OWNER'S & OPERATOR'S GUIDE: CRJ FAMILY

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The Canadair Regional Jet (CRJ) was developed in the early 1990s by Bombardier of Canada. The CRJ family is one of the most numerous regional jets (RJs), with more than 1,500 in service.

The CRJ-200, based on the original CRJ-100 variant, but with improved engines, represents about half the CRJ fleet. The stretched variants, the CRJ-700, CRJ-900 and the CRJ-1000, have also sold well. Production of the CRJ-100/200 has now ceased.

Typical seat numbers for the CRJ family are: 50 for the CRJ-100 and CRJ-200; 70 for the CRJ-700 (although it can be configured up to 78 seats); and 88 (or up to 90) for the CRJ-900. The latest variant, the CRJ-1000, seats 100. The larger variants fill the gap between the older 50-seat RJs and larger airliners produced by Airbus and Boeing.

**Engines**

All models of the CRJ are powered by the General Electric (GE) CF34 engine. Although the CF34 has kept its original designation, later models are different from early variants. The CF34-3A1 powered the first CRJ-100s. The CF34-3A1 was followed by the CF34-3B1 in January 1997, and the first aircraft was delivered to Lufthansa CityLine in October 1992. The first flight of the CRJ-200, which was essentially a CRJ-100 with updated GE CF34 engines, took place on 13th November 1995.

The CF34 engines have range of 1,840nm. The standard take-off field length is 5,271ft for the basic N extGen model, 5,657ft for the ER and 6,072ft for the LR. Landing field lengths are all at or slightly below 5,120ft.

A Series 705 was produced to provide some regional airlines with a business-class section. This was due to limited passenger capacity allowed under US airline pilot union ‘scope clauses’ (this model has 10 business-class seats plus 65 standard ones). It is in fact based on the CRJ-900.

**CRJ-100/CRJ-200**

The CRJ-100 programme was launched in March 1989, and the first aircraft was delivered to Lufthansa CityLine in October 1992. The first flight of the CRJ-200, which was essentially a CRJ-100 with updated GE CF34 engines, took place on 13th November 1995.

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The CRJ-100 and CRJ-200 are nominally 50-seat, five-crewmember, twin-turbofan-powered aircraft with a maximum design airspeed of Mach 0.85. The only difference between them is that the CRJ-200 has a later engine, the CF34-3B1. The CRJ-100 is powered by the CF34-3A1.

The CRJ-100 and CRJ-200 are able to operate in a range of environments, from high-altitude regions to low-altitude areas. They are also capable of operating in areas with limited space, such as airports with short runways. The CRJ-100 and CRJ-200 are also used in the cargo transport market, allowing airlines to transport freight efficiently.

The CRJ-100/200 is a very successful aircraft, with more than 1,500 in service worldwide. It has been delivered to many airlines, including United Airlines, Delta Air Lines, and American Airlines. The CRJ-100/200 is also popular with regional airlines, such as Mesa Airlines and SkyWest Airlines.

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The engine changes being introduced on the -700 and -900. The engine development on the -1000 will also become available on the -700 and -900. The CRJ-1000 NextGen EL, the CRJ-1000 NextGen, and the CRJ-1000 NextGen variants. It also be available for CRJ-700 NextGen and CRJ-900 NextGen variants. It also offer reduced fuel consumption, lower trip operating costs and lower airframe operating costs compared to the standard aircraft.

The NextGen programme. To increase market appeal, three years ago Bombardier introduced the CRJ-700/900 NextGen programme. Features include a new cabin and lower maintenance costs because the A and C check intervals have been extended. There have also been improvements in the engines, and the aircraft has a lower weight. This has allowed Bombardier to republish the aircraft flight manual (AFM) with a 4% improvement.

Bombardier also introduced a computerised AFM and integrated it with the Electronic Flight Bag (EFB), and it is now working with navigation authorities to allow more accurate navigation capabilities.

CRJ-1000

The most recent variant, the CRJ-1000, was launched in February 2007 (as the CRJ-900X). Although it made its first flight in 2008, its entry into service with Air Nostrum and BritAir has been delayed until early 2010.

When Bombardier launched the CRJ-1000 it soon announced that the interiors and windows of the new variant would also be available for CRJ-700 NextGen and CRJ-9000 NextGen variants. It also said that these NextGen aircraft would offer reduced fuel consumption, lower trip operating costs and lower airframe direct operating costs compared to the standard aircraft.

The NextGen aircraft benefit from larger overhead luggage bins, larger windows, improved lighting, and redesigned ceiling panels and sidewalls. The increased size of the luggage bin permits the storage of up to 27% more roller-bags in the CRJ-700 NextGen, and up to 21% more roller-bags in the CRJ-900 NextGen.

The CRJ-1000 has three variants: the CRJ-1000 N ExtGen EL, the CRJ-1000 N ExtGen, and the CRJ-1000 N ExtGen ER. Standard ranges are 909nm, 1,345nm and 1,535nm respectively. M aximum landing weight for the CRJ-1000 models is 81,500lbs in all cases and OEW is 51,100lbs. Payload maximum is 26,400lbs, with 7,180lbs maximum cargo weight.

Engine development

The engine development on the -700 and -900. The next step for GE is the NG34, its next generation engine, aimed at aircraft from 2015 onwards. GE predicts that this technology programme will bring a 10-15% operating cost reduction and higher reliability. A key feature of the next generation engine (which may well power future CRJ’s) is the ‘eCore’. This will take advantage of the technologies that GE has developed for the GEnx (the Boeing 787 engine). The aim is to have a common core architecture for engines in the 10,000-30,000lbs thrust range, using the most advanced aerodynamics, a combustor (which will be ‘eTAPS’, a more efficient version of the current Twin Annular Pre-Swirl design), and scaling the fan and low pressure turbine (LPT) for the particular engine, such as the CF34 development. The first core test was completed in mid-2009 and ‘Core 2’ will be tested in Q2 2011, ahead of the full next-generation engine test planned for 2012.

For the CRJ-1000 models, the CRJ-1000-ER has a MTOW of 80,500lbs, with a maximum payload of 22,750lbs. The CRJ-1000-ER has a MTOW of 80,500lbs, with a maximum payload of 22,750lbs.

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CRJ family fleet summary

There are more than 1,500 CRJ family aircraft in operation. The demographics of the CRJ family’s population is reviewed.

There have been 1,718 orders for the CRJ family, of which 1,583 have been fulfilled, leaving a backlog of 135, according to Flight’s Aircraft Fleet & Analytical System (ACAS) data for July 2009.

The CRJ family includes: commercial aircraft (the CRJ-100, -200, -440, -701, -705, -900 and -1000 series); and corporate jets, known as the Challenger 850/870/890, based on the commercial variants. Of the 1,583 aircraft that have been delivered, 1,521 are commercial and 36 are corporate. Another 26 aircraft have been destroyed or retired. This fleet analysis will examine commercial aircraft.

