Dash 8 & Q series maintenance analysis & budget

The Dash 8 & Q400 have similar maintenance programmes. The Dash 8 is mature, while the Q400 is still young. Their maintenance costs are examined.

Although the Dash 8-100, -200, -300 and Q400 are part of the same family, in technical and maintenance terms there are two main types: the Dash 8-100/-200/-300 series; and the Q400 series. The two have different maintenance programmes, engines and rotable components. The Dash 8-100/-200/-300 have similar maintenance programmes, common components, and share variants of the same basic engine model, the PW100 series. The Q400 was the last to be developed. All four main variants are used in regional roles.

The Dash 8-100/-200/-300 have a base check maintenance cycle interval of 20,000 flight hours (FH). The first aircraft went into service in 1984, while the last Dash 8-200s and -300s will be built in 2009. The fleet leader has accumulated 61,000FH, so it has passed its third heavy check.

The Q400 has a base maintenance cycle of 16,000FH, and the fleet leader has accumulated about 20,000FH. It has therefore had its first heavy check. The first aircraft were built in 1998 and 1999. With most aircraft operated at 2,100FH per year, the majority have yet to reach their first heavy check.

Dash 8 family in operation

The Dash 8 and Q400 series are universally operated in commuter and regional roles. Virtually all operators have average flight cycle (FC) times of less than 1.0FH.

The Dash 8-100 fleet is split between a few major regional carriers and a larger number of small commuter-type airlines. Air Canada regional feeder Air Canada Jazz operates a fleet of 36 Dash 8-100s at 2,200FH per year and an average FC time of 1.0FH. Piedmont and Wideroe have 42 and 18 aircraft respectively, operating at similar rates of utilisation.

Other Dash 8-100 operators have small fleets and achieve low utilisation rates, of less than 1,500FH per year.

The smaller Dash 8-200 fleet has some regional carriers that operate at 2,000-2,300FH per year and an average FC time of about 0.70FH.

The Dash 8-300 fleet is dominated by typical regional carriers. Average FC times are 0.65-1.00FH, and most have annual utilisations of 1,700-2,300FH.

The Q400 fleet also has a large number of regional operators. These have average FC times of 0.75-1.0FH, and annual utilisations of 1,900-2,400FH.

The maintenance costs of the three Dash 8 variants and the Q400 are analysed for aircraft completing 2,000FH and 2,350FC per year and operating at an average FC time of 0.85FH, equal to 51 minutes.

Maintenance programme

The maintenance programmes of the Dash 8 and Q400 are described in the maintenance review board (MRB) and airworthiness limitations (AWL) documents. The maintenance programmes of the two types should be considered separately.

Dash 8-100/-20/-300

The Dash 8 maintenance programme has steadily evolved since the aircraft first entered service in 1984. "The Dash 8-100 and -200 and -300 actually have almost identical maintenance programmes, with only small differences between the three. These relate to tasks such as structural items that differ between the types due to fuselage length, for example," explains Marco Snippe, customer service engineer at SAMCO Aircraft Maintenance, Netherlands. "The latest revision number of the Dash 8-100/-300's MRB is revision number 22 from November 2008, while the Dash 8-200's MRB is at revision number 13 from November 2008. The Dash 8's maintenance programme differs from the Q400's in that the tasks are numbered differently.

"The Dash 8's maintenance programme comprises systems, structures, zonal, corrosion prevention and control programme (CPCP) and electrical wiring interconnection system (EWIS) inspection programmes," continues Snippe. "The systems inspections are for the airframe systems, engine and auxiliary power unit (APU). The structures programme is for structurally significant items (SSIs). The zonal inspections are for general visual inspections of the aircraft's systems and structures. The EWIS programme is for the inspection of wiring installations, and the CPCP for protection against corrosion.

"The inspections are arranged into maintenance checks, of which there are three main check types: the L check with a 50FH interval, an A check with a 500FH interval, and a C check with a 5,000FH interval," continues Snippe. "The lowest check is the L check, which is done about once a week for most operators' rate of utilisation.

"There are no specified lower line checks, such as pre-flight (PF), transit (TR) and daily checks, in the maintenance programme," adds Snippe. "Most operators introduce their own line checks to their maintenance programmes. Since there are no line checks listed in the MRB, the routine tasks of the line checks added by the airline can be performed by the flightcrew. These involve mainly visual inspections of panels and wheels, and checks for leakages and of the aircraft technical log. Most defects that occur during operations can be deferred to daily or L checks. Defects must be corrected by line mechanics, who have to be available during daily checks and possibly at PF checks."

The Dash 8's A check basic interval is 500FH for the 1A tasks. There are five other groups of A checks with multiples of the basic 500FH interval: the 2A at 1,000FH; the 3A at 1,500FH; the 4A at 2,000FH; the 5A at 2,500FH; and 6A at 3,000FH.

These can be performed in block checks, so the A4 check would comprise the 1A, 2A and 4A tasks, while the A6 check would comprise the 1A, 2A, 3A and 6A tasks. All the A check multiple tasks would come into phase at the A60 check, at an interval of 30,000FH.

