OWNER'S & OPERATOR'S GUIDE: ERJ-135/-140/-145

ERJ-135/-140/-145 specifications

There are 16 variants available for the ERJ-135, ERJ-140 and ERJ-145 models. Their specifications are analysed.

The ERJ-135, ERJ-140 and ERJ-145 are all members of the ERJ-145 family of aircraft. This is a family that was designed for the regional market from the outset. The design offers the operator 95% commonality in parts and systems across the three main types and their variants. It is also possible for flightcrew to be cross-type-rated for all three model series. The main differences between the three models are the fuselage sizes and seat capacities.

The ERJ-145 was first introduced to airlines in 1989 as a development of the EMB-120. After many design changes, the ERJ-145 entered service in 1996 with rear-fuselage-mounted engines, swept wings and a 'T-tail' configuration. It maintained the three-abreast cabin layout of the EMB-120.

The ERJ-145 family met the needs of regional airlines at the time for a cost-effective jet aircraft for commuter and feeder routes. It also offers Stage III and Stage IV noise compliance capability and low NOx emissions levels that are characteristic of the ERJ-145 family, which makes it acceptable for operations in all parts of the world. Its design makes it suitable for routes where fast turnarounds and a high daily utilisation are required.

The shortest ERJ-135 has a maximum range of 1,750nm with a full load of 37 passengers. The ERJ-140 has a range of 1,650nm, and can carry an additional seven passengers. The original member of the family, the ERJ-145, has 50 seats but a shorter range of 1,550nm *(see table, page 8)*. The newer ERJ 145-XR still has 50 seats, but an increased range of 2,000nm.

With all the aircraft having 50 or fewer seats, the crew can consist of just two pilots and one cabin crew member. Many carriers might prefer, however, to operate with two cabin crew if they have a need for enhanced service standards, especially if business-class products are offered. This minimal crew requirement can give an economical versatility to the aircraft, especially when commonality for all crew on all types is taken into consideration.

All the ERJ-145 family have the same cargo capacity of 325 cubic feet (9.2 cubic metres), found aft of the cabin with the cargo door located under the engine mountings on the left side of the fuselage. The maximum load is 2,205lbs (1,000kg) for the ERJ-135 and 2,645lbs (1,200kg) for the ERJ-145.

The ERJ-145 has 11 variants in total, including the ERJ-145XR and various types designed for air forces around the world. There are eight airline variants.

The ERJ-135 has three variants: a business jet, and two that are used by airlines.

The ERJ-140 has two variants but only one is used by airlines. The other is a single aircraft operated by Embraer.

Therefore, of the 16 possible variants of the ERJ-145 family, commercial operators use only 11. It is the specifications of these 11 variants that will be discussed in further detail.

ERJ-145

The original ERJ-145 went into service with ExpressJet late in 1996. The 50-seat aircraft has a maximum take off weight (MTOW) of 46,000-48,000lbs, depending on the variant, and a maximum operating speed of Mach 0.78 *(see table, page 8)*. The ERJ-145LR is by far the most popular of all the family models, and shows that 50-seat aircraft are increasingly popular with regional and feeder airlines.

The number of seats can be reduced from 50 to 48, if a larger galley is required on board, assuming that a seat pitch of 31 inches is maintained. The galley is at the forward starboard of the cabin and the single toilet is at the rear. Additional stowage and wardrobe space is at the front of the cabin opposite the galley. As the galley and stowage area is adapted, so the wardrobe can double in size. This is an important factor for an aircraft that will be operated on routes favoured by day-return business men, who need hanging space for suit jackets.

The main passenger door is on the port side just aft of the flight deck, while the main service door is not opposite, but is offset and located in the middle of the galley. These are both type I doors. Due to the three-abreast seating, the aisle is off-centre, which means that the large overhead locker is above the twin seats only. This aircraft has two type III over-wing exits that are generally positioned just aft of row 11.

The engines on all variants of the ERJ-145 family are versions of the Rolls-Royce (RR) AE 3007A. On the -145s, the version is the AE3007A1 with a maximum take-off thrust of up to 8,169lbs. Many sub-variants exist due to variations in Full Authority Digital Engine Control (FADEC) software. All

The ERJ-145 family has a common pilot type rating for the three main variants, allowing airlines to operate with a single pilot pool.

ERJ-135/-140/-145 SPECIFICATIONS

Aircraft	Engine	Take-off thrust lbs	MTOW lbs	Basic OEW lbs	Maximum payload lbs	Fuel capacity USG	Seats at 31" pitch	Range nm full payload & LRC	Maximum cruise speed
ERJ-135ER	AE3007A3	7,201	41,887	25,137	9,255	1,360	37	1,300	0.78
	AE3007A1/3								
ERJ-135LR	AE3007A1/3	7,580	44,092	25,355	9,919	1,690	37	1,750	0.78
ERJ-140ER	AE3007A1/3	7,580	44,313	26,050	11,649	1,360	44	1,250	0.78
ERJ-140LR	AE3007A1/3	7,580	45,517	26,032	11,667	1,690	44	1,650	0.78
ERJ-145EP	AE3007A1, A1/1	7,580	46,275	26,339	11,359	1,360	50	1,200	0.78
	AE2007A1P	8,338							
ERJ-145ER	AE3007A1, A1/1	7,580	45,415	26,339	11,359	1,360	50	1,170	0.78
	AE3007A1P	8,338							
ERJ-145EU	AE3007A1, A1/1	7,580	44,070	26,339	11,359	1,360	50	940	0.78
	AE3007A1P	8,338							
ERJ-145LI	AE3007A1/2, A1	7,580	48,502	26,707	12,755	1,690	50	1,550	0.78
ERJ-145LR	AE3007A1/1	7,580	48,502	26,707	12,755	1,690	50	1,550	0.78
	AE3007A1P	8,338							
ERJ-145LU	AE3007A1	7,580	48,480	26,707	12,755	1,690	50	1,550	0.78
	AE3007A1P	8,338							
ERJ-145MP	AE3007A1/1	7,580	46,275	26,539	12,923	1,360	50	1,200	0.78
	AE3007A1P	8,338							
ERJ-145XR	AE3007A1E	8,895	53,131	27,758	13,027	1,965	50	2,000	0.80

the engines offer uncomplicated maintenance procedures thanks to engine inter-changeability design, common hardware among all ERJ family members and trend data monitoring capability. A dual-channel FADEC system and functional redundancy help to reduce the pilot's workload and deliver maximum engine reliability.