Of the 1,521 aircraft that have been delivered, just 73 are parked. Over 80% of those are in North America. Only four have been converted to freighters: two in Europe and two in North America.

SkyWest Airlines (USA) is the largest CRJ operator, with 228 aircraft from the CRJ-100, -200, -700 and -900 model series, and 14 on order, for delivery over the next year. The next largest fleets are with Atlantic Southeast Airlines (161), Pinnacle Airlines (140), Comair (122) and Mesa Airlines (101), all in North America. The largest CRJ operators are mainly in Western Europe, which has 16% of the global fleet; Lufthansa Cityline (54), Air Nostrum (46), Brit Air (30) and Eurowings (24). The CRJ fleet in the Asia Pacific is in India, Japan and China, accounting for just 4% of the global fleet. The largest operators are the Chinese Air Force and Shandong Airlines (12 each), J-Air in Japan (9) and JetLite in India (7). There is a good spread of the CRJ fleet across Africa. South African Express is the largest operator (14). The largest of the three operators in South America is MexicoLink (9). The largest of the four operators in South East Asia is Yemen’s Felix Airways (4).

There are four main variants of the CRJ family of aircraft: the original -100; the similar -200; the -700 (including the -701 and more recent -705); the -900 series; and the very recent -1000. Each model series is divided into two or three models or sub-variants.

Fleet forecast

According to ACAS, as of July 2009, in addition to the 1,521 commercial CRJ aircraft in operation, there is an order backlog for all CRJ variants of 135. As three are Challenger 850s, this means that 132 commercial jets are yet to be delivered, the vast majority to airlines that already have CRJs. The exceptions are Estonian Air, which has three on order, and the Iraqi Government, which has a backlog of nine, although Iraqi Airways already operate one CRJ-900.

Of the 132, the most popular variant is the CRJ-1000, with a backlog of 64. There is only one example of this new model, which is still with Bombardier for testing and development, and is first due for delivery to airlines from 2010.

The next most popular variant with a delivery backlog is the CRJ-701, with 37 on order. 33 will be the -ER sub-variant and there are four of the -LR sub-variant.

The CRJ-900 has 20 aircraft yet to be delivered, and 11 -900ER sub-variants. This emphasises the growing popularity of the newer -900 along with the -1000.

The largest backlog is for Air North, which has ordered 35 CRJ-1000s for delivery from 2010 to 2016, followed by myair.com (15 aircraft), Brit Air (14), SkyWest Airlines (USA) (14) and Lufthansa Eurowings (11).

CRJ-100

There are 214 examples of the CRJ-100, with 37 operators, of which 12 -100ERs and 10 -100LRs are parked. The three sub-variants are the ER, LR and SE, with the ER taking 58% of the share.

The ER sub-variant accounts for 125 aircraft, all with the CF34-3A1 engine. Nearly 80% are in North America and nearly 17% in Europe. Just 4% are in Africa and the Asia Pacific, with none in the Middle East and South America.

Comair is the largest operator of the CRJ-100 (84 aircraft), the -100ER (46) and -100LR (38). The next largest -100ER operators are Jazz Air (24), SkyWest Airlines (USA) (16) and Brit Air (15). The next largest -100LR operators, after Comair, are Lufthansa Cityline (12) and Cimber Air (7). The -100LR accounts for 77 aircraft, representing 36% of the -100 fleet. Like the -100ER, it is spread across four continents, with the vast majority in North America and Europe.

The -100SE fleet is much smaller with just 12 aircraft. The Chinese Air Force is the largest operator, with five aircraft that have low flight cycles (FC) of just 10 hours each, compared to well over 1,000 FC for the other seven. All bar two aircraft in the -100SE fleet have upgraded CF34-3B1 engines.

More than two thirds of the CRJs in operation are in North America. The CRJ-200 is the most popular type, with more than 700 in service. SkyWest Airlines has the largest CRJ-200 fleet, with 100 aircraft.
CRJ-200
There are three main sub-variants of the CRJ-200: the ER, LR and SE models. Altogether there are 711, with 64 operators, equating to 47% of the global CRJ fleet. The ER and LR are the most popular by far with a 46.5% and 52.5% share of the CRJ-200 market respectively.

The CRJ-200ER accounts for 331 aircraft and 64% are operated in North America, although it is found worldwide. Just 11% are currently parked. Atlantic Southeast Airlines is the largest operator (112) followed by Air Nostrum (35), Jazz Air (33) and SkyWest Airlines (USA) (22).

There are 375 CRJ-200LRs, including four package freighters (-200LR(PF)), in Europe and South America. The standard -200LR fleet is in Asia Pacific, Europe and North America which has 78%. SkyWest Airlines (USA) is the largest operator (100 -200LRs), followed by PSA Airlines (35) and M esa Airlines (28).

Only three aircraft are parked. The CRJ -200SE has just five aircraft: two each in North America and Asia Pacific; and one in Europe. All are active. All the CRJ-200s have the upgraded CF34-3B1 engines, except the four package freighters which have the original CF34-3A1s. The average age of the CRJ-200 is seven and a half years. The average FC utilisation for the past year is 1,968FC, while average flight hours (FH) are 2,195FH, and the average flight time has been 70 minutes.

CRJ-440
There are just 86 CRJ-440 aircraft, all in North America: 71 with Pinnacle Airlines (with a further one parked); and 15 with M esa Airlines. The average age of the fleet is just over five and a half years. The average utilisation for the last year has been 2,302FH and 1,968FC, so the average flight time is 70 minutes.

CRJ-700
There are 292 CRJ-700s, with just 20 operators. The fleet is split into four sub-variants. For the CRJ-701, the standard model, the ER and the LR total 276 aircraft. There are 16 CRJ-705LRs. All the -701ER and standard aircraft are equipped with the CF34-8C1 engine. The -701LR is powered by the CF34-8C5B1 and the -705LR has CF34-8C5 engines.

The largest operator is SkyWest Airlines (USA) (69), followed by Atlantic Southeast Airlines (39), American Eagle Airlines (25), and Lufthansa Cityline (20) and M esa Airlines (20).

There are 22 CRJ-701LRs. All but one are with GoJet Airlines in the US.
The average age of the CRJ-700 fleet is five years. Utilisation over the past year has averaged 3,021FH and 1,812FC. The average flight time is just over 1.5FH.

CRJ-900
There are 217 CRJ-900s with 21 operators, with just two sub-variants. All the aircraft are powered by the CF34-8C5. The largest operators are Mesaba Airlines (41), M esa Airlines (38) and SkyWest Airlines (USA) (21).

There are 205 standard aircraft around the world, except for the Asia Pacific. Five are already parked. The largest operator is M esa Airlines again with the same results for the top three operators as in the previous paragraph.