The Dash 8's basic C check interval is 5,000FH. "Most of the tasks have FH-related intervals, but the majority have calendar intervals if the aircraft is operated at less than 1,500FH per year, and on a low utilisation maintenance programme," explains Snippe. "The C check tasks in the regular maintenance programme have a mixture of FH, FC and calendar intervals. The tasks are grouped into four multiples of C check tasks: the 1C with a 5,000FH interval; the 2C with a 10,000FH interval; the 3C with a 15,000FH interval; and the 4C with a 20,000FH interval.

The C2 check at 10,000FH therefore comprises the 1C and 2C tasks, while the C4 check at 20,000FH has the 1C, 2C

The Dash 8's maintenance programme consists of many groups of tasks. Ultimately most are packaged into a system of four C checks which have an interval of 5,000FH.

and 4C tasks. The C4 check is the heaviest, but the three groups of tasks do not get in phase until the C12 check at 60,000FH. This is the third heavy check.

"The base check tasks can be sub-divided into nine groups," explains Snippe. "The first of these are the system, structural and zonal inspections in the 1C, 2C, 3C and 4C groups of tasks that all have FH-related intervals. The second group are tasks with calendar intervals. The third group is tasks with FH and calendar intervals. The fourth group is FC-related tasks. The fifth group is tasks with FC and calendar intervals.

"A sixth group of tasks has both FH and FC intervals," continues Snippe. "The seventh group has FH intervals, but is out-of-phase with the first group. The eighth group are opportunity tasks, like those performed in the engine cowling area after an engine is removed. The ninth group is fatigue damage tasks, which are normally FC-related and have a threshold interval with a high number of FC, and are followed by regular repeat intervals. The MRB lists which tasks are included in which group of C check task multiple and so which C check."

Q400

The Q400 has a more advanced maintenance programme. This has the same L checks as the Dash 8, with a 50FH interval. The Q400's basic A and C check intervals in the original MRB were 400FH and 4,000FH.

"The Q400's maintenance programme is laid out by Bombardier in the maintenance requirements manual (MRM). This contains the MRB and the airworthiness limitation items (ALIs). Like the Dash 8, the Q400's maintenance programme comprises six groups of inspections (Systems, Structures, Zonal, EWIS, CPCP and L/HIRF)," explains Stefan Kontorravdis, director of engineering at Flybe.

There are six A check multiples. The basic 1A task group interval was 400FH, and has recently been escalated to 600FH. The 6A tasks' interval of 2,400FH has been extended to 3,600FH. The 3A tasks, originally at 1,200FH, were removed from the latest revision. The five remaining task groups are in phase at the A60 check, as with the Dash 8. The original A60 interval was 24,000FH, and this is now 36,000FH.

"We have equalised our A checks, so we have smaller checks at a shorter interval. These smaller packages can be done in an overnight check," says Kontorravdis.

Other operators opt for an equalised A check programme. "Baboo of Switzerland, for example, has no A checks, but has E checks every 100FH. These are equalised A check tasks. This means that the 1A tasks are divided into four similar-sized groups, and the 2A tasks into eight similar-sized groups and so on," explains Jeroen Roumen, customer service engineer at SAMCO Aircraft Maintenance. "Based on the original A check interval of 400FH, the 1A, 2A, 3A, 4A, 5A and 6A tasks are not in phase until the A60 check at 24,000FH. Equalising the A check items into 100FH intervals therefore means all the tasks come in phase at the 240th E check in the cycle at 24,000FH. Because the basic A check interval has been escalated to 600FH, the E check interval may be extended to 150FH in the future.

The C checks comprise four multiples of task groups. The basic 1C group of tasks has an interval of 4,000FH. The 2C tasks therefore have an interval of 8,000FH, the 3C tasks an interval of 12,000FH, and the 4C tasks an interval of 16,000FH. The heaviest check is the C4, at 16,000FH, and includes the 1C, 2C and 4C tasks. The task groups are not in phase until the C12 check at 48,000FH.

The basic C check interval is due to be escalated in 2010, probably to 6,000FH, giving the C4 check an interval of 24,000FH, and the C12 check an interval of 72,000FH. "We have stuck with the 4,000FH interval, and will wait for the escalation to 6,000FH," says Kontorravdis. "Some operators have already escalated their C check intervals to 5,000FH. An interval of 16,000FH means the heavy check will be performed once every eight years. This will increase to 12 years when the basic interval rises to 6,000FH. Maintenance planning also takes into account the large groups of structures tasks with 36- and 72-month intervals. There are also some small groups of out-of-phase (OOP) tasks."

In addition to the five groups of tasks in the C check packages, there are the ALIs, which comprise three groups of tasks: the certification maintenance requirement (CMR) tasks; the structural maintenance tasks; and safe life component (SLC) tasks. The CMR tasks have a calculated limiting interval (based on safety analysis) to achieve compliance with certification regulations. The structural maintenance tasks have Airworthiness Limitations, which include all fatigue damage tasks and must be performed at or before the prescribed intervals.