Some of the ERJ-145 variants are specific to their operator, for example the ERJ-145LU, which is only operated by Luxair. The ERJ-145LI, which is only operated in China, is the aircraft designator for ERJ-145s that have been assembled in China by a joint venture between Harbin Aircraft Manufacturing Corporation and Embraer. The partnership started in 2003, under the name of Harbin Embraer and the aircraft produced are not for export. The -EU model was designed for the European market, and is essentially the same as the -LR apart from the -EU's lower MTOW. The lower MTOW was planned in order to take advantage of lower airport and navigation charges in Europe. The -MP and -MK models are the updated versions of the -ER and -EU, but no -MKs have been sold so far.

All of the standard models for each of the three types have a maximum fuel capacity of 9,110 US Gallons (USG). This is the case for all -ER models. The -LR models on the other hand have a maximum fuel capacity of 11,323USG. The only change from this is the slightly lower maximum fuel capacity of the ERJ-145XR, 113,168USG, which gives it a longer range.

The ERJ-145XR is the extra-long-range version of the ERJ-145, designed for long and thin routes. Not only does it have greater range and fuel capacity, but its MTOW (53,131Lbs), speed (Mach 0.80) and engine power have also been increased. The more powerful RR AE 3007A1E engine, with up to 8,917lbs of take-off thrust, has lower fuel consumption and improved performance in hot and high situations than the previous models. This has been made possible through new engine software and upgraded mechanical components. Other structural differences on the ERJ-145XR are additions such as winglets and a third fuel tank.

ERJ-140

The ERJ 140 entered service in mid-2001, with the ERJ-140LR the only variant to be flown commercially. The aircraft was designed with only 44 seats, and the American market in mind. The ERJ-140 satisfied many of the agreements that US carriers had with their pilot unions.

The ERJ-140 shares more than 95% parts commonality with the ERJ-145 and has the same pilot type rating. The fuselage is shorter by four feet and six inches (1.42m), but the aircraft has 100nm more range than the -LR versions. The ERJ-140's MTOW is 44,313lbs and 45,518lbs for the -ER and -LR models respectively. This is generally less than the ERJ-145s, but similar to the ERJ-145EU that was developed for the European market.

Again the AE3007A1 engine is used, but this time it is slightly de-rated, with a maximum take-off thrust of up to 7,426lbs.

The ERJ-140 also has two overwing exits like the ERJ-145, but these are behind row 10.

ERJ-135

The ERJ-135 is the smallest aircraft in the family, and entered service in 1999. Of the three variants of this aircraft, one is marketed as a corporate jet, and two are commercial airliners: the ERJ-135ER and ERJ-135LR. As with the ERJ-140 and ERJ-145 types, the -ER is the standard or baseline model, while the -LR is the longer-range version, which has increased fuel capacity and upgraded engines.

The ERJ-135 also shares 95% parts commonality and a pilot type rating with the ERJ-145. The ERJ-135's fuselage is 11 feet and seven inches (3.54m) shorter than that of the ERJ-145, and the -135 carries only 37 passengers. Due to the reduction in weight, but no reduction in fuel capacity, the ERJ-135 has a longer range. This works out as 100nm more than the ERJ-140 and 200nm more than the ERJ-145, when comparing -LR versions.

The general internal layout is the same as for the ERJ-145, but with a shorter fuselage, with the overwing exits being behind row eight. The galleys and toilet are in the same place, except on Delta's feeder aircraft, which have a small galley at the rear of the cabin forward of the toilet, thereby reducing the number of passengers. AC

ERJ-135/-145 fleet summary

The ERJ-145 family is divided into three main types, of which there are over 1,050 in operation. This consists of 142 business jets and the remainder in commercial passenger operations.

There are currently over 900 ERJ 145 family aircraft in commercial airline operation. The business jet version, the ERJ 135-BJ Legacy, is not included in this fleet analysis.

Most ERJ 145 family aircraft are still flown by their original operator, or one of its subsidiaries.Three aircraft have been destroyed: two ERJ 145-ERs and one ERJ 135-LR, all on the American continent and more than five years ago.

The ERJ-145 was launched in 1989 by Embraer and, after many design changes, the first was delivered in late 1997. The aircraft entered service with Continental Express, now called ExpressJet, which remains the largest operator of the ERJ-145 family, and is the only operator for the longer-range ERJ-145XR variant.

The ERJ-135 entered service in mid-1999. The -ER flew with Continental Express (now ExpressJet) and the -LR with American Eagle.

Another derivative, the ERJ-140, was introduced in 1999, and entered service in 2001 with American Eagle.

All the ERJ-145 family are powered by variants of the Rolls-Royce (RR) AE3007A engine with take-off thrust ratings from 6,495lbs to 8,917lbs.

According the Aircraft Fleet & Analytical System (ACAS), the 910 aircraft in commercial airline service comprise: 123 ERJ-135s; 75 ERJ-140s; and 712 ERJ-145s.

The ERJ-145 accounts for 78% of ERJ-145 family in operation. The ERJ-145LR and ERJ-145XR account for 45% and 12% of the family total respectively. The ERJ-135 accounts for 14% of the total in operation, while the ERJ-140 accounts for only 8%.

The breakdown of all the aircraft variants and their general global location is shown *(see table, page 10)*. This shows that the ERJ-145 family has been particularly popular with the North American market, which operates 68% of the fleet. This is as feeder aircraft linking up all the hubs of the major carriers. This is also shown by the major ERJ-145 family operators, most of which are the regional arms of the major carriers such as American Airlines and Continental.

All three main types of the ERJ-145 family have flightdeck commonality, so pilots are qualified to fly all three sub-types on one type-rating. This shows in the operator fleet mixes, which often have more than one main type. This enables them to swap about aircraft within the schedule and route network depending on passenger demand, and avoid the cost of maintaining two separate pilot pools.

Fleet forecast

In addition to the 900-plus aircraft currently being flown, there are 42 aircraft on order, 40 of which are to be delivered to Hainan Airlines over the next five years. These are ERJ-145LI variants to be built in China, by an Embraer joint venture. The remaining two on order are one each for the Royal Thai Army and Navy, and should be delivered this year.

There are also order options for an additional 327 aircraft, with most going to North American feeder airlines. As some have been disposing of some of their ERJ-145 family aircraft, these options are unlikely to be fulfilled.

There seem to be no additional firm orders for America and Europe, possibly signifying that the market has reached its peak, since there are 54 aircraft currently parked. Potential customers, or those that want to add to their fleet, are now interested in the larger E-Jets. Other than the aircraft ordered by Hainan Airlines, most new ERJ-145s due for delivery until 2013 are ERJ-135BJ Legacy aircraft.