There are only 12 -900ERs, in Europe and Africa. Four European aircraft are parked. Arik Air, Eurowings and myair.com all have four aircraft each, although myair.com’s are parked.

The average age for the -900 fleet is 2.5 years, making it the youngest CRJ fleet. The average annual utilisation over the past year is 2,090FH and 1,634FC, so the average flight time is 75 minutes.

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There are several sub-variants of the four main variants of the CRJ family. Since most CRJs are operated on routes of up to 80 minutes, the differences in specification weights will result in small differences in fuel burn performance between these sub-variants. The main objective is to analyse the fuel burn performance of the most numerous sub-variants as being representative of the performance of each main variant. Four models have therefore been analysed (see table, page 17).

These four aircraft have been examined on four routes of 140nm to 580nm. The performance of the largest model, the CRJ-900, has also been examined on a longer route of more than 800nm, since this aircraft may be used on more than just regional city-pairs.

Flight profiles

Results of performance calculations have been provided by Jeppesen, based on parameters and specifications provided by the manufacturer. Performance on the four routes was analysed (both outbound and inbound segments) to illustrate the effects of wind speed and direction. This results in an equivalent still air distance (ESA D) for each direction on a city-pair, and affects the fuel burn and flight times.

Average weather for the month of June has been used, with 85% reliability winds and 50% reliability temperatures. Optimum flight levels are used where possible, unless air traffic control (ATC) have restricted this, and International Civil Aviation Organisation (ICAO) flight rules have been used for standard assumptions on fuel reserves, diversion and contingency fuel. Engine manufacturer fuel burn rates have been used for taxi and flight times, with a standard 20-minute taxi time being assumed to give block times. Speed in all cases has been assumed to be long-range cruise for the type/variant combination, which may mean slightly better performance than would be achieved in real operational conditions.

The aircraft are assumed to have single-class cabins with full passenger loads. The standard weight for each passenger and their luggage, as used by airlines in performance calculations, is assumed at 200lbs per person, with no additional cargo in the hold. The passenger numbers and payloads are therefore as follows: CRJ-100 (50 passengers; 10,000lbs); CRJ-200 (50 passengers; 10,000lbs); CRJ-700 (70 passengers; 14,000lbs); and CRJ-900EP (88 passengers; 17,600lbs). Variations in passenger numbers in reality have little effect on fuel-burn figures for a single flight, so the examples are useful illustrations of performance.

Route analysis

The four routes analysed are operated by Air Canada Jazz, so they are representative of a regional carrier. These are as follows, with International Air Transport Association (IATA) three-letter codes in brackets, followed by to/from track distances in nautical miles:

1. Calgary-Edmonton (YYC-YEG), 139/166nm.
2. Edmonton-Saskatoon (YEG-YXE), 261/261nm.
3. Toronto-Boston (YYZ-BOS), 405/433nm.
4. Toronto-Thunder Bay (YYZ-YQT), 503/528nm.

In addition the one longer-range route analysed for the CRJ-900EP was:

5. Toronto-Winnipeg (YYZ-YWG), 832/857nm.

The first route was from Calgary (YYC) to Edmonton (YEG), and had an equivalent still-air distance (ESA D) of 139nm outbound and 169nm on the inbound (170nm for the -900EP aircraft). These distances reflect the equivalent tracked distance that would have been flown in zero wind conditions. Block time was increased by 3-5 minutes on the return, or about 10%. This illustrates the effect of en-route wind and routing.

The second route was slightly longer, from Edmonton (YEG) to Saskatoon (YXE). The outbound ESA D was about 260nm, and inbound about 300nm. Wind outbound was negligible, but on the return journey a 46-knot headwind was encountered, causing a block time increase of 3-5 minutes, as in the earlier example. The block times were therefore just over an hour outbound and 1:06-1:08 on the return.

The CRJ family fuel burn performance improves with larger variants. Fuel burn per seat-mile is higher, however, than the Embraer E-jets.
The third route was from Toronto (Y Z Y) to Thunder Bay (Y Q T) with a headwind encountered on the way out, and a light tailwind on the return. This turned a track of 503nm outbound into an ESAD of 573-580nm (depending on aircraft model), and track of 528nm on the return into ESAD of 573-580nm. Block time was 1:44-1:49 outbound, and a 1:36-1:40 returning.

Finally, a trip from Toronto (Y Z Y) to Winnipeg (Y W G) in the CRJ-900 had track distances of 832nm out and 857nm back. ESADs were 963nm and 832nm, reflecting the strong 65-knot headwind outbound and a 14-knot tailwind on the return leg. Block times were respectively 2:34 and 2:17.

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**Fuel burn performance**

The fuel-burn performance of the four CRJ variants is shown for four routes, inbound and outbound legs being shown separately. For the fifth route these are only shown for the CRJ-900 (see table, this page).

The data also include the associated fuel-burn per passenger or per seat, and fuel-burn per passenger-mile for both sectors on each route.

The fuel burn increases on all sectors as the power and size of aircraft increases, apart from the CRJ-100 which has less efficient engines than the similarly-sized CRJ-200. The pattern is that the CRJ-900 has less efficient engines than the CRJ-700. It is clear that the real advantage of a stretched variant comes from increasing seat numbers from 70 to 88 seats. The longer sectors are far more efficient with the fuel per seat-mile falling from 0.035-0.039 US Gallons (USG) to 0.020-0.024USG. To a great extent this will reflect the increasing proportion of flight time spent in the cruise, whereas the maximum fuel-burn per mile would occur in the climb phase, a more or less constant factor between the routes.

Although fuel-burn per seat-mile was lowest for the CRJ-900 in all cases, it can be seen how critical it is to fill the seats by comparing the overall fuel burn per route between the CRJ variants. For example, total fuel-burn on the fourth route (to Boston) was 1,103USG for the CRJ-200 and 1,624USG for the CRJ-900. This is a one-third increase in fuel-burn.

The key measure is the fuel-burn per seat-mile, where the CRJ-900 model is always more efficient and is followed by the CRJ-700. It is clear that the real advantage of a stretched variant comes from increasing seat numbers from 70 to 88 seats. The longer sectors are far more efficient with the fuel per seat-mile falling from 0.035-0.039 US Gallons (USG) to 0.020-0.024USG. To a great extent this will reflect the increasing proportion of flight time spent in the cruise, whereas the maximum fuel-burn per mile would occur in the climb phase, a more or less constant factor between the routes.

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CRJ family maintenance analysis & budget

The CRJ has a complex maintenance programme, with several groups of tasks with different interval parameters. The maintenance costs of the CRJ-100, -200, -700 & -900 are examined.

The CRJ-700 first entered service in 1995. The last CRJ-100/-200 entered service in 2001. There are nearly 1,200 CRJ aircraft in service in North America, which has a small number of large fleets. Europe is the second largest operator with 239 aircraft. Few are operated elsewhere in the world.

