to routine inspections, base checks will include: non-routine rectifications; clearing any defects left from operation; incorporation of service bulletins (SBs) and airworthiness directives (ADs); additional OOP tasks; component changes; general interior work; interior refurbishment; and stripping and repainting. Interior refurbishment and stripping and repainting will be done in later base checks.

"The non-routine ratio for the CRJ-100/-200 starts off at about 50% of routine MH for young aircraft up to three years old," says Fisher. "It then increases to about 70% for aircraft aged three to seven years old, rising to 80% between eight to 10 years old, 90% for 11- to 13-year-old aircraft, and 100% for aircraft aged 17 years and older."

The MH required for non-routine rectifications therefore increase the labour used. In the analysis and check planning used, the sub-total for routine and non-routine labour starts at about 500MH for the 24-month check, rising to 1,100MH for the 48-month check, to 2,200MH for the 72-month check, and 3,200MH for the 96-month check. The largest is the 144-month check, with 3,700MH, with a dip for the 120-month check at 780MH.

The first additional item to be considered is the clearing of deferred defects. "The MH required for this are variable, and are 40-200 for base checks," says Olivier. An average of 100MH can be budgeted for base checks.

The second additional item involves the incorporation of SBs and ADs. The CRJ-100/-200 has not suffered any major ADs, but it should be assumed that some labour will be required for SBs and ADs. "The amount of labour can vary according to check size and the SBs and ADs that are actually issued, but a typical range is almost zero MH for some checks up to 300MH in the largest cases," explains Olivier.

Component changes are the third item. "A landing gear shipset, for example, uses about 50MH for removal and reinstallation," says Olivier. Components removed will be hard-timed units, plus on-condition rotables that have failed or require removal. An average of 50MH should be used for this element of the check.

Interior cleaning and light refurbishment comprise the final element. "A light clean will use about 40MH, while a light refurbishment of seats and carpets can use 200MH. Obviously the condition of the aircraft will deteriorate as it ages, and MH will increase until a complete refurbishment is required," says Olivier. An average of 100MH per base check should be used.

These additional items therefore add 300-550 MH to the main portions of routine and non-routine labour for the checks. This takes the total for the 24-month check to about 800MH. Most checks are larger, with the 48-month check using 1,500MH and, the 72-month check 2,600MH. The 96-month check is one of the largest, requiring about 3,800MH. The following check is small, however, at 1,100MH.

Check reserves

Labour rates vary, but a generic rate for base maintenance can be used to illustrate the approximate cost of the checks. A labour rate of $50 per MH results in labour costs of $40,000-55,000 for the smaller base checks, and $75,000-200,000 for the larger checks.

The associated cost of materials and consumables for these checks will be $15,000-100,000, depending on the size of the check. This results in total costs of $55,000 for the 24-month check and $75,000 for the 120-month check. The 48-month check has a cost of $100,000, climbing to $180,000 for the 72-month check and $260,000 for the 96-month check.

These checks occur at intervals of 4,000FH, and reserves can be calculated for each subsequent check over its interval, or for the cost of a series of checks over this collective interval. Calculated in constant 2007 US Dollars, the reserves for the 24-month check are $14 per FH. This amount increases to $25 per FH for the 48-month check, to $65 per FH for the 96-month check, and $73 per FH for the 144-month check.

The reserves for all inputs for the first five checks amount to 9,800MH and $200,000 of materials and consumables, taking the total cost to about $700,000. Amortised over an interval of 20,000FH, this equals a reserve of $35 per FH.

The aircraft will also require interior refurbishment, and stripping and repainting at some stage. Both of these items are typically required every five to seven years on jetliner types. AC