ERJ-135

There are two variants of the ERJ-135: the -ER and the -LR.

The standard model is the -ER, of which there are 34 in operation, split almost 50:50 between Europe and the US. The largest operator is ExpressJet, with 12, and the second largest is Regional in France, with nine.

There are 89 longer-range -LR aircraft, with 84% of these being in the US. The remaining 16% are split exactly 50:50 between Africa and Europe, with seven aircraft each. Of those that are based in the US, nearly one-third are parked, possibly showing a move away from the ERJ-135, towards cheaper turboprops or larger ERJ-145s. The largest fleet is obviously in the US, with American Eagle Airlines, which has 39. Over the past year the average daily utilisation for this variant has been nearly

The ERJ-135/-140/-145 fleet is concentrated in West Europe and North America. The fleet is now mature, with few firm orders outstanding. The ERJ-145LR is the most numerous of all variants.

ERJ-135/140/-145 FLEET SUMMARY

Aircraft model	Africa Active	Asia Active	Europe Active	Europe Parked	M.East Active	North America Active	North America Parked	Asia Pacific Active	South America Active	Total
ERJ-135BJ Legacy	1	5	55		15	41	1	7	17	142
ERJ-135ER			16			6	12			34
ERJ-135LR	7		5	2		52	23			89
ERJ-140ER									1	1
ERJ-140LR						74				74
ERJ-145EP	1		25	1		10			2	39
ERJ-145ER						26			15	41
ERJ-145EU			33			2	4			39
ERJ-145H			1	3						4
ERJ-145LI								26		26
ERJ-145LR	1		18	4		346	3	7	30	409
ERJ-145LU			6							6
ERJ-145MP	1		25	2				2	2	32
ERJ-145RS								5		5
ERJ-145SA								6		6
ERJ-145XR						104		1		105
TOTAL	**11**	**5**	**184**	**12**	**15**	**661**	**43**	**42**	**79**	**1,052**

six hours and 20 minutes, while the average flight cycle (FC) has been just over one hour.

ERJ-140

The ERJ-140 fleet consists of 75 aircraft and two variants.

There is only one example of the -ER model, which is operated by Embraer and is more than 13 years old.

The -LR model consists of 74 aircraft, all of which are in the US. The largest operator is American Eagle, with 59. The oldest aircraft is only seven years old. The average flight time over the past 12 months has been nearly 80 minutes, which is slightly more than all the other variants except for the -XR. The daily utilisation is a healthy seven hours and 45 minutes, with Chautauqua Airlines generally getting a bit more out of their aircraft than American Eagle.

ERJ-145

The ERJ-145 is the original aircraft of the family, and is also the most popular, with 712 in operation. It comprises 11 variants, three of which are military variants. The eight commercial passenger variants have 697 aircraft in service.

Standard -ER models are operated by 41 airlines. Two-thirds are in North America, the majority with ExpressJet, and one-third in South America.

Of the 39 -EPs in operation 25 are in Europe. More than half of these are in the United Kingdom, with bmi regional the largest operator (10 aircraft). The remainder are operated in Africa, North America and South America.

Originally, the -EU was designed specifically for the European market. It differs from the -EP only in its slightly smaller maximum take-off weight (MTOW), which allows cheaper landing rates at many European airports. Of the 39 -EUs in operation, 33 are predictably in Europe. The rest are in the US, with two operated by Chautauqua Airlines and four parked up by their lessor. Regional in France is the largest operator, with 13 aircraft followed by Flybe, which operates 10, in addition to three -EPs, all of which it inherited when it bought BA Connect from British Airways.

Another European variant is the -LU, of which Luxair is the sole operator of six aircraft. The -EU and the -LU both have an FC time of 1.0 flight hour (FH) and the daily utilisation is nearly 5.0FH and just over 6.5FH respectively.

The -LI is also specific to a geographical area, this time China. It has been, and will continue to be, built in China for Chinese airlines. There are 26 -LIs in operation, with 40 on firm order, all for Hainan Airlines. China Eastern Airlines and Grand China Express Air currently have 10 each and China Southern Airlines has six.

-LR variants account for 45% of the ERJ 145 family (excluding the business jet). This longer-range variant is operated everywhere, except for Asia, which only operates the business-jet variant. North America operates the most by far, with 346 active and three parked. The average FC time over the past 12 months is very similar to some of the -ER derivatives, at just over 70 minutes. The average daily utilisation, however, is more than the -ER, at 7.17FH. Some airlines achieve more, such as Aeromexico Connect, which has at least three aircraft that have averaged more than 9.0FH per day over the past year. Conversely, SATANA, Alitalia and Freedom Airlines often have aircraft that do only 4.5-6.0FH per day. ExpressJet, the largest operator of this variant, has daily utilisations ranging from 5.0FH to over 8.5FH.

A newer form of the -ER is the -MP variant. To date, 32 have been delivered, mostly to Europe. The largest operator, with 15, is Regional in France. There are also operators in Australia, South America and Africa. The average FC times across the fleet over the past 12 months have been 1.17FH and daily utilisation is 6.25FH. Again Aeromexico Connect manages to do more, and gets well over 8.0FH of utilisation per day.

The three variants that are used in military operations are the -H, -RS and -SA. Fifteen are flown by the Air Forces of Greece (which also operates the ERJ 135-ER), Brazil and Mexico. Brazil's Air Force also operate eight ERJ 145-ER, and their Federal Police operate one.

The final variant is the -XR, which has a faster maximum speed than all the other variants, and an even longer range than the ERJ 135-LR, and can still carry 50 passengers. ExpressJet in the US is the only commercial operator of this aircraft at the time of writing. It operates 104 aircraft, and has an additional 100 on order option. Embraer has also kept one, so there are 105 in total. The -XRs average FC times of nearly 2.0FH, due to their longer range, and their daily utilisation is longer at 8.0FH. They are a useful addition to an airline's fleet mix for those thinner routes that would otherwise go to a larger jet, with the bonus of no extra pilot type ratings needed. AC

ERJ 145 fuel burn performance

The fuel burn performance of the most numerous ERJ-145 family member variants are analysed on a range of mission lengths.

Analysis of the fuel-burn performance of three members of the ERJ-145 family reveals that for a given payload flown over 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; weather; and cruise speed.

Aircraft variants

The three sub-types of the ERJ-145 family are the ERJ-135, ERJ-140 and the ERJ-145, with two, two and eight commercial passenger variants respectively. The –ER variants of all three main types are considered the standard or base-line models. Since only one ERJ-140ER has been produced, the fuel burn performance of just the ERJ-135ER and ERJ-145ER is assessed. The most popular variant of the ERJ-145 family is the ERJ-145LR, with over 400 aircraft in operation, so this is the third variant that will be assessed. The majority of the remaining variants are just adaptations of the –ER and –LR models.