The CRJs do not have a maintenance planning document (M PD). Instead there are the maintenance requirements manual (M RM ) and a maintenance planning manual (M PM ). The M RM has two parts. The first relates to systems, structures, zonal inspections and the corrosion prevention and control programme (CPCP). The second part relates to airworthiness requirements, powerplants and fuel systems.

The M PM lists all the inspection tasks. There have been 21 revisions to the CRJ-100/-200’s maintenance programme to date. Airframe maintenance falls into three categories of line and light maintenance, A checks and base checks. Base checks will include interior refurbishment and stripping and repainting in addition to the tasks specified in the M PM.

The pattern of operation by many of these fleets is similar to the CRJ-100/-200, although aircraft are operated on longer average FC times of 1.40FH. Average rates of utilisation are 2,600FH and 1,900FC per year. The exceptions are Jazz Air and SkyWest Airlines which operate their aircraft on longer average cycles of 1.70-1.82FH. and consequently have higher annual utilisations of 2,750-2,900FH.

The CRJ-700 first entered service in 2003. The pilot union scope clause of most US majors allow specified numbers of 70-seat RJs to be operated by their regional affiliates, so the CRJ-700 is operated most by regional carriers for feeder services. These include American Eagle (25), ASA (39), Comair (15), GoJet (21), Horizon Air (18), Jazz Air (16), Mesa (20), PSA (14) and Skywest (69).

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The CRJ-700 is also operated by three CRJ-100/-200 operators: Brit Air, Eurowings and Lufthansa Cityline. Air India and South African Express also have the CRJ-700.

The CRJ-900 has similar fleet parameters. The maintenance costs of the aircraft are analysed here for aircraft operating at 2,300-2,400FH and 2,100FC per year, equal to an average FC time of 1.15FH.

Maintenance programme

The CRJ’s three maintenance programmes are relatively complex compared to other jetliners. The programmes comprised A checks and base checks. A checks consist of three groups of tasks, and base checks consist of three other groups of tasks. The CRJ fleet has a maintenance planning document (M PD). Instead there are the maintenance requirements manual (M RM ) and a maintenance planning manual (M PM ). The M RM has two parts. The first relates to systems, structures, zonal inspections and the corrosion prevention and control programme (CPCP). The second part relates to airworthiness requirements, powerplants and fuel systems.

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Line checks

There are no actual line check tasks specified in the M PM, but many operators have written tasks for their own line maintenance programmes. “We have a pre-flight check and a recommendation to perform a service check every night on our CRJ-200 and -900 fleets, but only if this is possible at the homebase,” explains Robert Rozman, engineering manager at Adria Airways. “The service check has a maximum interval of three days, but will be carried out more frequently than this. There is also a line check in the M PM known as the routine check. This has an interval of 100FH, but we added an additional eight-day limit and treat it as a weekly check. There are two sets of task cards.
A checks

The next higher level of checks are the A checks. In the case of the CRJ-100/200, the basic interval for a group of 1A tasks is 500FH. At an annual utilisation of 2,300FH, this is equal to 11 weeks of operation.

There are five groups of tasks with multiples of these, so there are also 2A tasks with an interval of 1,000FH, 3A tasks with an interval of 1,500FH, 4A tasks with an interval of 2,000FH and 5A tasks with an interval of 2,500FH. The 5A tasks therefore come due every 12-14 months.

These tasks can be formed into similar-sized ‘equalised’ checks or into ‘block’ checks as tasks come due. The A1 check will therefore comprise just the 1A tasks, the 2A check will comprise the 1A and 2A tasks, the 3A check just the 1A tasks, and the A4 check the 1A, 2A and 4A tasks. The five different intervals and task groups do not actually come into phase with each other until the A60 check at 30,000FH, so no A check gets finished. Task groups are continually carried out, and the A60 check comes due after 25-30 years’ operation.

The 1A and 3A routine tasks each require 50 man-hours (MH) to complete. The 2A and 5A tasks each use 80MH, and the 4A tasks are the largest group, using 95MH (see first table, this page).

If grouped as block checks, the A1 check will therefore have 1A tasks and require 50MH for routine inspections. The A2 and A5 check routine tasks will use 130MH, while the A3 check routine tasks will consume 100MH. The larger checks will be the A4, with 1A, 2A and 4A tasks, and require about 225MH. The A6 check is also relatively large, including the 1A, 2A and 3A tasks. These will consume 180MH for routine inspections.

In the case of the CRJ-700 and -900 the basic 1A interval is 400FH, but this will be escalated to 600FH in the near future. This means the A5 check comes due at 2,000FH, but will be extended to 3,000FH.

The five task groups have routine M H consumption of 15-55MH, with the 1A group of tasks being the largest. If grouped into block checks, the A4 check is the largest, requiring 135MH for routine inspections. The smallest is the A1 check, with just 1A tasks, which will use 55MH for routine inspections.

There are, however, two more groups of tasks that are included in A checks by most operators. The first of these is inspections of the auxiliary power unit (APU). There are several groups of tasks with different intervals, which are based on APU hours (APUH) and FH. These intervals are unique to each operator.

One example is for tasks at 300FH, 700FH, 1,200FH, 1,500FH, 1,800FH and 3,000FH. Unlike most other tasks, these groups are not multiples of the basic interval of the first group of tasks.

“In the case of the CRJ-700 and -900 the APU tasks are at 500APUH, 2,000APUH and 3,000APUH,” says Rozman.

Any of these are small tasks related to inspecting oil levels and detectors. There is also a fixed interval at 3,500APUH for removal and replacement of the APU.

The third group of tasks included in the A checks is the out-of-phase (OOP) tasks. These do not have intervals that match those of the main groups of A check tasks, and have odd intervals such as 400FH, 800FH and 1,200FH in the case of the CRJ-100/200. These have to be planned into the A checks or Routine checks as appropriate for the aircraft’s operation and utilisation.

“There are OOP tasks at 500FH and
The MH required to complete the routine inspections for each small group of OOP tasks is in the region of 2-5MH, and so their impact on additional work for Routine and A checks is small.

**Base checks**

The C checks or Base checks have inspections that are grouped into three lots of tasks by most. “In fact there are six groups of tasks,” explains Rozman. “These relate to systems, powerplants, structures, zonal, corrosion and electrical wiring interconnection.” These are grouped into the three types of tasks used by most operators in their planning.

The first of the three groups is the main inspections. In the case of the CRJ-100/-200, the basic interval for 1C tasks is 5,000FH. There are another four groups of tasks with multiples of this basic interval: the 2C tasks at 10,000FH; the 3C tasks at 15,000FH; the 4C tasks at 20,000FH; and the 5C tasks at 25,000FH. In the case of the CRJ-700/900 the basic interval for the 1C tasks is 4,000FH, so the 5C tasks come due at 20,000FH. “The basic interval will soon be escalated to 6,000FH, so the 5C tasks will come due at 30,000FH,” explains Rozman.

