OWNER'S & OPERATOR'S GUIDE: DASH 8 & Q SERIES

Dash 8 & Q Series specifications

There are four main variants of the Dash 8 & Q400 Series, and several sub-variants. Their specifications are reviewed and listed.

The de Havilland Dash 8 family of aircraft first entered into service in 1984 with the Dash 8-100 variant. The Dash 8-200 and -300 followed in 1995 and 1989. The Dash 8-200 has the same fuselage length and seat capacity as the Dash 8-100, but the -200 has more powerful engines. These give it a 30-knot faster cruise speed than the -100 *(see table, page 7)*. The Dash 8-300 is a stretched variant with an additional 13-17 seats.

In 1996 Bombardier renamed the Dash 8 family the Q Series, after adding the active noise and vibration suppression system (ANVS), which reduces the noise and vibration levels inside the aircraft's cabin. The Q stands for quiet, which is enabled by an intricate system of microphones and a computer that initiates counter vibrations to reduce the sound and movement felt in the cabin.

To emphasise the introduction of the ANVS and new name, the Dash 8-100, -200 and -300 delivered with the ANVS system were named the Q100, Q200 and Q300. These were aircraft built from the middle of 1996 onwards. The Q100s were from line number 472, the Q200s from line number 421, and the Q300s from line number 408. They also had a new, more spacious cabin design, with insulation and acoustically sealed joints, to absorb and reduce noise. In 2000, the larger Q400 with additional seat capacity was introduced. This was a stretched version of the Q300, with newer, more powerful engines, 68-78 seats, and the ANVS system as standard. The Q400 also has a higher cruise speed than the three smaller variants *(see table, page 7)*.

Bombardier has recently started re-launching many of its aircraft types as next generation (NextGen) aircraft. The Q400 is no exception, with its NextGen development being announced in March 2008 *(see page 7)*.

At the same time, Bombardier also stated that production of the Q200 and Q300 will cease in May 2009, along with the Q100, which has not been produced for a number of years.

The engines powering the three basic Dash 8 models are variants of the Pratt & Whitney Canada (P&WC) PW120. These are rated from 2,000 shaft horse power (shp) on the Dash 8-100 to 2,500SHP on the Q300 *(see table, page 7)*.

The Q400 series is powered by P&WC's PW150A engine, rated at 5,071shp *(see table, page 7)*.

The three main Dash 8 variants have the same fuel capacity of 835 US Gallons (USG), while the larger Q400 has a capacity of 1,724USG. The maximum range varies from 760nm on the Dash 8-100 to 1,340nm on the Q400. Maximum cruise speed varies from 265 knots on the Dash 8-100 to an impressive 360 knots on the Q400.

The cruise speeds of the three small Q series variants are comparable at 265-300 knots and, in many cases, exceed those of other turboprop aircraft. The Q400 in fact is just 100 knots slower at 360 knots than smaller regional jets, such as the CRJ.

Bombardier is currently assessing the benefits of further stretching and developing the Q400 into a Q400X variant, to take advantage of increased passenger loads on many turboprop routes, as well as assisting operators to reduce unit cost per seat-mile.

With the Q100 and Q200 seating just 37-39 passengers, only one cabin crew member or flight attendant is needed, with the standard flightcrew of two pilots. The Q300 seats 50-56, but once seat numbers exceed 50, an additional flight attendant is needed.

The Q400 requires two flight attendants, although the Q400NextGen will accommodate an additional third flight attendant, used in many cases to improve in-flight service standards.

An operator of these aircraft will benefit from cost savings in the training of flightcrew, since all four Q Series variants have a common pilot type rating. Further commonality is realised with maintenance, parts inventory and ground operations.

The three main Dash 8 variants have similar cruise speeds of 265-300 knots. The Q400 is faster at 360 knots.

Dash 8-100/Q100

Originally launched as the Dash 8-100, this aircraft entered service in 1984 with norOntair. The Dash 8-100 was the first variant, and its most recent maximum take-off weight (MTOW) is 36,300lbs *(see table, page 7)*.

The earlier Dash 8-102 is powered by the PW120A rated at 2,000shp, has a cruise speed of 265 knots, and a maximum range of 1,159nm.

The later -103 is powered by the PW121 rated at 2,150shp, has a cruise speed of 270 knots, and a maximum range of 1,148nm *(see table, page 7)*.

The later Q106 is powered by the same engine, and has a similar cruise speed and slightly shorter range.