All three variants are powered by the Rolls-Royce AE3007, but each have different engine variants and thrust ratings. The ERJ-135 is equipped with the AE3007A3 engine model and is rated at 6,495lbs of take-off thrust. The ERJ-145ER has the AE3007A1/1 engine model and is rated at 7,036lbs of take-off thrust, while the ERJ-145LR is equipped with the AE3007A1 and rated at 8,169lbs of take-off thrust.

The increase in engine thrust for these three models is echoed in the increase in maximum take-off weight (MTOW), which goes from 41,887lbs for the ERJ-135ER to 48,502lbs for the ERJ-145LR. The OEW and maximum payload for each aircraft variant also increase with thrust, although the range does not follow the same pattern. The fuel capacity is the same for all –ERs (9,109USG) or -LRs (11,322USG).

There are many thrust and MTOW variants, as mentioned above, used by different airlines. The basic specifications, as stated by the manufacturers, have been used for these calculations.

Flight profiles

Aircraft performance has been analysed both inbound and outbound for each route in order to illustrate the effects of wind speed and its 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 for that month in the flight plans produced by Jeppesen. The flight profiles in each case are based on International Flight Rules, which include standard assumptions on fuel reserves, diversion fuel and contingency fuel. 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. This equates to additional fuel of about 300lbs on the ERJ-135 and about 350lbs on the ERJ-145, which is similar to the amount that is factored in by the large operators of this aircraft type. Long-range cruise (LRC) speed was used for these flight plans, because it enables an aircraft to use less fuel per nautical mile. It can mean longer block times, but this is the economical and operational compromise between fuel consumption and flight times. Economy cruise is more likely on the shorter routes, but for ease of comparison, LRC is used on all the flight profiles.

The aircraft being assessed are assumed to have a single-class cabin with a full passenger load of 35 on the ERJ-135 and 50 on the ERJ-145. The standard weight for each passenger and their luggage is assumed on these short-haul flights to be 200lbs per person, with no additional cargo in the hold. The payload carried is therefore 7,400lbs for the ERJ-135 and 10,000lbs for the ERJ-145. This is only varied when the ERJ-135 is assessed on the return sectors of the European routes. The payload on those three flights is reduced to allow the aircraft to stay within its landing weight restrictions. The reduction varies from 58-126lbs on each variant, and equates to less than one passenger.

The ERJ-145ER has lower fuel burn performance per seat and per seat-mile compared to the smaller ERJ-135 and heavier long-range ERJ-145LR variant.

FUEL BURN PERFORMANCE OF ERJ-135ER & ERJ-145ER/LR - OUTBOUND SECTOR

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
DFW-ABI	ERJ-135ER	AE3007A	41,887	35,719	203	48	37	158	5.5	0.03778	-41
EWR-MHT	ERJ-135ER	AE3007A	41,887	35,368	224	54	37	186	6.1	0.03172	11
DFW-LIT	ERJ-135ER	AE3007A	41,887	36,305	288	68	37	278	7.8	0.02796	2
DFW-JAN	ERJ-135ER	AE3007A	41,887	36,448	348	81	37	365	9.4	0.02570	2
ORD-SYR	ERJ-135ER	AE3007A	41,887	37,272	462	107	37	531	12.5	0.02295	12
LIS-AGP	ERJ-135ER	AE3007A	41,887	36,377	307	73	37	307	8.3	0.02691	7
LIS-VLC	ERJ-135ER	AE3007A	41,887	37,046	427	100	37	474	11.5	0.02402	6
LIS-TLS	ERJ-35ER	AE3007A	41,887	38,052	524	120	37	596	14.2	0.02362	3
DFW-ABI	ERJ-145ER	AE3007A	45,415	39,666	214	47	50	155	4.3	0.02952	-22
EWR-MHT	ERJ-145ER	AE3007A	45,415	39,435	239	53	50	189	4.8	0.02497	9
DFW-LIT	ERJ-145ER	AE3007A	45,415	40,333	312	68	50	278	6.2	0.02244	1
DFW-JAN	ERJ-145ER	AE3007A	45,415	40,514	379	82	50	367	7.6	0.02068	1
ORD-SYR	ERJ-145ER	AE3007A	45,415	41,387	502	107	50	529	10.0	0.01845	12
LIS-AGP	ERJ-145ER	AE3007A	45,415	40,392	330	72	50	307	6.6	0.02141	7
LIS-VLC	ERJ-145ER	AE3007A	45,415	41,121	462	99	50	477	9.2	0.01924	5
LIS-TLS	ERJ-145ER	AE3007A	45,415	42,173	564	119	50	598	11.3	0.01882	2
DFW-ABI	ERJ-145LR	AE3007A	48,502	41,299	231	49	50	154	4.6	0.03191	-25
EWR-MHT	ERJ-145LR	AE3007A	48,502	40,930	257	54	50	187	5.1	0.02696	10
DFW-LIT	ERJ-145LR	AE3007A	48,502	41,980	328	68	50	278	6.6	0.02362	2
DFW-JAN	ERJ-145LR	AE3007A	48,502	42,137	396	81	50	365	7.9	0.02162	2
ORD-SYR	ERJ-145LR	AE3007A	48,502	43,053	523	105	50	530	10.5	0.01922	13
LIS-AGP	ERJ-145LR	AE3007A	48,502	42,037	350	73	50	306	7.0	0.02271	8
LIS-AGP	ERJ-145LR	AE3007A	48,502	42,778	481	98	50	474	9.6	0.02003	6
LIS-TLS	ERJ-145LR	AE3007A	48,502	43,920	588	117	50	596	11.8	0.01961	3

Source: Jeppesen

Route analysis

Eight routes with varying lengths were analysed with tracked distances of 145-600nm. Five of the routes were in the USA and three were in Europe, and all were picked to examine the fuel burn per seat-mile with increasing mission length. All the routes are typical of the operators of these aircraft, which tend to have average FC times of just over 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 American route to be analysed is Dallas Fort Worth, TX (DFW) to Abilene, TX (ABI). This has a tracked distance of 145nm on the outbound sector and 211nm on the return. This is a route on which American Airlines often uses its ERJ-145 aircraft. Although there were strong headwinds on the outbound sector, the block time was still about 10 minutes quicker than the return sector. This was because of a much longer return routeing, and nominal tailwinds on the return sector. These winds had the effect of not changing the distance, so the ESAD is the same as the tracked distance.