"The SLC tasks have FH- or FC-related intervals, and operators must monitor the accumulated FHs or FCs of the components on the aircraft, and replace them with new items," explains Roumen. "There are also fuel system limitation (FSL) tasks, which are mandated by the Special Federal Aviation Regulation (SFAR 88). These are limitation requirements that identify all the necessary maintenance and inspection instructions to maintain the design features required to preclude the existence or development of an ignition source within the fuel tank system throughout the operational life of the aircraft. They must be performed at or before the prescribed intervals. The fifth group is the critical design and configuration control

The Q400 has a base check system of four checks. The basic interval is 4,000FH, but this will be extended; probably to 6,000FH. This will result in lower overall reserves per FH for base maintenance.

limitation (CDCCL) tasks that are mandated by the SFAR 88. A CDCCL is a limitation requirement to preserve a critical ignition source prevention feature of the fuel system design, which is necessary to prevent the occurrence of an unsafe condition identified by the SFAR 88 review. The CDCCL provides instructions to retain the critical ignition source prevention feature during configuration change that may be caused by alterations, repairs or maintenance actions. Many of the ALI inspections have high threshold intervals at 40,000FC, which is half the aircraft's design life. Many of them will not be performed until the aircraft is late in its second base check cycle or in its third base check cycle. Most ALI tasks do not fit in well with the C check packages, so many operators treat them as OOP tasks. It is also possible that some other FC-related tasks will be added later in life."

Maintenance checks

Further to the maintenance programme, items and inspections are added to the three main types of L, A and C checks. These will include routine inspections added by operators, non-routine work to clear defects, engineering orders (EOs) to deal with airworthiness directives (ADs) and service bulletins (SBs), modifications and upgrades, interior cleaning and refurbishment, and stripping and repainting. The content of line, A and C checks has to be examined.

Line checks

As described, the smallest and most frequent check in the aircraft's MRB is the L check with an interval of 50FH. Most operators add other line checks.

Flybe, for example, has a pre-departure check prior to every flight and a daily check every night. The pre-departure check has nine routine tasks. "These are carried out by the flightcrew, since they are not MRB items," explains Kontorravdis. "The nine tasks include: checking the aircraft technical log to see that all outstanding defects are deferred or rectified correctly; a walkround and visual inspection of the aircraft; verifying all panels and hatches are closed; checking tyres for condition; checking all blanks and flags are removed; removing landing-gear lock pins; de-icing the aircraft where necessary; inspecting for ice in temperatures below 10 degrees centigrade; and making a record in the technical log." In addition, defects may have occurred with previous operations. Although most can be deferred, they rarely are and are usually fixed straight away. Mechanics will only be required to clear defects that are 'no-go' items.

While flightcrew usually perform these checks, airlines may want to have a conservative estimate for non-routine labour. An input of 0.3MH is therefore used. They use minimal consumables.

A daily check involves a walkaround visual inspection to check for damage to the crew's oxygen system, wheels and brakes, water contamination, and oil and hydraulic levels. Kontorravdis says that there are 24 tasks in total, using 1.5-2.0MH. An allowance of $40-50 can be made for consumables and materials.

The L check, performed about once a week, is done on the day it comes due in addition to the daily check. Kontorravdis explains there are 24 tasks in the L check, which include inspections of the smoke detectors, oil filters, the reduction gearbox and the monitoring system for fault codes. Findings also arise.

The L checks are slightly larger than the daily checks, so an average labour input of 3MH can be used for them. An allowance of $150 for materials and consumables can be used.

About 2,200 pre-departure checks, 350 daily checks, and 45 L checks are performed each year. Using a standard labour rate of $70 per MH for line maintenance, the total annual cost for line maintenance will be $131,000, equal to $66 per FH *(see table, page 22)*.

A checks

The A checks total 70-80 tasks. They include cabin cleaning, external and internal visual inspections, and operational and functional checks. Kontorravdis explains that the operational and functional checks include APU start and ignition check, spoiler and aileron functional checks, and tension checks of aileron cables. There are also findings and non-routines.

Labour input for A checks on the Q400 averages 110-120MH, and materials average $3,000 per check. Using a labour rate of $70 per MH, total average cost for the check is $11,500. The maintenance programme interval of 600FH means the actual interval between checks will be 450-500FH. The reserve for A checks are therefore $23-26 per FH *(see table, page 22)*.

Labour consumption for the three smaller Dash 8 variants will be higher at 150MH, and materials are also higher at $4,000-5,000, giving an average total cost per check of $15,000. The 500FH programme interval means that A checks are likely to be performed every 350-400FH, so the reserve for A checks will be $38-43 per FH *(see table, page 22)*.

C checks

The routine inspections of the base checks have been described. The full content of these checks includes several other elements, however.

The first additional group of tasks will be non-routine rectifications that arise from the inspections. There will also be EOs, removal and replacement of rotables, engine changes, cleaning, interior refurbishment, and, in some cases, stripping and repainting.

The Q400 has similar reserves per FH to the Dash 8. The Q400 is, however, young and most aircraft are still in their first base check cycle. MH consumption will rise as the aircraft get older, but the base check interval is also due to be extended.

Routine inspections increase slightly during the life of the aircraft with some inspections added as their initial thresholds are reached. Routine inspections require 900MH for the C1 check, and 1,200-1,400MH for the C2-C4 checks for the Dash 8-100/-200/-300.