In the case of the CRJ-100/-200, the 1C tasks consume 210MH for routine inspections. The 2C tasks use 280MH for routine inspections, and the 3C tasks consume 60MH (see second table, page 20). Unlike many aircraft, the 4C tasks are a small group and use 26MH. The 5C tasks are also a small group, and use 3MH.

In the case of the CRJ-700/900, the MH distribution among the five C check tasks groups is similar to that of the CRJ-100/-200. The 1C tasks use 280MH, the 2C tasks 350MH, and the 3C tasks use 80MH. The two smaller groups are the 4C and 5C which use 50MH and 80MH for routine inspections.

The second group of base check tasks are OOP items. These are grouped and treated differently by operators. One example for the CRJ-100/-200 is for tasks to be expressed in FH. They vary in routine MH requirements. There are six groups with different intervals between 3,000FH and 24,000FH (see second table, page 20). The first is due at 3,000FH and uses only 1MH, so it can easily be combined with a line or base check as it comes due. The second group is due at 4,000FH and uses about 70MH for routine inspections (see second table, page 20). The third group has an interval of 8,000FH and consumes about 40MH for routine inspections. The fourth group has an interval of 12,000FH. It is also small and used only about 2MH. The fifth and sixth groups of tasks have intervals of 16,000FH and 24,000FH, and use 50MH and 80MH for routine inspections.

Rozman explains that the CRJ-700/-900’s maintenance programme results in different groupings of OOP tasks. “The APU is removed at 3,000APUH, and other APU-related tasks are carried out every 1,000APUH thereafter, with some engine-related tasks at 3,000 engine flight hours (EFH) and every 2,000EFH thereafter,” says Rozman. “In addition there are nine groups of tasks with FH intervals: 3,000FH, 4,400FH, 4,500FH, 5,000FH, 5,500FH, 6,500FH, 10,000FH, 25,000FH and 30,000FH (see second table, this page). Routine MH for these nine groups of tasks are small for the first and fourth groups of OOP tasks, at only a few MH. The four other groups use 10-15MH (see second table, this page).” The third main group of base check inspections are tasks with calendar intervals. These are mainly related to structures and corrosion. As with OOP tasks, calendar inspections are treated differently by operators.

One example for the CRJ-100/-200 is for up to 11 groups with intervals of 12, 18, 24, 36, 48, 60, 72, 96, 120, 144 and 180 months (see second table, page 20). All, except the 18-month tasks, occur at convenient annual intervals up to 15 years. In terms of MH consumption for routine inspections, the 24-, 48-, 72-, 96- and 120-month tasks are the largest, using 40-900MH (see second table, page 20). The other tasks use only relatively few MH for routine inspections.

“In the case of the CRJ-700/900, there are eight different groups of tasks,” continues Rozman. “The intervals are six,
12, 18, 24, 36 and 48 months, 96/48 and 96/72 months. The routine MH required for these tasks are small for the first five groups up to a 36-month interval. The 48-month and both 96-month groups consume large numbers of routine MH.

Check planning

Grouping the three sets of inspection tasks for the A and base checks into check packages is complicated by the large number of OOP and calendar tasks with intervals that are not in phase with the FH inspections. How tasks are grouped and formed into checks depends on rates of aircraft utilisation. This analysis assumes aircraft operating at 2,300-2,400FH and 2,100FC per year.

The first consideration of check planning is base checks. The large number of tasks means that if each group was performed as they come due then the aircraft would have to be grounded frequently at irregular intervals for maintenance. To generate a regular stream of base checks with regular frequencies means bringing forward some tasks and performing them early by combining them with others. This inevitably means the utilisation of intervals on some tasks is poor, but fewer checks are made on the aircraft.

In the case of some OOP and calendar tasks the number of inspections and MH required are small, and these can actually be grouped into A checks or even Routine checks if convenient.

CRJ-200/-200

The annual utilisation of 2,400FH means that 4,800FH are completed every 24 months. This is convenient in the case of the CRJ-100/-200, which have the large groups of FH-related inspections in multiples of 5,000FH. The CRJ-100/-200 also have the five largest groups of calendar-based tasks at two-, four-, six-, eight- and 10-year intervals. The most efficient way of planning base checks would therefore be to have a C check every two years (see first table, this page). Other smaller groups of inspections would have to be planned into these checks by performing them early, or by being included in other smaller checks.

C checks every two years for the CRJ-100/-200 means a check every 4,700-4,800FH. Some of the OOP and calendar-based tasks inevitably drop out. There are six groups of OOP tasks. The first two groups have intervals of 3,000FH and 4,000FH. For simplicity in maintenance planning it is easiest to perform these annually, every 2,400FH, so that the second group is performed 1,600FH early in relation to its interval. This means that these two groups of tasks, which use 70MH for routine
In terms of maintenance planning, the CRJ family should be considered in the two groups of the CRJ-100/-200 and the CRJ-700/-900. The maintenance programmes of both have large numbers of tasks that are not in phase with each other, and consequently complicate check planning.

inspections, are not included in a base check when the aircraft is one year old and then every two years thereafter. On these occasions they would drop out and be included in A checks. On even numbered years they would be included in the C checks (see first table, page 22).

The third group of OOP tasks, with an interval of 8,000FH and which use about 40MH for routine inspections, could be performed early, and grouped with every C check and performed at 4,800FH intervals.

The fourth group of OOP tasks only uses 2MH and has an interval of 12,000FH. These can then be performed at their interval, every five years, and then alternate between heavy A checks at five and 15 years, and every fifth C check every 10 and 20 years (see first table, page 22).

The fifth and sixth groups, which use about 50MH and 80MH for routine inspections, can conveniently be included in every third and fifth C check according to their intervals (see first table, page 20).

The largest groups for the calendar-based tasks are the 24-, 48-, 72-, 96-, 120- and 144-month inspections. These all conveniently have intervals that are multiples of 24 months, and so are combined with the relevant C checks as they come due (see first table, page 22).

The other six groups only use a small number of M H.

For ease of planning, the 12- and 18-month tasks can be performed annually. On odd-numbered years they drop out into large A checks with the first and second group of OOP tasks. On even-numbered years they come due with C checks.

It is simplest to perform the 36-month tasks at 24-month intervals, so they are always combined with C checks.

The 180-month checks use only a few M H, and so are can be grouped into a large A check when they come due. Overall, the first and second group of OOP tasks are the large A checks and 180-month calendar-based tasks drop out as they come due, and are grouped into large A checks.

This raises the issue of how A checks are planned. While the Routine and A check intervals are 100FH and 500FH, it is likely that they will be performed at roughly 80FH and 400FH intervals. The APU tasks can then be grouped into the A checks as close as possible to their intervals. In some cases they will not coincide with A checks, but will then be included with Routine checks.