The second American route is an example from ExpressJet's network, and is Newark, NJ (EWR) to Manchester, NH (MHT). The tracked distance is 191nm on the outbound sector, and a much longer 271nm on the return. The difference between the outbound ESAD and the return sector ESAD is even more pronounced at more than 116nm - an increase of more than 60%. This comes from longer routeings and a massive headwind of 65-68kts on the return sector. This is compared to a tailwind of 9-11kts and a block time of 53-54 minutes, which is about 20 minutes faster than the return sector's block time *(see tables, this page & page 14)*.

The third route is an American Airlines route from DFW to Little Rock, AR (LIT). The outbound distance is 278nm, and with small tailwinds, the ESAD does not differ. The return sector has a similar tracked distance of 289nm, but, due to large headwinds of about 39kts, the ESAD is increased to about 318nm and the block times are increased by four to six minutes *(see tables, this page & page 14)*.

The fourth US route is again an American Airlines example from its DFW base. The destination this time is Jackson, MS (JAN). The outbound sector has a tracked distance of 366nm and a tailwind of one or two knots, meaning that the ESAD stays roughly the same as the tracked distance. The return sector has a less forgiving headwind of 41-43kts. This increases the longer tracked distance of 432nm to an ESAD of about 473kts. These two aspects mean that the block time is 15-19 minutes faster on the outbound leg.

The final American Airlines route is Chicago (ORD) to Syracuse, NY (SYR), which is a route also flown by United and US Airways. Both sectors on this route have similar routeings, with the tracked distances being 544nm on the outbound sector and 536nm on the return. The outbound tailwind is 12-13kts, which means that there is an improvement in the ESAD, but the return sector has a strong 69kts headwind, resulting in a drastic increase of the ESAD to about 640nm, over 100nm more than the outbound ESAD. This also means an increase in the block time for the return of about 20 minutes.

The first European route is Lisbon, Portugal (LIS) to Malaga, Spain (AGP), which is flown by TAP Air Portugal and Spanair. The outbound tracked distance is 308nm and due to a tailwind of just 7-8kts, the ESAD is only 1-2nm less. The return sector has a stronger wind that is a headwind this time, so the 339nm tracked distance increases to an ESAD of about 369nm. This also increases the block time by about 10 minutes.

FUEL BURN PERFORMANCE OF ERJ-135ER & ERJ-145ER/LR - RETURN SECTOR

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
ABI-DFW	ERJ-135ER	AE3007A	41,887	35,252	235	57	37	211	6.3	0.03009	3
MHT-EWR	ERJ-135ER	AE3007A	41,887	36,050	309	73	37	309	8.4	0.03081	-67
LIT-DFW	ERJ-135ER	AE3007A	41,887	35,790	311	74	37	318	8.4	0.02912	-40
JAN-DFW	ERJ-135ER	AE3007A	41,887	36,589	425	100	37	476	11.5	0.02658	-43
SYR-ORD	ERJ-135ER	AE3007A	41,887	37,440	545	127	37	647	14.7	0.02747	-69
AGP-LIS	ERJ-135ER	AE3007A	41,887	37,303	359	83	37	371	9.7	0.02859	-43**
VLC-LIS	ERJ-135ER	AE3007A	41,887	38,236	498	113	37	550	13.5	0.02746	-48**
TLS-LIS	ERJ-135ER	AE3007A	41,887	38,665	562	127	37	654	15.2	0.02596	-45**
ABI-DFW	ERJ-145ER	AE3007A	45,415	41,141	271	58	50	210	5.4	0.02569	3
MHT-EWR	ERJ-145ER	AE3007A	45,415	40,023	326	72	50	305	6.5	0.02408	-68
LIT-DFW	ERJ-145ER	AE3007A	45,415	39,975	335	72	50	318	6.7	0.02316	-37
JAN-DFW	ERJ-145ER	AE3007A	45,415	40,842	458	98	50	469	9.2	0.02120	-41
SYR-ORD	ERJ-145ER	AE3007A	45,415	41,704	578	122	50	643	11.6	0.02155	-69
AGP-LIS	ERJ-145ER	AE3007A	45,415	41,411	383	82	50	368	7.7	0.02257	-46
VLC-LIS	ERJ-145ER	AE3007A	45,415	42,452	530	110	50	550	10.6	0.02165	-48
TLS-LIS	ERJ-145ER	AE3007A	42,965	42,965	603	125	50	648	12.1	0.02063	-45
ABI-DFW	ERJ-145LR	AE3007A	48,502	39,402	253	56	50	211	5.1	0.02402	1
MHT-EWR	ERJ-145LR	AE3007A	48,502	41,668	349	72	50	307	7.0	0.02572	-65
LIT-DFW	ERJ-145LR	AE3007A	48,502	41,723	354	73	50	317	7.1	0.02447	-41
JAN-DFW	ERJ-145LR	AE3007A	48,502	42,612	480	97	50	474	9.6	0.02222	-43
SYR-ORD	ERJ-145LR	AE3007A	48,502	43,539	609	121	50	637	12.2	0.02272	-69
AGP-LIS	ERJ-145LR	AE3007A	48,502	43,081	404	82	50	367	8.1	0.02385	-45
VLC-LIS	ERJ-145LR	AE3007A	48,502	44,143	555	109	50	547	11.1	0.02265	-46
TLS-LIS	ERJ-145LR	AE3007A	48,502	44,673	630	123	50	648	12.6	0.02154	-45

** payload reduced to stay within landing weight.

Source: Jeppesen

The second European route is LIS to Valencia, Spain (VLC), operated by Iberia. Again on the outbound sector the ESAD decreases only slightly from the 480nm tracked distance due to a small tailwind. The return sector's tracked distance is only 10nm more than on the outbound, but due to headwinds of about 48kts, the ESAD increases to about 550nm. The block time also increases by 11-13 minutes.

The third and final European route is also from LIS, but this time to Toulouse, France (TLS), also operated by TAP Air Portugal. The outbound tracked distance is 600nm, with the return routeing giving a reduced distance of 585nm. The small tailwinds outbound mean little change in the ESAD. On the return sector, however, the ESAD increases to 648-654nm because of 45kt headwinds. This has less effect on the block times than would be expected and, assisted by the shorter routeing, the return sector's block time is just 6-7 minutes longer.

On all three European routes, as mentioned above, the ERJ-135ER has to have its payload reduced by the equivalent of less than one passenger.

Fuel burn performance

The fuel burn performance of the three ERJ 145 family variants is shown for all the routes across a range of mission lengths, together with the associated fuel burn per passenger and per passenger-mile for the outbound and return sectors on each route.