Clearing findings and implementing non-routines is the other element of the checks that accounts for a high percentage of the total MH. The non-routine ratio for the mature Dash 8-100/-200/-300 models varies from a factor of 0.9 to 1.5 of routine MH. "The average non-routine ratio for our Dash 8-100s/-300s has been about 0.8," says Espen Stahl, engineer maintenance programme at Wideroe.

A non-routine ratio of 0.9 would result in about 800MH being needed for clearing defects and performing non-routines in the C1 check, rising to 1,250MH for the C4 check for the Dash 8-100/-200/-300.

The sub-total of MH for these two portions of the base checks would be 9,000MH for the four C checks for mature Dash 8-100/-200/-300 aircraft.

Routine inspections for the Q400 would use a similar number of MH, despite the aircraft being larger than the Dash 8-100/-200/-300. The non-routine ratio would be lower for the Q400, partly because most Q400s are in their first base check cycle and will naturally have a lower non-routine ratio. "The non-routine ratio for the Q400 is definitely lower than the Dash 8s," says Stahl. "The older Q400s had a lot of fixes, however, so they had higher non-routine ratios than the younger aircraft that have been built more recently."

The non-routine ratio of an aircraft at its first base check, the C1 check, will be in the region of 0.2. The ratio will climb as the check cycle progresses, and reach about 0.7 at the C4 check. On this basis the MH used for non-routines in the first cycle of four base checks will be about 2,600MH. The sub-total for these two portions will therefore be 7,400MH for the Q400 in its first base check cycle. This is likely to rise closer to 9,000MH as the non-routine ratio increases in the second base check cycle.

The third element of base checks is labour for ADs, SBs and EOs. The number of MH used for this is highly variable, depending on an operator's requirements for each of its aircraft. A budget of 200-500MH per check can be used to give an estimate of typical requirements, with a higher number of MH usually used during heavier checks.

Interior work is another consideration. Each check will include general interior cleaning and light refurbishment, and will use 50-120MH during these four checks.

Interior refurbishment on the Dash 8 and Q400 will be relatively basic compared to larger aircraft flying longer sectors and offering higher levels of cabin service. Seat covers and cushions, carpets, panels, overhead bins, galleys and toilets will all nevertheless require refurbishment at varying intervals. A budget of 800-1,000MH can be used at the C4 check for this.

Stripping and repainting is one final element of base checks that operators have to consider. "We strip and repaint the aircraft every five to six years," says Kontorravdis. "This is because the condition of the aircraft required a new paint job. This is no longer done together with a heavy check, because of the environmental regulations concerning aircraft painting."

Stripping and repainting an aircraft the size of the Dash 8 and Q400 consumes about 800MH and $25,000 in materials.

The total labour for the check is 2,000MH for the C1 check, rising to about 4,000MH for the C4 check. The total for the four checks for the Dash 8-100/-200/-300 is 12,600MH, equal to $630,000 with base maintenance labour charged at $50 per MH.

Materials and consumables also have to be added. These will cost $40,000-80,000 for the first three checks, rising to $160,000 for the heavier C4 check when interior refurbishment is performed.

The total cost for the four checks is about $960,000 for the Dash 8-100/-200/-300. While the maintenance programme interval for the C checks is 5,000FH, the actual interval achieved by operators is more likely to be in the region of 4,500FH. The cycle of four checks will therefore be completed every 18,000FH, so the reserve for the inputs for these four checks is in the region of $55 per FH *(see table, page 22)*.

The total MH for the C checks on the Q400 are: 1,200-1,300 for the C1; and 2,100-2,300 for the C2 and C3 checks. The heavier C4 check will consume about 3,700MH, and the four checks in the cycle will use 10,400MH, equal to a labour cost of $520,000. This is expected to rise to more than 12,000MH in the second cycle as the non-routine ratio rises.

The cost of materials and consumables for the three smaller checks will be $25,000-65,000 each, and about $150,000 for the heavy C4 check. Total materials and consumables for the four checks will therefore be $280,000.

The total cost for the four checks is therefore about $800,000 for the first cycle of four checks. The maintenance programme interval between checks is 4,000FH, and actual achieved interval between checks will be about 3,500FH. The cycle will therefore be completed in about 15,000FH, so reserves for these four checks for the Q400 will be about $50-53 per FH *(see table, page 22)*.

Heavy components-Dash 8

Heavy components comprise four categories: the landing gear; wheels and brakes; propellers; and the APU.

DASH 8 & Q400 MAJOR MODIFICATIONS & UPGRADES

The original members of the Dash 8 family have been the subject of ongoing development by the manufacturer. One significant development is the introduction of the Active Noise and Vibration Suppression (ANVS) and the associated "Q" designation of aircraft equipped with the system. Field Aviation of Canada provides a retrofit for noise and vibration suppression, including the installation of Ultra Electronics' NVS in non-Q series Dash 8s.

SBs and ADs

The original Dash 8 family members (-100/-200/-300) are relatively free from major SBs and AD. There are two major ADs issued by Transport Canada affecting the Q400 that are currently applicable. These are ADs CF-2007-20R2 and CF-2009-11, which both relate to landing-gear problems. The background to these two ADs is that Bombardier recommended all Q400s with over 10,000 landings be grounded for inspection of their landing gear after two non-fatal accidents involving Scandinavian Airlines (SAS) aircraft.