One large check will therefore be the A 3 check. It will have two A check task groups and four APU task groups. The A 6 check will also be large.

The 400FH interval for OOP tasks will conveniently come due at the likely interval for the A check. The OOP tasks can otherwise be grouped into Routine checks.

The OOP and calendar-based tasks that drop out of C checks can be included in the A 6 check package, which is due every 2,400FH.

**CRJ-700/-900**

The case of the CRJ-700/-900 is different. These currently have five groups of FH-related tasks with intervals that are multiples of 4,000FH, with a fifth multiple at 20,000FH. An annual utilisation of 2,400FH means the 4,000FH interval is reached every 19-20 months.

There are also OOP tasks with intervals from 3,000FH to 30,000FH, although most are up to 10,000FH. The intervals of these are awkward in relation to C checks at 3,600FH intervals. Those with intervals of 4,400-5,000FH are best scheduled with each C check. Others have to be scheduled at other intervals to make best use of their intervals, and so drop out and have to be included in heavy A checks, or occasionally be scheduled into C check packages (see second table, page 22).

The calendar-based tasks are between six months and eight years. The six-month tasks could be combined with the A checks.

There are another seven groups of tasks that have intervals of 12-96 months, and that are also multiples of six months. Two sets have initial intervals of 96 months, but different repeat intervals. The 12-month tasks are scheduled annually, and so are often not included in a C check package. The same applies to other tasks, and most groups on most occasions drop out from C check packages (see second table, page 22).

The escalated C check interval of 6,000FH for the FH-related tasks means the base checks of C1 up to 5 would be performed once every 30 months.

OOP and calendar-based tasks would therefore be scheduled differently. On most occasions they would not be included in C check packages, but would instead be packaged into heavy A checks at six- or 12-month intervals between C checks.

**Line check inputs**

There are are no line checks in the CRJ’s MPM, and the smallest specified check is the Service check at 100FH. M any operators include ‘pre-flight’, ‘transit’ and daily checks in their line maintenance programmes to maintain operational reliability.

The pre-flight and transit checks are performed prior to each flight, often by flightcrew, but line mechanics will be required to rectify technical defaults. A conservative allowance of 0.5MH per check will cover all required maintenance throughout an operation. One check per FC means 2,100 pre-flight and transit checks will be made each year. An
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The CRJ-100/200 have C check tasks with an interval at multiples of 5,000FH. It is simplest to have base checks every two years. Most out-of-phase & calendar tasks can be planned into base checks, though their full intervals sometimes do not get fully utilised.

Additional allowance of $10 for materials and consumables should also be made. Service checks are daily, but some maintenance programmes allow an interval of up to 72 hours. An average of 275 checks will be consumed in a year. A budget for labour and material consumption is 1.5M H and $150.

Routine checks have an interval of 100FH, but some operators add a second interval parameter of seven or eight days, meaning about 50 service checks are made each year. Labour and material inputs are about 3.0M H and $200.

A final element of line checks will be APU tasks with OOP intervals. During one year's operation 12 groups of APU tasks will be completed, using 40M H.

Total consumption during the year will be 1.600M H in labour, and $75,000 in materials and consumables. Using a generic labour rate of $75 per M H, total inputs for a year's operation equal about $200,000, or $85 per FH when amortised over the year's annual FH utilisation (see first table, page 32).

A check inputs

The A check task grouping described for the CRJ-100/200 results in routine labour inputs of 55-265M H. In addition to routine tasks there are also non-routine rectifications, additional OOP tasks that have dropped out of base checks, the clearing of defects, and interior work.

The non-routine ratio for aircraft in their first 10 years of operation is 50%. A budget of 25M H for clearing defects and 10M H for interior cleaning should be allowed. Base check OOP tasks total 20M H, and are included in one A check per year.

This results in total labour inputs of 120-460M H. Costs of consumables and materials for these checks are $5,000-21,000. Using a standard labour rate of $70, total cost for the six checks in a year's operation is $190,000. Amortised over the annual utilisation of 2,400FH, the reserves for A checks are $78 per FH (see table, page 32).

In the case of the CRJ-700/-900, task grouping results in routine M H requirements of 60-140M H, once OOP and APU tasks have been added. Base check inspection tasks that have dropped out of C checks can be included in annual or semi-annual A checks.

It is assumed here that actual A check intervals average 320M H, so that seven or eight checks are performed each year.

Using the same 50% non-routine ratio and budgets for clearing defects and interior cleaning takes total annual M H consumption to 1,300M H. The cost of associated materials and consumables for each check is $5,000-11,000. Using the same standard labour rate, the total annual cost for A checks is $140,000. In addition, there are 30-day OOP tasks, which can be completed with every fourth weekly check. These consume 5M H each time, and so about 65M H per year at an additional cost of $4,500. Reserves for all these costs are equal to $61 per FH (see table, page 32).

Base check inputs

CRJ-100/-200

The content of the base checks will first include the routine inspections as described. The large number of different task groups means that the labour used in these routine inspections in the first five C checks varies from 400H to 1,725M H, with the C4 check being the largest.

The other elements of the base check include non-routine rectifications, the clearing of defects, engineering orders (EOs) and serviced bulletins (SBs), changing hard-timed components, and interior cleaning.

The non-routine ratio in the first base checks is in the region of 50%, but this then rises to about 80% by the fourth or fifth base check. The M H used for non-routine rectifications therefore increase during the first check cycle from 200M H at the C1 up to 1,400M H for the C4 check. The sub-total for routine inspections and non-routine rectifications is 8,500-9,000M H for the first five checks.

Clearing defects will be shared between A checks and base checks. The labour used will depend on operation and maintenance policy, but a budget of 100M H for a base check should be used.

There is then labour for completing airworthiness directives (ADs), SBs and EOs. This is variable, and depends on the ADs and SBs that are used, which aircraft they are applicable to, and airline policy with respect to upgrading aircraft. A budget of 50-300M H should be used, depending on the size of the check workscope and downtime.

A budget of 50M H should be used for component changes, and another 100M H allowed for interior cleaning.

For the first five base checks the total labour varies from about 900M H for the C1 up to 3,700M H for the C4. The total for the four checks is 10,500-11,000M H. At a generic labour rate of $50 per M H this is equal to $530,000.

In addition to labour there will be the cost of parts and materials. This varies from about $17,000 for the C1 check to about $68,000 for the C4 check, and the total reaching about $200,000 for the five checks. The total cost of about $750,000 for the first five checks amortised over the interval of 12,000FH is equal to a reserve of about $30 per FH.

The labour and material inputs for the five checks in the second base check cycle will be higher. Routine M H will increase to 6,900M H, due to the arrangement of inspection task packages.

The non-routine ratio will also continue to increase, starting at about 90% for the C6 check and rising to more than 100% by the C8 or C9 check. The
The final element will be stripping and repainting. This will cost in the region of $100,000, and will be performed on average once every five C checks, resulting in a reserve of $5 per FH (see table, page 32).