During the course of Dash 8-100/Q100 production many sub-variants

DASH 8 Q SERIES SPECIFICATIONS

	Dash 8 -102/ Q100	Dash 8 -103/ Q100	Q106	Dash 8 -201/ Q200	Dash 8 -202/ Q200	Dash 8 -311HGW/ Q300	Dash 8 -314HGW/ Q300	Dash 8 -315HGW/ Q300	Q402 EHGW
Engine	PW120A	PW121	PW121	PW123C	PW123D	PW123	PW123B	PW123E	PW150A
Engine power -shp	2,000	2,150	2,150	2,150	2,150	2,380	2,500	2,380	5,071
MTOW -lbs	34,500	34,500	36,300	36,300	36,300	43,000	43,000	43,000	65,200
MZFW -lbs	31,300	31,300	32,000	32,000	32,000	39,500	39,500	39,500	58,000
Basic OEW -lbs	22,380	22,880	23,593	23,744	23,763	26,683	26,683	26,683	38,986
Maximum payload -lbs	8,420	8,420	8,407	8,256	8,237	12,817	12,817	12,817	19,014
Fuel capacity -US Gal	841	841	841	841	841	841	841	841	1,737
Seats	37-39	37-39	37-39	37-39	37-39	50-56	50-56	50-56	69-80
Crew	2+1	2+1	2+1	2+1	2+1	2+1/2	2+1/2	2+1/2	2+2
Max. Range -nm	1,159	1,148	1,099	1,082	1,082	921	921	921	1,457
Range with longer-range tanks -nm	2,328	2,290	2.277	2,093	2,092	1,960	1,960	1960	N/A
Max. cruise speed -kts	265	270	268	300	300	287	285	287	360
Standard baggage capacity -cu.ft.	300	300	300	300	300	320	320	320	502
Maximum operating ceiling -ft	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000
Take-off noise level -dB	80.8	79.8	79.8	79.9	79.9	79.5	79.9	79.5	78.6
Sideline noise level -dB	86.3	86.1	86.1	84	84	87	87.3	87	84
Approach noise level -dB	94.3	95.7	94.7	94.7	94.7	95.1	95.1	95.1	93.1

of the aircraft were developed, comprising at least five passenger and three military sub-variants. This meant that MTOWs varied from 33,000lbs to 36,300lbs depending on the engine used and the aircraft configuration.

The standard interior layout is four-abreast seating with 37 seats at 31-inch pitch. The toilet and galley are located at the front of the cabin, with the 300-cubic-foot baggage compartment located at the rear of the cabin. An additional two seats are possible in the galley position if the forward wardrobe is replaced with the galley. Although this increases seat numbers, it would not be a good idea to do this on aircraft on routes that have many business travellers that expect to hang up suit jackets.

Exits consist of a main passenger-entry door at the forward left of the cabin, a type II service door at the forward right of the cabin and two type III emergency doors either side of the cabin, slightly forward of the wing. In addition there is a cargo door into the baggage compartment on the left side of the aircraft. Bombardier is proposing an extended life programme for the -100 series. This will include a 100,000 life limit, a weight upgrade, and a flightdeck upgrade.

Dash 8-200/Q200

The Dash 8-200 was in fact the third variant to be launched, following the -300, and entered service with BPX Colombia in 1995. There are four sub-variants, with the last being the one fitted with the ANVS system. The Dash 8-200 has the same fuselage and therefore the same cabin seat capacity as the Dash 8-100/Q100.

The earlier Dash 8-201 variant is powered by the PW123C rated at 2,150shp, has a cruise speed of 300 knots, and a maximum range of 1,082nm. The later -202 is powered by the PW123D also rated at 2,150shp, but its specifications are otherwise similar to those of the -201 *(see table, this page)*.

The Dash 8-200/Q200 has the more powerful PW123 engines used on the Dash 8-300/Q300. This combination is designed to provide better airfield performance and increase payload/range capability. Bombardier says this variant is ideal for those operators that fly in areas where strong hot and high performance is necessary.

Interiors on the Q200 are the same as on the Q100, and both aircraft feature a moveable rear bulkhead that allows an operator to use a convertible passenger/cargo (combi) interior. The Q200 has the added benefit, like all the Q series, that it can be changed from all-passenger to all-cargo configuration in just 20 minutes.

Dash 8-300/Q300

The second variant to enter service was the Dash 8-300 in 1989 with the Canadian operator, Time Air. This aircraft is similar to the Dash 8-100, except that its fuselage is 11 feet (3.4m) longer, and it is equipped with the more powerful PW123 engine series.

The Dash 8-311 is powered by the PW123 rated at 2,380shp, has a cruise speed of 287 knots, and has a maximum range of 921nm *(see table, this page)*.

The later -314 is powered by the PW123B rated at 2,500shp, but is essentially the same as the -311.

The -300E is the last -300 variant, and is powered by the PW123E rated at 2,380shp, but otherwise it has the same specifications as the -311 *(see table, this page)*.

The -300 has a capacity of 50-56 passengers, depending on seat pitch and cabin layout. The wardrobe and toilet are still at the front of the aircraft, but the standard layout includes the galley at the rear. At a 32-inch pitch, the -300 can seat 50 passengers, but if this is reduced to 29 inches, and part of the galley is pushed into the baggage compartment, then 56 seats can be fitted. The exits consist of a main passenger-entry door at the forward left of the cabin, a type II service door at the forward right of the cabin and two type III emergency doors either side of the cabin aft of the wings.