CF-2007-20R2 relates to the failure of the main landing-gear retract actuator and is dated February 2009. It supersedes the directive CF-2007-20R1 that was issued in October 2007. The AD requires the visual inspection of the main landing gear system and is applicable to all Q400 models up to and including serial number 4,182. There is also a requirement to perform a visual inspection of the retract-actuator jam nut to ensure it is correctly wire locked. This action is to be repeated after every 250 landings or every month, whichever is sooner. The incorporation of a new retract actuator (part number) 46550-13) terminates the requirement.

CF-2009-11 refers to the failure of the main landing-gear stabiliser brace, and mandates that a non-destructive test is to be carried out on it. Aircraft that have completed 12,000 landings must be tested within 50 landings. Aircraft with between 9,000 and 12,000 landings must be inspected within 500 landings, but they must not exceed 12,050 landings. Aircraft that have accumulated between 4,500 and 9,000 landings must be inspected within 1,500 landings, with an upper limit of 9,500 landings. Aircraft with fewer than 4,500 landings must be inspected prior to 6,000 accumulated landings The non-destructive testing is to be repeated at intervals that do not exceed 2,000 cycles.

EASA and the FAA have issued their own versions of these ADs. The EASA ADs are identified by the same numbers as the original Transport Canada versions. The corresponding FAA AD numbers are: 2007-22-09 and 2009-09-02. The FAA estimates the cost of implementing the AD for the retract actuator to be $1,040 per aircraft, assuming that parts are covered by warranty.

There is one major SB (SB 84-34-77) that relates to upgrading the Q400 weather radar. In addition there are two bulletins (SB 84-54-04 & SB 84-54-05) that refer to modifications of the engine nacelle.

Third-party programmes

Canadian MRO Cascade Aerospace provides a number of upgrades and modifications for the Dash 8 family. For the -100/200/300 models, Cascade offers a modification or upgrade for the environmental control system (ECS), which provides improved performance and lower maintenance costs. The supplier says that the upgraded system has been shown to reduce pack output temperature by 5 degrees Centigrade. It claims that customers consistently report that the enhancement kit greatly improves aircraft cooling when the aircraft is on the ground and in flight. The upgrade is approved by EASA, FAA, JCAB, and Transport Canada.

For the Q400, Cascade offers a programme that converts the passenger aircraft to a package freighter by means of its Q400-PF-Kit. The modification involves removing interior passenger-related elements and installing a full cabin-length Class E cargo compartment. The compartment is designed for package freight and/or containers. Cascade says that the cargo payload of the converted aircraft is 19,800lbs (assuming a maximum zero-fuel weight of 58,000 lbs). The useable volume is said to be 2,730 cubic feet.

The cargo compartment and aircraft ventilation system is modified to provide climate control, so that perishable goods can be transported. A new floor structure and suspension system is installed, together with protective panels to minimise maintenance and repair costs. The aircraft's baggage door is modified to improve height clearance.

Conair, another Canadian company, also markets a modification kit aimed at improving performance of the environmental control system of series Dash 8-100/-200/-300 models.

The landing gear overhaul life for the nose and main gears is different. The nose gear has a life of 25,000 cycles or 10 years, and the main landing gear has a life of 30,000 cycles or 12 years. Given the average utilisation of 2,350FC per year the majority of landing gear overhauls will take place at about the same time that the calendar limits are reached. A typical exchange and overhaul fee of $450,000 results in a reserve of $15 per FC for the shipset. This is equal to $18 per FH *(see table, page 22)*.

The thickness of brake units is monitored during operation, and these are removed for repair and overhaul. Estimates for the cost of wheels and brakes vary between operators but a typical operator reserve for the wheels, brakes and tyres is $25 per FC, equal to $30 per FH *(see table, page 22)*.

Unlike other propeller manufacturers, until recently there was no calendar overhaul limit on Hamilton Sundstrand propellers. From 1st October 2009 the manufacturer, however, is introducing another calendar limit of seven years in addition to the major inspection (MI) interval of 10,500FH. The reason for the introduction of the calendar limit is that while some factors, such as fatigue, are a function of hours of operation, corrosion is a function of calendar time.

The cost of overhauling the propellers depends on the level of corrosion found when the propeller has its first inspection in the shop. Assuming a fairly typical repair cost of $84,000 and a utilised interval of 10,500 engine flight hours (EFH), the reserve will be $8 per propeller EFH. The reserve for the two propellers is $16 per FH *(see table, page 22)*.

The installation of an APU is an option on the Dash 8-100/200/300 family. The APU is a Hamilton Sundstrand Model APS 500 (T-62T-40C7B/D), and overhaul is on-condition. A typical overhaul reserve is $20 per APU hour (APUH). Assuming an APU utilisation of 0.8APUH per FH this is equal to $16 per FH *(see table, page 22)*.