### Heavy components

Heavy components comprise: wheels, tyres and brakes; landing gear; thrust reversers; and the APU.

Tyres are not remoulded by most operators on the CRJ, and are instead replaced at every removal. Removal intervals are 250-300FC, while new nose tyres are $300-350, and new main tyres are $1,300-1,400. The cost of replacing worn tyres is therefore $19 per FC for the CRJ-100/-200, and $22/FC for the CRJ-700/900.

Wheels are inspected at tyre removal, and then have an overhaul about every fifth removal. Taking into account the typical costs of wheel inspections and overhauls, the cost of wheel repairs is $8 per FC for the CRJ-100/-200, and $13 per FC for the CRJ-700/900.

Brakes are steel, and have a shop visit about every 2,000FC for the CRJ-100/-200 and every 1,600FC for the CRJ-700/900. Taking typical third-party shop visit costs into account, the cost of brake repairs is $30 per FC for the CRJ-100/-200, and $50 per FC for the CRJ-700/900.

The total cost for wheels and brakes is $57 per FC for the CRJ-100/-200, equal to $50 per FH. The total for the CRJ-700/900 is $85 per FC, equal to $74 per FH (see table, page 32).

Landing gear shop visit intervals take place every 10 years and 20,000FC. Using a heavy annual A or base check as the appropriate time to change landing gears, the interval for the CRJ-100/-200 and CRJ-700/900 is 19,000FC. Typical landing gear exchange and overhaul fees are $180,000 for the CRJ-100/-200, and $360,000 for the CRJ-700/900. Reserves are equal to $9 per FC for the CRJ-100/-200, and $15 per FC for the CRJ-700/900. These are equal to $8 and $12 per FH for the two types.

Thrust reversers are maintained on-condition, and intervals are variable. Taking 15,000FC as an expected average for a reverser shipset of the appropriate size, the cost per FC is $20 for the CRJ-100/-200 and $23 for the CRJ-700/900. These are equal to $17 and $20 per FH (see table, page 32).

The APU on the CRJ is a Garrett APU. APU intervals and APU utilisation vary. A typical interval is 3,500APUH.
LLPs in the fan module have lives of 20,000-25,000EFC, LLPs in the HPC and HPT modules have lives of 9,000-17,000EFC, and LLPs in the LPT have lives of 26,000EFC (see table, page 27). A shiptset of parts has a list price of $1.94 million. The fan and LPT module LLPs account for $814,300 of this, while the HPC and HPT account for the remaining $1.13 million.

The -8C1 had a problem with retaining exhaust gas temperature (EGT) margin, so it had poor on-wing performance.

To harmonise the CF34-8 family and solve the CF34-8C1 issues, General Electric introduced an upgrade modification to upgrade the -8C1 to a -8C5B1. This is best installed during the -8C1 to a -8C5B1. This is best installed during the engine's first shop visit when the LLPs in the HPC and HPT expire after 9,000EFC. The upgrade involves the replacement of the HPC stage 3-5 vanes, HPC rotor assembly, HPT drive shaft, first stage nozzle assembly, the HPT module, the combustor, the LPT shaft, and the LPT third-stage blades and shrouds. This is introduced to improve EGT margin retention.

The LLPs in the HPC and HPT are also exchanged for parts with longer lives. The LLPs in the HPC are 20,000-25,000EFC, and those in the HPT are 14,700-25,000EFC (see table, page 27). These two groups have a list price of $1.09 million.

The upgrade is encompassed in several SBs issued by GE, and there are several kits of parts to complete the modification. The kits vary with each engine, but they cost in the region of $1.3 million, including the LLPs.

Already about 70% of -8C1 engines have been upgraded to -8C5B1 standard.

**-8C5 series**

The CF34-8C5 was introduced in late 2002 on the CRJ-900, but also on the CRJ-700 in 2005 following problems with the -8C1. The -8C5 was later introduced on the CRJ-700 in 2005. This engine has longer life LLPs in the HPC and HPT, an improved design, and overall better EGT margin retention.

There are four sub-variants: the -8C5B1, -8C5A1, -8C5A2, and -8C5A3. The -8C5B1 has an installed rating of 12,500lbs thrust, the -8C5 has an installed rating of 13,100lbs thrust, the -8C5A1 has an installed rating of 13,400lbs thrust, the -8C5A2 an installed rating of 13,800lbs thrust, and the -8C5A3 an installed rating of 14,260lbs thrust. Bypass ratio is 5.0:1, and all variants are flat rated to 15 degrees Centigrade. The engine has the same configuration as the -8C1.

Current LLP lives in the -8C5 series are 15,000EFC and 25,000EFC in the fan, 20,000-25,000EFC in the HPC, and 25,000EFC in the LPT (see table, page 27). These three groups have list prices totalling $1.45 million.

LLP lives are more variable in the HPT. These are 14,700-25,000EFC in the -8C5B1, and -8C5A1, and 13,200-20,000EFC in the -8C5A2 and -8C5A3. These parts have a list price of $447,100, thereby taking the total cost of LLPs for the whole engine to $1.9 million.

GE, however, has stated that it will extend the lives of all LLPs in all modules to a uniform life of 25,000EFC. The exception is the HPT LLPs in the -8C5A2 and -8C5A3, which will have a uniform life of 20,000EFC. GE has said that this extension will be made before the engines reach their first shop visit. Some of the earlier-built engines are reaching their first shop visit now. This extension will simplify shop visit planning and engine management.

**CF34-3 & -8C in service**

As described, most CRJ-100/-200 operations are at an average FC time of 1.15FH, and so the average EFC time for the -3 series is the same; about 1.15 engine flight hours (EFH).

The -8C on the CRJ-700 and -900 operates on longer average EFC times of 1.30-1.50EFH. These can have an impact on LLP life consumption and removal intervals.

**CF34-3A1/-3B1**

“The EGT margin of new CF34-3B1 engines is 55-60 degrees Centigrade in most cases,” says Guillermo Pablo, CF34 production support engineer at Iberia M maintenance.

EGT margin erosion and loss of EGT margin is a typical cause of engine removal for engines operated on short cycle times. “The rate of EGT margin erosion on the CF34 family is low, especially in new engines,” says Donald Stricklin, manager engine product lines at Delta TechOps. “We see rates of 1.5-2.5 degrees Centigrade per 1,000EFC.”

The -3A1 initially had hot section and EGT margin retention problems, so it had short removal intervals in the early years of operation. “These were related to cracks in the combustor liner and deterioration in the stage 1 HPT nozzles,” explains Stricklin.