Q400

The fourth variant of the Dash 8/Q Series is the Q400. In response to the

The Q400 is now the only member of the Dash 8 & Q Series to be manufactured. Bombardier has launched an enhanced version, the Q400 NextGen, and a stretched model is also being considered.

further success of the modern turboprop aircraft, and route density, a larger Q Series was needed. This variant is a further stretch of the fuselage by nearly 35 feet, compared to the Q100/Q200, and 23 feet compared to the Q300. This allows the Q400 to carry 69-80 passengers. The aircraft first entered service in 2000 with SAS Commuter of Scandinavia. The highest MTOW is 65,200lbs.

All Q400 aircraft have the ANVS system installed, having been launched after its introduction. In addition, they have full authority digital engine controls (FADEC) and increased propeller-fuselage clearance to reduce blade passage build-up. Noise reduction has been aided by the introduction of a six-bladed prop, advanced synchrophasers to minimise propeller beat, and advanced engine mount technology to reduce transmission of engine vibrations at source.

This variant is equipped with PW150A engines with an increased 5,071shp, over previous variants. The engines' propeller revolutions per minute (RPM) are 6-19% lower than on the previous variants of the Dash 8/Q Series.

The Q400 also has a faster maximum cruise speed of 360 knots, and an improved range of 1,457nm. The range is assisted by the increased fuel capacity that is more than double that of previous Dash 8/Q Series types.

Although the interior of the Q400 is similar to that of previous variants, it nevertheless has some differences. The standard layout has 70 seats with a 33-inch pitch, or 74 seats at a 31-inch pitch. The toilet and wardrobe remain at the front, with the galley at the rear between the seats and the baggage compartment.

The most significant change is in the bigger baggage compartment areas to accommodate the increased number of passengers' bags. There is the larger compartment at the rear of the cabin, which is now 411 cubic feet as well as a small compartment of 91 cubic feet at the front of the cabin between the toilet and the passenger seats.

An optional layout has 70 seats with a 31-inch pitch, a larger baggage compartment of 135 cubic feet at the front and the toilet moved to the rear. Another optional layout has 78 seats at a 30-inch pitch, standard interior locations, but a smaller rear baggage compartment of 365 cubic feet.

There are two flight-attendant jump seats, one at the front and one at the rear as standard, and the option of an extra crew place. The exits consist of two passenger doors at the forward and rear left of the cabin, a type III emergency exit at the forward right of the cabin and a service door at the rear right of the cabin.

The Q400 has six sub-variants, many of which are just cabin layout variants. One is the Q400 NextGen.

Q400 NextGen

The Q400 NextGen was launched in 2008 as a further development of the successful Q400, and will be delivered from 2009. Improvements have been made in the cabin and to the maintenance and fuel consumption procedures.

The cabin has been improved with larger overhead lockers that can now accommodate trolley bags of the size decided by the International Air Transport Association (IATA). The cabin lights have been replaced with softer, longer-lasting LED lights, and the windows have been adapted to allow more light into the cabin and a better external view for passengers.

The Q400 NextGen has had its A check intervals increased from 400 flight hours (FH) to 500FH, while the C check has been increased from 4,000FH to 5,000FH. This compares to a new A check interval of 600FH for the Q400 *(see Dash 8/Q400 maintenance analysis, page 13)*.

The way that pilots operate the aircraft has also been addressed for the Q400 NextGen, and procedures in the operator manual will be changed. These changes could account for at least a 2% reduction in fuel consumption during high speed cruise and the associated reductions in the aircraft's CO2 emissions.

This all improves passengers' comfort and the airline's costs, which in turn increases the benefits of the aircraft compared to alternative turboprops and smaller regional jets.

ANVS

Turboprop aircraft have traditionally been considered noisy by passengers, both internally and externally. The Q Series has aimed to reduce this impression by using the ANVS system.

The internal noise on previous Dash 8 aircraft was louder at the front of the cabin and forward of the propeller arc. With the ANVS system in place, no area of the cabin suffers from excessive noise, and the average noise level is just 75dB - virtually the same as on regional jets, and in particular the CRJ aircraft. In fact the quietest place to sit is now in seat rows adjacent to the propellers.

Bombardier believes that a lot of the noise in the cabin is from airframe vibration, so it has reduced this through interior joints, seals and insulation and technology. Microphones in the cabin measure the noise and vibration and relay the information to a computer. This is passed on to active tuned vibration absorbers attached to the fuselage frame, that emit counter vibrations. This not only reduces noise, but also the vibration and flexing of the airframe, resulting in a smoother flight and less wear and tear of the airframe. AC

Dash 8 & Q Series fleet summary

The Dash 8 & Q Series fleet is sub-divided into four main types. Their displacement is analysed.

There have been 1,018 Dash 8 & Q series aircraft ordered, of which 898 have been delivered since 1984, leaving a backlog of 120. Of the 845 aircraft still in service, 71 are used in military, utility or corporate configurations, while the remaining 774 are in an airline passenger or freighter configuration. It is these 774 aircraft that will be discussed in this fleet analysis. Of the 774, 49 are parked, representing just 6% of the fleet. About half of the parked aircraft are in the North America area, and only two of the 774 aircraft have been converted or are being converted to package freighters. There are 53 aircraft that have been destroyed or retired.