For every route the performance order is generally the same. The ERJ-145ER is the most fuel-efficient when looking at both the fuel burn per passenger and per seat-mile. The ERJ-135ER burns the least fuel, but it is also the least efficient per passenger and seat-mile.

The ERJ-145LR comes between the other two variants. It is likely that the ERJ-145LR comes into its own on much longer routes, or when weather conditions would necessitate the additional fuel capacity. Nevertheless, it is debatable whether airlines actually use this aircraft family regularly on much longer routes, since the average FC time of all the ERJ-145 family is about 80 minutes.

When looking at all the outbound American Airlines routes, the DFW-ABI sector has the lowest fuel burn per passenger for each variant. Then in terms of the burn per seat-mile, the ORD-SYR sector produces the best results for each aircraft variant. For the return American Airlines routes, the best fuel burn per passenger performance is again seen on the shorter ABI-DFW sector *(see table, this page)*. The best performance per seat-mile is not on the longest route, as would be expected, but on the JAN-DFW route. This is only by a fractional amount, however, and could be due to the longer route having a very large headwind and, therefore, additional workload.

The European routes follow the same patterns as the American Airlines routes, with the ERJ 145-ER producing the better results. On the outbound sector, ORD-SYR produces the lowest fuel burns per passenger-mile and on the return, TLS-LIS produces the lowest fuel burn per passenger-mile. Overall, the best fuel burn per passenger is seen on the DFW-ABI sector using the ERJ-145ER. The best fuel burn per passenger-mile is delivered by the ERJ-145ER, again on the ORD-SYR sector, closely followed by the same variant on the LIS-TLS sector.

Generally, the figures show that the shorter the route, the lower the fuel burn per passenger, as would be expected. Conversely, the longer the route the better the fuel burn per seat-mile, although JAN-DFW is the exception, since it produces fractionally better figures than the longer SYR-ORD route.

As with most aircraft, the larger the size, the more the thrust and weight increase and with it the fuel burn. But, with bigger aircraft, come more seats, which is why the ERJ 145 performs better on a per seat-mile basis. AC

ERJ-135/-145 maintenance analysis & budget

The ERJ-145 family has a relatively simple maintenance programme, and most engines are maintained with fleet-hour agreements.

The ERJ-145's maintenance programme is optimised for operators flying 2,500 flight hours (FH) and 2,500 flight cycles (FC) per year. Operators with lower or higher utilisations, flying short or very long sectors, will find maintenance planning more complicated. Many tasks will have to be performed without using a high proportion of their interval, or the aircraft will have to be grounded and opened up for maintenance more frequently.

The ERJ-145 has a base maintenance cycle of 20,000FH, and many aircraft have been though their first base cycle. In fact the fleet leader, a PGA - Portugalia aircraft, has accumulated over 30,000FH and is halfway through its second base maintenance cycle. With a structure designed for a minimum economic life of 60,000FC, some aircraft may go through three, or even four, base maintenance cycles during their service lives.

ERJ family in operation

In North America the ERJ-135/-140/-145 are used almost exclusively to provide regional services for the major airlines. The only major exception to this is ExpressJet, which has 30 aircraft dedicated to its ExpressJet Corporate Aviation business.

Discounting non-scheduled airline operators, the average annual utilisation by North American ERJ-145 operators is 2,750FH and 2,100FC. This equates to an average flight time of 79 minutes.

In Europe the scheduled operators achieve an average annual utilisation of 2,250FH and 2,000FC, equating to an average flight time of 67 minutes.

The equivalent figures for the ERJ-135 are: 2,450FH, 2,150FC and 68 minutes in North America; and 1,800FH, 1,900FC and 57 minutes in Europe. Utilisation of the ERJ-140 is close to that of the ERJ-145 at 2,800FH, 2,175FC and 77 minutes.

Excluding the few aircraft operating as corporate shuttles or those with non-commercial operators, all the ERJ-145s are in operation as passenger aircraft and their maintenance costs are analysed here for aircraft completing 2,500FH and 2,000FC per year, at an average flight time of 75 minutes.

Maintenance programme

The ERJ-145 family has a Maintenance Steering Group 3 (MSG3) maintenance programme. "Embraer only published a maintenance review board (MRB) document, and did not publish a maintenance planning document (MPD) that has a maintenance programme, unlike most aircraft types," explains Stefan Kontorravdis, director of engineering at Flybe. "Each operator devises its own maintenance programme from the MRB. Several groups of tasks have similar or equal intervals, however, so maintenance programmes are similar."

Carlos Almeida, director of market strategy at Ogma, explains that the ERJ-145's maintenance programme is divided into two manuals: the scheduled maintenance requirements document (SMRD); and the MRB. "The SMRD outlines the scheduled minimum maintenance requirements. The first part has the MRB, and all sections are mandatory," says Almeida. "The second part has additional information and data, and helps each operator develop a maintenance programme that is compatible with their operation. The second part also allows the operator to prepare their own unique operations specification for approval by their authority. This would be its additional line checks for its own requirements. The MRB outlines the minimum scheduled maintenance requirements."

The tasks fall into four categories: systems and powerplant inspections; structural inspections; zonal inspections; and corrosion prevention and control programme (CPCP) inspections.

System tasks have intervals specified in FH, FC and calendar time. The tasks of the auxiliary power unit (APU) are specified in APU hours, and some engine-related tasks are specified in engine cycles. Some tasks have two criteria and intervals, and are therefore performed when the first one is reached.

All tasks in the structural programme have FC intervals. There are also CPCP tasks in the structural programme, which have intervals specified in calendar time.

Zonal tasks have their intervals specified in FH. These are the same groups as the C check tasks: the 1C every 5,000FH, the 2C every 10,000FH, and the 4C every 20,000FH.

There are more than 1,000 tasks in the MRB. Embraer explains that 380 have FH intervals, 30 have both FH and calendar intervals, and 300 have FC intervals. There are 16 landing-gear-related tasks with FC and calendar intervals, 290 tasks with calendar intervals, and 10 APU tasks with APU hour (APUH) intervals.

The maintenance plan also has initial thresholds for most structural and CPCP tasks. There are about 130 tasks with FC thresholds, and 100 with calendar thresholds.

The intervals for the FH tasks range from 100FH to 30,000FH, and for FC tasks from 2,500FC to 30,000FC. The calendar intervals start at 48 hours, and include tasks in the 48-hour line check. They go up to 180 months, or 15 years.