Heavy components-Q400

The landing gear overhaul life for the Q400 is the same as the earlier Dash 8 variants: 20,000FC and 10 years for the nose gear; and 25,000 cycles and 12 years for the main gear. Given the average

DASH 8 & Q SERIES TECHNICAL SUPPORT

MRO services
The Dash 8's smaller fleet size means that providing technical support for the Dash 8 and Q Series is more specialised than for more numerous types like the 737 and A320 family. About 80% of the global fleet of 840 aircraft is concentrated in North America and Europe, and most of the other 20% is based in the Asia Pacific.

The concentration of the fleet and the desire by many operators to have predictable per-flight-hour contracts means that a large proportion of the providers have a one-stop shop capability for the aircraft. Bombardier has several recognized service facilities. These offer comprehensive maintenance airline maintenance, repair and overhaul. The recognized service facilities include SAMCO Aircraft Maintenance in the Netherlands, and Flybe Aviation Services in the UK.

There are seven levels of technical support. Providers offering one-stop services offer most or all of the services that an airline or operator would require. Technical support provisioning is considered for the four main types: the Dash 8-100, Dash 8-200, Dash 8-300, and Dash 8-400.

North America has some of the largest providers, including: US-based AAR, Cascade Aerospace, Field Aviation, Avmax and ExcelTech. Bombardier also provides MRO capability in North America.

For the Q400 the major MRO providers include SAMCO in the Netherlands, Flybe in the UK, and Hawker Pacific in Australia. Samco is also a major Dash 8 maintenance provider. These three are part of Bombardier's Recognized Service Facility (RSF) network.

Some large operators have significant in-house capability, but perform little third-party work.

Engineering Management
The trend for regional airlines to outsource maintenance has led to MROs offering one-stop capabilities. The major providers for all four types are AAR, Avmax Montana, Fokker Services, Samco and ST Aerospace. The major providers for the three Dash 8 variants are Altenrhein Aviation and ExcelTech Aerospace. Flybe Aviation Services, Hawker Pacific Aviation, and Bombardier and the providers for the Q400.

Line and Light Maintenance
This is the least technical function to be outsourced. Altenrhein Aviation is the main provider for the Dash 8-100/-200/-300. Bombardier, Flybe and Hawker Pacific are the main providers for the Q400. AAR, Avmax, ExcelTech Aerospace and Samco offer for all four types.

Base Maintenance
The relatively small fleet means that there are few providers of base maintenance for the Dash 8/Q400. The three providers for all four main types are AAR, Avmax and Samco. Altenrhein Aviation is a major provider for the three Dash 8 variants. Bombardier, Hawker Pacific and Flybe Aviation Services are the major providers for the Q400, with these three companies having up to 20 base maintenance bays between them.

Engine maintenance
Pratt & Whitney are the sole supplier of engine maintenance for the Dash 8 family. The OEM offers an extensive network of overhaul centres with a wide geographic spread. The company has its own facilities in Quebec and Singapore. It also has designated overhaul facilities, which include Atlantic Turbines in Canada and Dallas Airmotive in Texas. There are six designated European facilities: Avio in Italy; Standard Aero in the Netherlands; Finnair in Helsinki; Volvo in Sweden; SECA EADS in France; and Lufthansa AERO in Germany.

Spare engine support
The relatively small market means that the engine leasing market is correspondingly under-developed. Spare engine support is therefore largely restricted to that provided by the OEM and the independent overhaul facilities.

Rotables & logistics
Regional aircraft manufacturers were among the first to offer component and rotable support on a cost-per-flight-hour basis. Despite having extensive experience of such schemes in the corporate aircraft market, Bombardier was relatively late into the market. It now offers such a repair and exchange scheme, which is marketed under its 'Smart Services'. The scheme operates along well-established lines, whereby operators return defective parts to Bombardier and are sent replacements from the manufacturer's exchange pool. The affected part is then repaired and returned to the exchange pool.
A number of independent MRO providers offer rotables & logistics schemes. This is one of the few areas where Lufthansa Technik offers a service, albeit only for the Q400. Other providers include AAR, Avmax, Fokker Services, Samco and ST Aerospace.

Heavy components
Heavy components include: wheels, tyres & brakes, landing gears, thrust reversers and APUs. It is rare for airlines to have the capability to maintain such equipment in-house and this is particularly the case for regional aircraft such as the Dash 8. The OEMs are the primary source for the repair of such components. Other major providers are AAR, Avmax and Flybe Aviation Services.

utilisation of 2,350FC per year, the majority of landing gear overhauls will take place at about the same time that the calendar limits are reached. A typical overhaul and exchange fee of $450,000 results in a reserve for all three gears of $18 per FC, equal to $21 per FH *(see table, page 22)*.

A typical operator reserve for the wheels, brakes and tyres is $30 per FC, equal to $35 per FH *(see table, page 22)*.

The overhaul interval of the R408 propeller is 10,000FH. A typical overhaul is estimated to cost $120,000 per propeller, resulting in a reserve of $12 per EFH. Reserve for the two propellers is $24 per FH *(see table, page 22)*.

The installation of an APU remains an option on the Q400, but when fitted the APU is a Hamilton Sundstrand Model APS 1000 (T-62T-46C12). Overhaul is on-condition and a typical overhaul reserve is $22 per APUH. Assuming an APU utilisation of 0.8APUH per FH this is equal to $18 per FH *(see table, page 22)*.