The largest Dash 8 & Q Series operators are Jazz Air (64 aircraft), Piedmont Airlines (53), Flybe (48), Horizon Air (42), Wideroe (30), Air Nelson (21) and Austrian Arrows (21). The largest North American operator is Jazz Air, while in South America it is LIAT (17), and Aires (15). In Europe the largest operators are Flybe, Wideroe and Austrian Arrows. In Asia Pacific it is Air Nelson, Air Nippon Network (19) and Eastern Australia Airlines (18). In Africa the largest operator is Tassili Airlines (8).

There are four main variants of the Dash 8/Q Series: the -100, -200, -300 and -400. These are divided into sub-variants including both the Dash 8 and the Q Series sub-variants.

Fleet forecast

There are six Q300 and 114 Q400 aircraft still to be delivered as of January 2009, according to Bombardier. Production of the Q100 series ceased in 2005, and the last 200 and 300 series aircraft are due to leave the production line in May 2009. The Q400 and its new NextGen incarnation will be the only Dash 8/Q series member of the family still available. It is possible, due to the success of the Dash 8 and its popularity with operators, that Bombardier will develop a stretch version of the Q400 to accommodate 90-100 passengers.

The future of the Q400 NextGen is promising, since SAS has placed a large order despite its previous concerns over the Q400's landing gear problems that caused a grounding of the entire SAS Q400 fleet. Other large deliveries are to be made to Colgan Air (15), Flybe (12), Horizon Air (11), with another 17 aircraft going to smaller operators. First-time operators of this type include airBaltic (8), Arik Air (4), Ethiopian Airlines (8) and SATA (4). There are also 80 options that could be converted into firm orders.

There are many uses for the Dash 8 aircraft. Bombardier produces it in many different passenger and combi configurations, but it is also a multimission aircraft that can be used as a freighter, and in medical evacuation or surveillance operations.

Dash 8-100/Q100

There are 236 examples of this standard passenger airline variant in operation, of which 19 Dash8-100 and no Q100s are parked. The mostly later aircraft are powered mainly by the PW120A, with 44 being powered by the PW121 (1 Dash 8-102, 28 Dash 8-103, 10 Dash 8-106 and 5 Dash 8-103Q).

There are three sub-variants of the Dash 8-100 and one Q100.

The DHC8-102 sub-variant is the most popular of this Dash 8 variant. There are 182 in operation with 46 operators, but it also has the largest number of parked aircraft (16) across the whole Dash 8/Q series fleet, probably because it is the oldest model. These aircraft are now 15-25 years old, and most of the active aircraft have average flight cycle (FC) times of 0.40-1.10 flight hours (FH) over the past 12 months. The biggest operators by far are Piedmont Airlines (42) in the United States and Jazz Air (36) in Canada. Airlines of Papua New Guinea and Skytrans (Australia) have eight aircraft each, while Air Creebec (Canada) and Air Inuit (Canada) have six aircraft each.

There are three passenger Dash 8-103 aircraft in operation, with 12 operators and only two aircraft parked. This sub-variant is 14-24 years old, with most entering service after 1989. Again, the majority have recent average FC times of 0.40-1.10FH, with one exception of 1.90FH. The largest operator of the Dash 8-103 is Wideroe (18) in Norway.

There are 18 Dash 8-106 aircraft, of 15-19 years of age, with 12 operators. One aircraft is currently parked. The average FC times for the past 12 months are 0.60-1.30FH. There are no large operators of this sub-variant, with operators having four or fewer Dash 8-106 aircraft each in their fleet.

The majority of Dash 8s & Q400s are based in north America, and concentrated in large fleets; used to feed major airlines.

DASH 8 Q SERIES FLEET SUMMARY

Aircraft model	Aircraft sub-variant	Africa		Asia Pacific		Europe		Middle East		North America		South America		Unknown	Sub-variant total	Variant Total
		Active	Parked	Active	Parked	Active	Parked	Active	Parked	Active	Parked	Active	Parked	Parked		
Dash 8-100	DHC8-102	14	1	26	1	8		2		114	13	2	1		182	231
	DHC8-103			4		18		1		5	2	1			31	
	DHC8-106	5		1		3				8	1				18	
Q100	Q103			5											5	5
Dash 8-200	DHC8-201			1											1	6
	DHC8-202			2						3					5	
Q200	Q200			2											2	71
	Q201			3		3				1	2	11			20	
	Q202	6		5				2		32	4				49	
Dash 8-300	DHC8-301			2						15		3	2	1	23	113
	DHC8-311	7		5	1	8				24	1	17			63	
	DHC8-314	7		6		1				10		3			27	
Q300	Q311	1	2	26		6				1	3	6			45	120
	Q314			6		16						1			23	
	Q315	9		22		20					1				52	
Q400	Q401	2		5	1	24	11			21					64	228
	Q402	6		43	1	64				50					164	
Dash 8/Q Series		57	3	164	4	171	11	5	0	284	27	44	3	1	774	774

The Dash 8-103Q, otherwise known as the Q100, is only operated by two airlines, both based in Japan. The oldest example is 12 years old and the youngest is just six years old. The average FC times are noticeably shorter on this aircraft, and are 0.45-0.59FH. Ryukyu Air Commuter operates four aircraft, and Amakusa Airlines operates one Q100 aircraft.