The structural tasks have initial thresholds varying from 10,000FC to 30,000FC, while the CPCP tasks have initial thresholds of 48 to 96 months. This indicates that the aircraft's maintenance requirements and routine inspection tasks start to increase from an age of four years.

Maintenance checks

Line checks

The ERJ-145's maintenance programme starts with line checks. The line maintenance programme consists of a 48-hourly 'service' check and a two-weekly/14-day (or 100FH whichever comes first) 'routine' check. There are no pre-flight checks specified in the Maintenance Review Board Report (MRB), although many operators add them into their own maintenance programmes.

"Although there are no pre-flight (PF) or transit checks (TR) in the MRB, we still have PF checks in our own maintenance programme," says Kontorravdis. "The difference between a PF and TR check depends on which tasks have to be done by mechanics and which by flightcrew. The smallest check in the MRB is the 48-hour check. We actually do this every night, and the 48-hour interval means we can skip it if the aircraft is at an unserviced outstation overnight. We then do a PF check, which we call a pre-departure inspection (PDI) after the 48-hour check and prior to the

The majority of ERJ-145 family aircraft operate at average FC times of 70-80 minutes, and generate annual utilisations of about 2,500FH and 2,000FC per year.

first flight of the day, and this can be done by the flightcrew. Most aircraft types then have a TR check prior to each subsequent flights of the day, and this is a check that has to be done by mechanics. We do not need to have these, and so have a PF check prior to each flight and these are done by the flightcrew. There are, of course, a few occasions when defects occur. Pilots can decide of the defect can be deferred by referring to the minimum equipment list, or if the fault has to be rectified prior to flying again. If it has to be rectified then mechanics are required to work on the aircraft.

The PF and checks can be performed by the flightcrew and use only a minimal amount of materials and consumables. No labour from mechanics is used, however, except for non-routine defects that occur at random during PF checks.

In addition to the service and routine checks, the ERJ-145 family has a system of A, C and structural checks which are independent of each other. The ERJ-145's maintenance programme has undergone 11 revisions since the aircraft entered into service in 1997, and the twelfth is due in the first quarter of 2009. The original maintenance programme had basic intervals of 400FH for A-checks, 4,000FH for C-checks and multiples of 2,000FC for Structural Inspection (SI) tasks and two years for CPCP tasks.

A major revision of the MRB in September 2004, with the release of issue 9, increased the A check interval from 400FH to 500FH, the basic C check interval from 4,000FH to 5,000FH, SI tasks to multiples of 2,500FC, and CPCP tasks to multiples of 30-month intervals.

A-checks

In most operators' programmes, there are five different multiples of A check tasks: the 1A, 2A, 3A, 4A and 5A tasks. The interval for the A tasks was 400FH under the original maintenance programme. The 2A tasks had an 800FH interval, and were performed at the second and fourth A checks, the A2 and A4 checks respectively. The 3A tasks had a 1,200FH interval and were carried out at the A3 check, while the 4A tasks had a 1,600FH interval and were carried out at the A4 check. The 5A tasks had a 2,000FH interval and were carried out at the A5 check. After the 5A is complete the cycle restarts at the A1 check.

The basic A interval was escalated to 500FH in September 2004, so that the A1 check is performed at 500FH, the A2 at 1,000FH, the A3 at 1,500FH, the A4 at 2,000FH and the A5 at 2,500FH, thereby completing the cycle *(see table, page 18)*.

UK operator bmi Regional has local approval for an amended A-check cycle with the 1A tasks at 550FH, 2A tasks at 1,100FH, 4A tasks at 2,200FH and the 5A tasks at 2,500FH. Flybe has escalated its A check interval to 600FH, and so the A check would be complete at 3,000FH.

Kontorravdis explains that in addition to the 48-hour, 14-day and A checks, some out-of-phase (OOP) tasks have intervals between the checks. "These OOP tasks fall between subsequent A and subsequent C checks, so they are brought forward to the nearest A or C check," he explains. "If a task can be carried out during a 48-hour check we refer to it as a line station requirement (LSR) task."

Base checks

There are three main groups of system C check tasks: the 1C, 2C and 4C tasks. These have intervals of 5,000FH, 10,000FH and 20,000FH.

The tasks are arranged in a series of four basic checks: the C1 at 5,000FH, the C2 at 10,000FH, the C3 at 15,000FH, and the C4 check at 20,000FH. The C1 check has the 1C tasks, the C2 check the 1C and 2C tasks, and the C3 check the 1C tasks. All four task groups come in phase at the C4 check, making it the largest C check *(see table, page 18)*.

The C4 check has an interval of 20,000FH, which at an annual utilisation of 2,500FH equates to eight years of operations. The second largest check is the C2 check every four years. Many operators also choose to carry out other large tasks such as major modifications, component changes and interior refurbishments at these checks.

The interval for the C tasks was 4,000FH under the original maintenance programme. The 2C tasks had an interval of 8,000FH, so they were performed every second C check, at the C2 and C4 checks. The 4C tasks had a 16,000FH interval, so they were performed at the C4 check.

From September 2004 operator experience was allowed to escalate the 1C and 2C tasks by 25% to 5,000FH and 10,000FH respectively. The interval for the 4C tasks, however, initially remained at 16,000FH, and was not escalated until Revision 10-4 of the MRBR was issued in January 2007 when the interval was raised to 20,000FH.

The basic interval for the 1C tasks has been escalated to 6,000FH by some operators, taking the C4 interval up to 24,000FH.

In addition to the system task inspections, there are SI and CPCP tasks, both of which are independent of the C check tasks.

The SI tasks are fatigue-related inspections. There are three main groups: the 1CS, 2CS and 4CS tasks. These initially had intervals of 4,000FC, 8,000FC and 16,000FC, which have since been extended to 5,000FC, 10,000FC and 20,000FC. Many of these inspection

ERJ-145 FAMILY A & BASE CHECK TASK COMPOSITION

Airframe check	Routine inspection tasks	Interval
A1	1A	500FH
A2	1A + 2A	1,000FH
A3	1A + 3A	1,500FH
A4	1A + 2A +4A	2,000FH
A5	1A + 5A	2,500FH
C1	1C +1CS +1CC	5,000FH/4,000FC/30 months
C2	1C + 2C +1CS +2CS +1CC +2CC	10,000FH/8,000FC/60 months
C3	1C + 1CS + +1CC	15,000FH/12,000FC/90 months
C4	1C +2C +4C + 1CS + 2CS + 4CS +1CC +2CC +4CC	20,000FH/16,000FC/120 months

tasks also have an initial threshold of 20,000FC, so that many will not be carried out until the C4 check. Some SI tasks do not fit into the multiples of 5,000FC intervals, and so do not fit in well with any of the C check inspections. These are treated as OOP items.