Rotable components

Given the relatively small size of the Dash 8 and Q400 global fleet, it is surprising that no less than three companies are offering rotable overhaul and support programmes. They are all similar, and cover most of the rotable parts with the exception of the larger items, such as the landing gear, propellers and APU.

Failed or hard-time components are removed from the aircraft by the operator

Although the Dash 8's & Q400's engines are maintained on an on-condition basis, most operators have fixed price per hour contracts to make engine maintenance costs predictable.

and exchanged for fresh components from the service provider, who arranges for the repair, testing and return of serviceable parts to the inventory. As well as benefiting from having predictable costs, the operator avoids the burden of warranty administration and arguments with a large numbers of vendors.

The most established of the Q400 providers is ST Aerospace Solutions (Europe) A/S (formerly SAS Component), based in Denmark. With its former sister company SAS being the launch customer for the Q400, it is no surprise that SAS Component took an active role in the Q400 programme. Aside from SAS, it also gained several other customers, most notably Flybe in July 2004. In December 2005 SAS Component was sold to ST Engineering (Singapore Technologies Engineering) and was subsequently renamed ST Aerospace Solutions (Europe) A/S. In February 2006 Bombardier and SAS Component signed a co-promotion agreement which called for joint marketing and sales activities. In February 2008 Flybe extended its contract to 2016 cementing the company's lead.

In May 2008 Lufthansa Technik became the second player in this market, when it announced Croatia Airlines as the launch customer. The component pool is based in Munich, Germany.

Notwithstanding its earlier agreement with SAS Component/ST Aerospace Solutions (Europe) in June 2008, Bombardier announced its 'Smart Services' component repair and exchange programme for the Q400. The basic package covers 291 components with values over $10,000. Luxair was the launch customer, with a five-year agreement. The component pool is located in Frankfurt, Germany.

Actual costs for these three competing programmes are commercially sensitive and depend on, among other criteria, fleet size, aircraft utilisation, route network and style of operation. Typical budgetary figures are estimated to be $120/FH for the fee covering repair and overhaul, plus $10,000 per aircraft per month for the pool-access fee covering the financing of the pool stock, insurance and administration (equating to $60/FH).

Equivalent figures for the older Dash 8 variants are estimated to be $105/FH for the FH fee, and $10,000 per aircraft per month for the pool-access fee (equal to $60/FH).

A third cost element is a lease rental fee for homebase stock. A fleet of five Q400s, operating at 2,000FH per year, is estimated to need a homebase stock with a value of $1 million. The monthly lease for this stock would be $15,000 shared between the five aircraft, equal to $16 per FH. The equivalent figure for the older Dash 8s would be $18/FH.

The total for these three elements would be $183 per FH for the Dash 8, and $196 per FH for the Q400 *(see table, page 22)*.

Engine maintenance-PW100

The Dash 8 family are powered exclusively by engines from the Pratt & Whitney Canada PW100 family. There are three main engine variants in the PW100 family: the PW120, PW120, PW123 and the PW150.

The original Dash 8-100 was powered by the PW120, with the option of the more powerful PW120A and PW121. The stretched Dash 8-300 introduced the PW123, which matched the turbomachinery of the higher-rated PW124 with the reduction gearbox of the Dash 8-100's PW120. The PW123 was retained in the Dash 8-200/Q200, although at a de-rated output of 2,150 shp.

PW100 in operation

Although there is the option of a hard time between overhauls which is set at 8,000 engine flight hours (EFH) for all models, the vast majority of the PW100 engines in service are maintained on an on-condition basis.

Typical overhaul intervals for the PW120 are 12,000EFH to 16,000EFH. The lower-rated engines achieve the longer on-wing life. Many operators cannot take full advantage of the inherent life in the engine because of life limited part (LLP) replacement considerations. The shortest-life LLPs, with a life limit of 15,000EFC, limit the on-wing life to a maximum of 12,750EFH or about six years of operation.

A good demonstration of how different operational profiles can affect engine overhaul planning is provided by Wideroe of Norway. This operator's fleet, comprising 18 Dash 8-100s, seven Dash 8-300s and five Q400s, operates on widely differing networks. The Dash 8-100s average 2,000FH/4,000FC per year, the Dash 8-300s average 2,000FH/2,000FC and the Q400s 2,000FH/1,800FC.

The PW121s powering Wideroe's Dash 8-100s are operated to a schedule dictated by the replacement of the lowest life (hot section) LLPs at 15,000 engine flight cycles (EFC). After 15,000EFC/7,500EFH the engines are sent into the shop for partial LLP replacement and a hot section inspection. After a further 15,000EFC/7,500EFH all the LLPs are replaced and the engine is overhauled (both hot and cold section).

The PW123s powering the Dash 8-300s are also operated to a schedule dictated by the replacement of the shortest life LLPs at 15,000EFC, but in this case overhaul is required at the first LLP replacement. After 15,000EFC/15,000EFH the engines are sent to the shop for partial LLP replacement and an overhaul. It is only after a further 15,000EFC/15,000EFH that all the LLPs are replaced (both hot and cold section) and the overhaul repeated. This is not to say that the engines are run continuously for 15,000EFH: a mid-life hot section inspection (HSI) is performed after 7,500EFH.