“One main benefit of the CF34’s military heritage is that it has been designed so that the HPT and LPT modules can be removed and replaced while the rest of the engine remains on-wing. The shaft LP remains in the engine, while the HP shaft is removed with the HP rotor,” explains Pablo. “The HPT can be removed and replaced and then the LPT can be put back on without having to remove the whole of the engine. While this means that an airline will have to hold spare HPT modules in its inventory, it simplifies maintenance planning. The HPT has LLPs with the shortest lives, and...
also may require performance restoration maintenance prior to LLP expiry. The remaining modules are able to remain on-wing until they reach their LLP limits."

The ability to remove just the H PT therefore makes maintenance planning more flexible. There is also the possibility of doing a top case inspection, where the casing of the H PC can be removed in the event of foreign object damage (FOD). H PC blades can be removed and replaced this way, thereby avoiding some unscheduled removals.

It is therefore possible for the engine to remain on-wing until the life limits of LLPs in the fan, H PC and LPT modules are reached. A removal and full overhaul is carried out at this stage, when H PC LLP lives expire and need replacing. Fan and LPT module LLPs can be replaced on-wing if necessary, although they would clearly be replaced during this overhaul.

-3A1

"The -3A1 engine has LLPs in the H PC and H PT that are both at 15,000EFC. Because they expire at the same time the whole engine has to come off," says Stricklin. "The workscope at the first shop visit would include the H PC, combustor and H PT. This would restore the hot section and replace the expired LLPs."

This workscope would consume about 1,500M H, $460,000 in parts and materials, and $430,000 for sub-contract repairs. Using a standard labour rate of $70 per M H, the total cost for the shop visit would reach about $1.0 million. This does not include the cost of LLP replacement. Another $20,000 should be added for H PT removal and installation.

"Following the first shop visit the engine can achieve a second removal interval of 12,000-15,000EFC, and the total time from new would be limited to 22,000EFC by LLPs in the LPT. All engine modules would then have a full workscope, and have their LLPs replaced."

The following overhaul at a total time of 21,000-22,000EFC would come to about 2,000M H in labour, about $500,000 in parts and materials, and another $500,000 in sub-contract repairs. A further $20,000 for engine test takes the total to about $1.2 million, not including LLP replacement.

The total of these two shop visits amortised over the interval of 22,000EFC is equal to a reserve of $100 per EFC.

The list price of the six LLPs replaced in the first shop visit is about $240,000, and the remaining parts have a list price of about $910,000. Amortising these over the respective replacement intervals equals a reserve of $57 per EFC. Total reserves are $157 per EFC. This is equal to $136 per EFH (see table, page 32).

-3B1

"In the case of the -3B1 we follow the practice of removing the H PT off-wing at Delta TechOps," continues Stricklin. "We first do a mid-life H PT removal at the first shop visit after 10,000-12,000EFC on-wing. We do minor work with the first stage H PT nozzles and combustor liners at this stage, as well as some minor stuff on the H PC.

"The engine can then remain on-wing to a total time of 18,000EFC when the LLP life is expired in the H PT," continues Stricklin. "The H PT and combustor have a full workscope at this stage, with H PT LLPs replaced. Little work is done on the fan and H PC, and the LPT needs no work at all until its LLP limit of 25,000EFC, when a third removal and shop visit are carried out and all modules are overhauled and have their LLPs replaced.

Iberia follows a pattern of two removals and shop visits for the -3B1. "Mid-life maintenance can be done on the H PT module at some point during the life limit of the LLP with the shortest life. This is 17,000-18,000EFC in the case of most engines," continues Pablo.

A workscope on the H PT will use about 300M H in labour, about $460,000 in parts, $50,000 for sub-contract repairs, and $20,000 for the H PT removal and replacement. This would have a total cost of $550,000.

The LLPs replaced at this stage would be the four H PT parts with lives of 18,000EFC, which have a list price of about $156,000.

The second removal interval depends on the remaining lives of LLPs in the replacement H PT, and the shortest life in the H PC. This is the blisk, which has a life of 22,000EFC for most currently operating engines. In 2008 a new post-SB 72-240 blisk part number was introduced to improve its life to 25,000EFC. A full overhaul of these modules was carried out at a total time of 22,000EFC or 25,000EFC. Usually, most LLPs in the fan, H PC and LPT would be replaced in the modules that have a full disassembly performed on them."

The second shop visit would be an overhaul, and have a similar cost to the -3A1 as described. The remaining LLPs in the engine would be replaced at this stage, and have a list price of $990,000.

The cost of the two shop visits would be amortised over 22,000EFC or 25,000EFC, depending on the H PC blisk part number fitted in the engine. The combined reserve would be $62-70 per EFC, depending on interval. The total reserves for the -3B1 would therefore be $111-134 per EFC. This is equal to $96-116 per EFH (see table, page 32).

-3C

GE has stated that it will extend the lives of all LLPs in all modules of the -8C series to 25,000EFC, and do this before the engines reach their first shop visit. The exceptions will be H PT LLPs in the -8C1A/A3 engines, which will have lives of 20,000EFC.

The two main variants of the -8C series are managed differently. The -8C1 and -8C2 are treated as a single component, with the -8C3, -8C4 and -8C5 series managed separately. The -8C1
have limiting LLPs in the H PC and H PT of 9,000EFC. This therefore forces a removal at this stage, at which point the engine gets upgraded to a -8C5B1.

The upgrade includes an extension to the engine’s LLP lives. LLPs in the H PC get increased to lives of 20,000-25,000EFC, while parts in the H PT get extended to 14,700-25,000EFC (see table, page 32).

In the case of the -8C1, the first shop visit will involve some work on the H PC, combustor and H PT parts, although much of the material in these modules will be replaced at this stage with the upgrade kit. The cost of the upgrade kit is borne by the operator, and once labour, in-house and sub-contract repairs and scrap replacements are added, the shop visit cost is $600,000-700,000. The reserve for this shop visit would be $783-$800 per EFC.

- **8C5B1** at the second shop visit at a total time of up to 24,000EFC will incur a similar cost to that of the -3B1: about $1.2 million (excluding LLPs). The reserve for this, over an interval of about 15,000EFC, would be $80 per EFC.

All LLPs in the fan, H PT and L PT modules would be replaced at this stage, and have a list price of $1.17 million. LLPs in the H PC would have 9,000-10,000EFC remaining, and could remain in the engine to the third removal. The reserve for all LLPs in the engine will be about $86 per EFC.

The reserve for both shop visits amortised over an interval of 24,000EFC would be $80 per EFC. Combined with reserves for LLPs, the total reserves for this engine would be $166 per EFC, equal to $144 per EFC (see table, page 32).

**Summary**

The differences between the CRJ-100/200 and the CRJ-700/900 are small compared to differences in their seat capacities. This is not surprising given that most costs are related to line checks and rotatable provisioning and heavy component costs, which are similar for the two types.

The difference between the two types comes from engine-related maintenance costs. These differences are small, and the CRJ-700/900 benefit from economies of scale and improvements made to their engines as a result of the operational experience gained with the 3A1 and -3B1. **AC**

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