Dash 8-200/Q200

In total there are 77 of these aircraft in operation with 24 operators. Only six are parked.

The Dash 8-200 has two sub-variants accounting for six aircraft with four operators. There is one Dash 8-201 and five Dash 8-202s (two Dash 8-202s and three Dash 8-202Bs). These sub-variants entered service from 1995 to 1997. The average FC times for the past 12 months are 0.88-1.21FH.

The Q200 has three sub-variants, consisting of 71 aircraft with 18 operators. There are two Q200Bs with a single operator, 20 Q201s with seven operators, and 49 Q202s with 13 operators. The average FC times are 0.50-1.70FH. The Q200 entered service in 1996 with the most recent aircraft delivered in January 2009.

For all the Dash 8-200/Q200 variants, the largest operators are Commutair (17), Mesa Airlines (12) and Aires of Colombia (10).

Dash 8-300/Q300

There are 233 of these aircraft with 51 operators, of which 11 are currently parked. The largest operators of this variant are Jazz Air of Canada (28), Air Nelson of New Zealand (21), LIAT of Antigua (14), Eastern Australia Airlines (13), Austrian Arrows (11), Denim Air of the Netherlands (11) and Piedmont Airlines (11).

The Dash 8-300 has three sub-variants involving 113 aircraft, of which five are parked.

The Dash 8-301 accounts for 23 aircraft, with Jazz Air being the biggest operator with 14. Aircraft ages range from 18-20 years, while average FC times for the past 12 months are 0.61-1.13FH.

There are 63 Dash 8-311 aircraft, with Jazz Air again being the largest operator with 14, followed by LIAT (12) and Piedmont Airlines (7).

The oldest Dash 8-314 is nearly 19 years old and the youngest is now 13 years old. It accounts for 27 aircraft, and the largest operators are South African Express (6), Piedmont Airlines (4), Skippers Aviation of Australia (4) and Voyageur Airways of Canada (4).

The average FC times for the Dash 8-311 and -314 are in the 0.60-1.60FH range.

The Q300 has three sub-variants, involving 120 aircraft with six aircraft parked. All the Q300 sub-variants have an average FC time of 0.33-1.36FH. The first Q300 was delivered in late 1996, and six are still to be delivered.

There are 45 Q311 aircraft, consisting of 44 Q311 and one Q311B (operated by LIAT). The largest operator is Air Nelson, with 21 aircraft. There are 23 Q314 aircraft, of which Austrian Arrows operates the largest fleet with 10.

The Q315 sub-variant accounts for 52 aircraft. The main operators are Eastern Australia Airlines (13), Denim Air (11), Air Nostrum (8) and Air Nippon Network (5).

Q400

There are 228 Q400 aircraft with 26 operators. There are 114 awaiting delivery, and the type consists of two main sub-variants. The main operators are Flybe (48), Horizon Air (37), Air Nippon Network (14), Colgan Air (14), Sunstate Airlines of Australia (14), Japan Air Commuter (11), Austrian Arrows (10) and Lynx Aviation (10).

There are 64 Q401 aircraft, of which 12 are parked. This sub-variant ranges in age from 5-11 years, and has recent average FC times of 0.67-1.38FH. The main operators are Horizon Air (20), Augsburg Airways (9), Austrian Arrows (8) and Air Philippines (6). SAS and SAS Norge have five Q401s each, but they are all parked due to SAS's concerns over the safety of the landing gear mechanisms, after a number of incidents in 2007. The 64 Q401 aircraft include two freighters operating with Sweden's Nordflyg, although one is currently parked.

The most popular sub-variant across the whole Q Series fleet is the Q402, of which there are 164, with only one currently parked. The recent average FC times are the same as those of the Q401. The delivery schedule for the Q402 has been from early 2000 until the present day, and will continue for at least the next few years. The largest operator by far is Flybe, with 44 aircraft. These are also some of the most recently delivered. Flybe is followed by Horizon Air, which has 17 Q402 aircraft, while Air Nippon Network, Colgan Air and Sunstate Airlines each have 14 aircraft. AC

Dash 8 & Q400 fuel burn performance

The fuel burn performance of the four main Dash 8/Q Series variants are analysed in routes of 110-425nm.

Analysis of the fuel burn performance of four main members of the Dash 8 and Q Series reveals that for a given distance, the fuel burn per seat-mile is influenced by several factors that include, but are not limited to: operating empty weight (OEW), engine power rating, weather, and cruise speed.

Aircraft variants

There are four main variants of the Dash 8 and Q Series: the Dash 8-100, Dash 8-200, Dash 8-300 and Q400. Standard models are used to analyse each one. All the aircraft variants are powered by the same family of engines, with more powerful engines being used for the larger aircraft type. The Dash 8-100/Q100 is powered by the PWC-120A, the Dash 8-200/Q200 and -300/Q300 by the PWC-123C, and the Q400 by the PWC150A.