For our generic utilisation of 2,000FH/2,000FC per annum, the LLP replacement at 15,000EFC will equate to 12,000EFH. All three basic variants (the PW120A/121, the PW123 and the PW123 de-rated on the Dash 8-200) should be capable of reaching 12,000EFH with only a single mid-life HSI. The total for the two elements, HSI and overhaul, will vary between the engine variants. An HSI is estimated to vary from $225,000 on a PW120A to $250,000 on a PW123 fitted to a Dash 8-300. Similarly, the overhaul is estimated to vary from $650,000 on a PW120A to $700,000 on a PW123. The combined cost of an HSI and overhaul over the full interval of 12,000EFH/12,000FC is therefore $875,000- $950,000, with a maintenance reserve of $73-79/EFH.

Unlike other manufacturers, which have actively tried to sign up their customers for power-by-the-hour (PBH) type programmes, Pratt & Whitney Canada in general has left this to individual overhaul shops. It has approved eight 'Designated Overhaul Facilities' (DOF) for the PW100: Atlantic Turbines (Canada), AvioService (Italy), Dallas Airmotive (USA), Finnair (Finland), Lufthansa Aero (Germany), SECA EADS (France), Standard Aero (Netherlands) and Volvo Aero (Sweden). Each DOF is left to compete for its own business and the degree of competition in the market is high.

Life limited parts

The PW100 series (PW120-123) have 10 different LLPs and all the current production parts have lives of 15,000EFC, 25,000EFC or 30,000EFC. There are several different part numbers for many of the LLPs, and some have lower life limits. There are four principal groups of LLPs belonging to: the compressor, high pressure (HP) turbine, low pressure (LP) turbine, and the power turbine (PT).

In the compressor the LP impeller has a life of 25,000EFC, and the HP impeller a life of 30,000EFC.

In the HP turbine the five components all have a life of 15,000EFC: the HP turbine front cover, HP turbine rear cover, HP turbine disc, HP turbine blades and interstage seal.

In the LP turbine there is one component, the LP turbine disc, with a life of 30,000EFC.

In the PT there are two components, the stage 1 PT disc and the stage 2 PT disc, both with a life of 30,000EFC.

DIRECT MAINTENANCE COSTS FOR DASH 8-100/-200/-300 & Q400

Maintenance Item	Dash 8 $/FH	Q400 $/FH
Line & ramp checks	66	66
A check	38-43	23-26
Base checks	55	50-53
Landing gear	18	21
Wheels & brakes	30	35
Propellers	16	24
APU	16	18
LRU component support	183	196
Total airframe & component maintenance	**422-427**	**433-439**
Engine maintenance:		
2 X $88-94 per EFH	176-188	
2 X $100 per EFH		200
Total direct maintenance costs:	**598-615**	**633-639**

Annual utilisation:
2,000FH
2,350FC
FH:FC ratio of 0.85:1

The list price of the current production standard parts, less airline discounts, is in the region of $300,000. Dividing each individual part cost by its cycle life puts reserves at $18 per EFC.

Reserves for LLP replacement, however, depend on the stub life that can be left at replacement. Given the lowest LLP life of 15,000EFC and an assumed annual utilisation of 2,000FH/2,350FC, LLP replacement will be the cause of the majority of shop visits for many engines after 15,000EFC/12,750EFH. LLP replacement will take place at the second shop visit and stub lives are likely to be minimal.

Total engine reserves at the average FC times used in this analysis are $88-94 per EFH *(see table, this page).*

Engine maintenance (PW150)

Although the PW150 shares the same architecture as the earlier PW100 engines (two centrifugal compressors, each driven by independent axial turbines, a reverse-flow annular combustor, and a two-stage power turbine that drives a gearbox) it is effectively an all-new design.

Original time between overhauls was expected to be about 10,000EFH, but as experience has been gained this has risen to 12,000EFH. There is less competition to provide engine overhaul services. Only one independent facility, Lufthansa Aero, is capable of overhauling the engine. PBH agreements are therefore more the norm, and these are estimated to be priced in the region of $100/EFH, including LLP replacement.

The PW150 has 12 different LLPs and all the current-production parts have lives of 15,000EFC, 16,000 EFC, 20,000EFC or 25,000EFC.

Summary

The Dash 8's total maintenance costs are $598-6215 per FH, and the Q400's total maintenance costs are $633-639 per FH *(see table, this page)*. These are close the ATR42's and ATR72's maintenance costs *(see ATR42 & 72 maintenance analysis & budget, Aircraft Commerce, December 2006/January 2007, page 12).*

The total maintenance costs for the Dash 8 and Q400 are close, with the Q400 $25-30 per FH higher *(see table, this page)*. This benefits the Q400, since its additional seat capacity compared to the smaller Dash 8 models is higher in proportion than the difference between the maintenance costs of the two. The small difference is explained, however, by the Q400 being relatively young and in its first base maintenance check cycle. As the aircraft enters its second base maintenance cycle the higher non-routine ratio, and the additional MH and materials that result, will equal an increase of $10-12 per FH in its base check maintenance reserves. This will still make the Q400's maintenance costs only 7% higher than the Dash 8's. AC