The increase in engine thrust for these aircraft is echoed in their higher OEW, maximum payload and maximum take-off weights (MTOW). The MTOWs rise from 34,500lbs for the Dash 8-100 to 64,000lbs for the Q400. The fuel capacity is the same for all variants except the Q400, which has over double the smaller variants' 841 US Gallon (USG) capacity.

Many different thrust and MTOW variants are used by different airlines, but the basic specifications, as pre-loaded in Jeppesen and stated by the manufacturer, have been used for these calculations.

Flight profiles

Aircraft performance has been analysed on inbound and outbound legs for four routes to illustrate the effects of wind speed and direction on the distance flown. The resulting distance is referred to as the equivalent still air distance (ESAD), or nautical air miles (NAM).

Average weather for the month of June has been used, with 85% reliability winds and 50% reliability temperatures used in the flight plans produced by Jeppesen. The flight profiles are based on International Flight Rules, which include standard assumptions on fuel reserves, diversion fuel and contingency fuel, but the fuel burn used to analyse each sector just includes the fuel used for the trip and taxiing. The optimum routes and levels have been used for every flight, except where it has been necessary to restrict the levels due to airspace or airway restrictions and to comply with standard routes and Eurocontrol restrictions.

A taxi time of 20 minutes has been factored into the fuel burns and added to the flight times to provide block times. Jeppesen says this equates to additional fuel of 200lbs on the Dash 8-100/Q100 & Dash 8-200/Q200, and 250lbs on the Dash 8-300/Q300 & Q400.

Two cruise speeds were listed in the system: high-speed cruise (HSC) and long-range cruise (LRC). Although HSC is more likely on shorter routes, LRC has been chosen so that all routes can be equally compared for all variants without the need to adapt payload figures. LRC allows an aircraft to use less fuel per NAM, meaning longer block times, but this is the economical and operational compromise between fuel consumption and flight times.

The aircraft being assessed are assumed to have a single-class cabin with a full passenger load of 37 on the Dash 8-100/Q100 & Dash 8-200/Q200, 56 on the Dash 8-300/Q300 and 78 on the Q400. The standard weight for each passenger and their luggage is assumed to be 200lbs per person, with no additional cargo in the hold. The payload carried is therefore: 7,400lbs for the Dash 8-100/Q100 & Dash 8-200/Q200; 11,200lbs for the Dash 8-300/Q300; and 15,600lbs on the Q400.

Route analysis

Three routes of varying lengths were analysed with tracked distances of 111-386nm. All three routes are within Europe and were picked to examine how fuel burn per seat-mile changes with increasing mission lengths. All routes are typical of the operators of the Dash 8 and Q Series, which tend to have average FC times of roughly 1.0FH. All routes have been analysed in both directions, to gain a better picture of each aircraft's fuel burn and the effect of wind.

The first route to be analysed, and the shortest, is Southampton, UK (SOU) to Jersey, UK (JER). This has a tracked distance of 111nm on both the outbound and return sectors and is typical of the routes on which Flybe uses its Q400s. There were headwinds of 9-12kts on the outbound sector (increasing the ESAD to 113-116nm) but very light, almost non-existent headwinds on the return (so that the tracked and the ESAD distances were

Despite being larger than the Dash 8-300, the Q400 does not have lower fuel burn per seat-mile. The Q400 nevertheless has almost the same fuel economy, and the two are superior in fuel burn to the Dash 8-100 and -200.

FUEL BURN PERFORMANCE OF DASH 8 & Q400

City-pair variant	Aircraft	Engine model	MTOW lbs	TOW lbs	Fuel burn USG	Block time mins	Passenger seats	ESAD nm	Fuel per seat	Fuel per seat-mile	Wind speed
SOU-JER	Dash 8-100	PWC-120A	34,500	32,464	117	52	37	113	3.15	0.0284	-9
	Dash 8-200	PWC123C	37,000	33,137	119	50	37	114	3.22	0.0290	-10
	Dash8-300	PWC123C	43,000	40,808	129	51	56	115	2.31	0.0208	-9
	Q400	PWC150A	64,000	54,693	191	52	78	116	2.45	0.0221	-12
JER-SOU	Dash 8-100	PWC120A	34,500	32,450	115	52	37	111	3.11	0.0280	-1
	Dash 8-200	PWC123C	37,000	33,132	117	50	37	111	3.17	0.0286	-1
	Dash 8-300	PWC123C	43,000	40,801	128	51	56	111	2.29	0.0206	-1
	Q400	PWC150A	64,000	54,688	190	52	78	111	2.43	0.0219	0
VIE-VCE	Dash 8-100	PWC120A	34,500	33,275	234	99	37	315	6.32	0.0217	-20
	Dash 8-200	PWC123C	37,000	34,197	246	95	37	318	6.64	0.0228	-18
	Dash 8-300	PWC123C	43,000	41,861	259	100	56	313	4.62	0.0159	-18
	Q400	PW150A	64,000	56,228	370	94	78	314	4.75	0.0163	-18
VCE-VIE	Dash 8-100	PWC120A	34,500	33,236	211	88	37	265	5.70	0.0216	-3
	Dash 8-200	PWC123C	37,000	34,147	221	88	37	265	5.97	0.0226	-2
	Dash 8-300	PWC123C	43,000	41,727	234	90	56	265	4.18	0.0158	-2
	Q400	PW150A	64,000	56,193	330	84	78	266	4.24	0.0160	-3
SZG-DUS	Dash 8-100	PWC120A	34,500	33,591	295	127	37	426	7.97	0.0209	-29
	Dash 8-200	PWC123C	37,000	34,503	306	121	37	425	8.27	0.0216	-24
	Dash 8-300	PWC123C	43,000	42,112	325	128	56	420	5.81	0.0152	-25
	Q400	PW150A	64,000	56,647	466	117	78	418	5.97	0.0156	-21
DUS-SZG	Dash 8-100	PWC120A	34,500	33,851	285	120	37	390	7.70	0.0199	-5
	Dash 8-200	PWC123C	37,000	34,777	300	116	37	390	8.10	0.0210	-5
	Dash 8-300	PWC123C	43,000	42,423	328	123	56	391	5.85	0.0152	-
	Q400	PW150A	64,000	57,145	443	110	78	387	5.68	0.0147	-5

Source: Jeppesen

the same). The winds had no effect on the resulting block times, which did not vary between each variant's two sectors. The resulting flight times, for all four variants, were close at 50-52 minutes.

The second route was Vienna, Austria (VIE) to Venice, Italy (VCE), which is operated by Austrian Arrows' Dash 8 and Q Series aircraft. The tracked distance is 291nm outbound and a shorter 264nm on the return sector; the difference coming from longer flight routings outbound. The outbound sector had headwinds of 18-20kts that increased the ESAD to 314-318nm. The return sector still had headwinds but not as strong at just 2-3 knots, meaning the ESAD remained similar at 265-266nm.

Block times on the outbound sector were 94-100 minutes with a 10-minute block time improvement of 84-90 minutes on the return, as a result of the shorter routing and weaker headwinds.

The third and longest route is Salzburg, Austria (SZG) to Dusseldorf, Germany (DUS), which is also typical of routes operated by Austrian Arrows. The outbound distance is 382nm, but, with a large headwind of 21-29kts, the ESAD rises to 418-426nm. The return sector has a tracked distance of 386nm, and lighter headwinds of 5kts mean that the ESAD only increases slightly to 287-391nm.

Fuel burn performance

The fuel burn performance of the four Dash 8 and Q Series variants is shown for all three routes, both outbound and inbound *(see table, this page)*. The data also include the associated fuel burn per passenger and per passenger-mile for both sectors on each route. The fuel burn increases on all sectors as the power and size of aircraft increase, but this is not necessarily the case for fuel burn per passenger or passenger-mile.

On all six sectors, the performance is similar, with the Dash 8-100/Q100 always taking third place and the Dash 8-200/Q200 always performing the worst. Even so, the Dash 8-100/Q100 & Dash 8-200/Q200 are not far behind the Dash 8-300/Q300 and Q400, so the smaller variants would still be cost-effective. This would be the case if operators intended to carry no more than 37 passengers, with economies of scale being generated only when carrying larger payloads. The Dash 8-300/Q300 is the best fuel-per-passenger performer for the shortest and middle routes, but the Q400 performs better on the longest *(see table, this page)*.

The lowest fuel burn per passenger is predictably found on the shortest route, particularly with the Dash 8-300/Q300 on the return sector. The highest fuel burn per passenger was on the longest route, and on the outbound sector in particular, with the Dash 8-200/Q200 *(see table, this page)*.

To compare the routes fairly, the fuel burn per passenger-mile was examined. The best results were on the longest sector and the worst on the shortest. For the first and shortest route the Dash 8-300/Q300 performed best, with 0.0206-0.0208 USG per passenger-mile, followed by the Q400, Dash 8-100/Q100 and the Dash 8-200/Q200 with 0.0286-0.0290 USG per passenger-mile. For the second route, the best performer was the Dash 8-300/Q300 with 0.0158-0.0159 USG per passenger-mile, followed by the Q400, Dash 8-100/Q100, and then the Dash 8-200/Q200 with 0.0226-0.0228 USG per passenger-mile *(see table, this page)*.

On the last and longest route the performance order differs for each sector. On the outbound, the Dash 8-300/Q300 performs best with 0.0152 USG per passenger-mile (which it also burns on the return sector). On the return the Q400 performs better with 0.0147 USG per passenger-mile. On both sectors, the Dash 8-200/Q200 performs worst with 0.0210-0.0216 USG per passenger-mile. AC

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

Dash 8 & Q Series aftermarket & values

The Dash 8 & Q Series are popular types, and few have been available on the used market. The aftermarket activity, and aircraft values and lease rates are reviewed,

The Dash 8 family has achieved 1,018 sales, more than any other turboprop and narrowly outselling the European ATR42/72. During the bottom of the turboprop market in 2004-2005, large numbers of Dash 8-100s were available, and aircraft could be acquired for $1.0-1.5 million. The market has since turned round, and many operators are finding it difficult to acquire further aircraft. The few good aircraft that are on the market are being offered for $4.50-5.50 million.

Dash 8-200/Q200 market

The majority of Dash 8-200s were built for the North American market (67 in total). The balance were sold in Europe (5), Asia (6), Australasia (10), South/Central America and the Caribbean (6) and Africa and the Middle East 11), the latter accounting for the second highest number of aircraft.

There are few Dash 8-200/Q200s on the market. The only advertised availability is from Bombardier, which is currently marketing five ex-Horizon aircraft for sale at around $6 million.

Dash 8-300/Q300 market

Unlike the smaller family members the Dash 8-300 made comparatively little impression on the North American market. As a general rule of thumb, 60% of regional airliner sales have been to North America, 30% to Europe and 10% to the rest of the world. In the case of the Dash 8-300, North America only accounted for 31 orders out of the total of 267. The majority were sold in Europe (83), Australasia (44), Asia (33), Africa and the Middle East (23) and South/Central America and the Caribbean (16). The remaining 29 aircraft were delivered to leasing companies.

As of January 31st 2009 Bombardier has six more Q300s to deliver to: Air Nelson/Air New Zealand (2); the Japanese Coast Guard (3); and an undisclosed customer (1).

The Dash 8-300/Q300 is a sought-after asset. Apart from aircraft that have been damaged in accidents, only two examples are known to have been parted out. Even at the bottom of the turboprop market, Dash 8-300s are believed to have commanded a price of about $2.50 million. Operators that acquired small numbers of aircraft have expanded their fleets on the used market. For example, Wideroe took four aircraft direct from the factory, and has subsequently added a further three used examples. Others have acquired their entire fleets on the used market, for example Piedmont. In February this year Piedmont extended the leases on its 11 aircraft with Nordic Aviation Capital.

There are few used aircraft on the market. The only advertised availability is from Austrian Airlines, which is marketing one of its aircraft for $6.50 million.

Q400 market

Bombardier's decision, announced in April 2008, to cease production of the Q200 and Q300 from May 2009, leaves the Q400 as the only turboprop in the manufacturer's product line. Bombardier continues to develop the baseline Q400, and in March 2008, coincident with the SAS Group's order for 14 new aircraft for Air Baltic (8) and Wideroe (6), it launched the Q400 NextGen. The Q400 NextGen incorporates a number of refinements to the cabin and extended maintenance intervals. Bombardier also continues to study a stretched 90-seat Q400X in a 2013/14 timeframe.

As of 31st January 2009, Bombardier had received orders for 347 Q400s, of which it had delivered 233, leaving a backlog of 114. Production is currently at a rate of about four aircraft per month, providing nearly two and a half years of production. (A total of 47 were delivered in FY2007/08, and 43 in FY2008/09). Supply chain challenges resulting from the transfer of fuselage production from Japan to China and Belfast account for the reduction.

Despite what are generally quite poor overall market conditions, the Q400 continues to find new customers as well as repeat orders from existing operators. In FY2008/09 the company received orders for 67 Q400s and delivered 43.

Orders from new customers totalled 37 aircraft: Air Baltic (8), Air Berlin (10), Cirrus (1), Ethiopian Airlines (8), SATA (4) and Wideroe (6). Existing customers also ordered a total of 37 aircraft: ANA (3), Austrian Arrows (4), Colgan Air/Pinnacle (15), Croatia Airlines (2), Frontier (2), Hydro-Quebec (1), Luxair (2), Porter Airlines (8). There was a net reduction of seven aircraft from the undisclosed customer's total, the Air Berlin order for 10 aircraft was converted into a firm order, and three new undisclosed orders were added.

Although Bombardier received its first order from Horizon in 1999, the subsequent decade can be described as 'a slow build-up'. It was not until February 2006 that another north American operator ordered the Q400. Canada's Porter Airlines ordered 10, Frontier then placed an order for 10, and in March 2007 Pinnacle followed with an order for 15. Both of these operators have subsequently placed repeat orders.

Aside from Bombardier the only other source of Q400s until recently has been SAS. Following the well publicised grounding of their 27-strong fleet, SAS has been trying to dispose it. Two of the three aircraft involved in accidents have been scrapped and of the remaining 27 aircraft, 17 have so far been sold or leased. Aircraft were sold to LAM (2), Malev (4), Nord-Flyg (2), and Philippine Airlines (5) while the only lease customer was Flybe (4).

Although it appears early, the Q400 has already been selected for cargo conversion. Nord-Flyg of Sweden took delivery of its first conversion in January 2009 and the aircraft entered service in April. Designated the Q400PF package freighter, the conversion was undertaken by Cascade Aerospace of Canada and the STC was awarded on 31st December 2008. Capable of carrying 9.5 tons, the Q400PF is not only able to carry the highest payload of the 1980s-generation turboprops, but it also has a clear speed advantage.

Aside from the SAS aircraft, there have been relatively few transactions involving the Q400. In 2006 Airstream arranged the sale of two ex-Changan Airlines aircraft to Horizon. The only aircraft currently advertised are the four aircraft belonging to Jeju Air, which has appointed Airstream to remarket them.

SAS was known to be asking for $11-13 million for its aircraft, and market lease rates are believed to be in the order of $150,000 per month. AC