The CPCP tasks inspect for corrosion on structures. These initially had three tasks grouped into intervals that are multiples of two years (24 months): the 1CC tasks at 24 months; the 2CC tasks every four years (48 months); and the 4CC tasks every eight years (96 months). These three groups have subsequently been extended to 30 months, 60 months and 120 months.

Both the SI and the CPCP tasks coincide reasonably well with the C1, C,2 C3 and C4 checks at most operators' average annual utilisation rate of 2,500FH and 2,000FC, and FH:FC ratio of 1.25FH per FC. That is, the 2,500FC SI 1CS and 30-month CPCP 1CC tasks are grouped in every C check every 2,500FH, the 5,000FC SI 1CS and 60-month CPCP 1CC tasks are grouped in the C2 and C4 checks, and the 10,000FC SI 4CS and the 120-month CPCP 4CC tasks are grouped in the C4 checks *(see table, this page)*.

At typical rates of utilisation most operators will be performing the SI tasks and CPCP tasks earlier than required. Alternatively, they can carry out the system tasks first and then the SI/CPCP tasks separately. This is unlikely, however, since it would incur more labour man-hours (MH) for repeated access and an increased downtime for the aircraft.

The base cycle is therefore completed at the C4 check. At this stage the 4CS and 4CC tasks are performed. Some SI and CPCP tasks have initial thresholds of up to 30,000FC and 96 months. The aircraft's routine maintenance tasks will therefore increase after the first C4 check during the second base check cycle.

Line & A check contents

FlyBe has a PDI check in its line maintenance programme that it performs prior to the first flight of each day. This has nine tasks, which include: checking the deferred defects recorded in the aircraft's technical log; a walkaround visual inspection; checking wheels and tyres; removing all blanks and flags; removing landing gear locking pins; and de-icing the aircraft as necessary.

The MRB has a higher 48-hour 'service' check, whose tasks include: checking tyre pressures and brake wear indicators; checking the technical and cabin defect logs; checking OOP task requirements; checking all safety equipment; various landing gear and gear bay inspections; making wing and engine nacelle inspections; and a series of flightdeck and cabin inspections.

The tasks for the two-weekly or 14-day 'routine' check consist largely of visual inspections. These are similar to the 48-hour check, but there are additional requirements.

Defects also occur during operation, and operators use line checks wherever possible to clear and rectify them, during the ground time if allowed, or if the defect is a no-go item. If the defect is large and can be deferred, the airline will rectify it at a larger check, such as an A-check, if one is due in a relatively short time. In addition to the MPD tasks, workscopes for these line checks also include interior checks, deferred items, hard-timed tasks, troubleshooting and component changes.

Labour inputs for each PF check are about 0.3MH. These are performed by flightcrew, but an allowance has to be made for mechanics when required for non-routine defects. A budget of 0.3MH per PF check is this used on a conservative basis.

Labour inputs for the 48-hour 'service' checks are estimated at 1.5MH, and for the routine 14-day/100FH checks are estimated at 3.0MH. An allowance of $50-60 for consumable and material consumption can be used for 48-hour checks. These use oil, nitrogen, oxygen and skydroil. An allowance of $150 for materials and consumables for 14-day/100FH checks is used.

Under the annual utilisation assumption of 2,500FH and 2,000FC, the aircraft will require 2,000 PF checks, 183 48-hourly checks and 26 14-day checks every year. This will use a total of about 960MH per year for these aircraft. At a labour rate of $75 per MH, these three types of line check will incur an annual labour cost of $72,000. Once the cost of materials and consumables for all these checks are considered, the total cost for line maintenance is about $86,000 per year. This is equal to $35 per FH *(see table, page 22)*.

The lighter A checks are the A1 and A3 checks *(see table, page 22)*. These only need 30-35MH. The A2 uses about 50MH, the A4 75MH and the heaviest A5 check 125MH. These five checks will consume 315MH. At a labour rate of $75 per MH, this is equal to $24,000.

The lighter A checks will use about $1,000 of materials and consumables for the routine and non-routine rectification. The heaviest 5A check is estimated to need $5,000 of materials and consumables. The total consumption of materials and consumables for the five checks will be $9,000-10,000, taking the total cost for the checks to $34,000. While the checks have a limit of 500FH, few operators fully utilise this. It is assumed about 80% of this interval is used, meaning that the A check cycle is completed about every 2,000FH. On this basis, the A checks will have a reserve of about $17 per FH *(see table, page 22)*.

Base check contents

Many operators take advantage of the extended downtime and access provided by base checks to perform additional tasks such as: modifications and upgrades; engineering orders (EOs); removing rotables for overhaul; engine changes; clearing deferred defects; exterior and interior cleaning and refurbishment; and stripping and repainting. As a result, it is possible for two airlines with similar operations to have wildly differing check costs. The importance of distinguishing between basic check costs and these 'additional' items is particularly important for lessors, since claims on maintenance reserve funds are typically only payable against work carried out directly on routine inspection tasks and their related non-routine rectifications. Other issues that should be considered are analysed here.

The ERJ-145's base maintenance programme consists of three groups of system, structural and CPCP checks. Most operators have a base maintenance check programme cycle of four checks, that have a basic interval of 5,000FH, 4,000FC and 30 months.

Routine inspections

The arrangement of MRB tasks for the base checks is summarised. These are covered by the current MRB revision.

Check planning and workscope contents first take into account probable interval utilisation. This cannot be 100% due to the constraints of aircraft operational requirements, check planning limitations, and appropriate hangar and facility availability. Given the nature of the relationship between the system inspection tasks (2,500FH intervals), SI tasks (2,500FC intervals) and the CPCP tasks (30-month intervals), most operators will typically achieve 85% of the System check intervals, and will lose some of the life of the SI and CPCP task intervals by grouping them in the checks as described. This means the C1 check will be performed after about 4,250FH, the C2 check after 8,500FH, the C3 check after 12,750FH, and the C4 check after 17,000FH or seven years' operation.

As well as the MPD tasks, operators may add items unique to their own maintenance programme, such as deep cabin cleaning and other interior work.

The aircraft's age and serial number will also have an impact. Early production aircraft are particularly affected and, as they undergo inspections, particularly the first round of C4 checks, inspection findings are reported back to the manufacturer in order to develop repairs, and where necessary issue Service Bulletins (SBs) to prevent a repeat of the problem. Later-serial-numbered aircraft will have had many of these improvements incorporated on the production line, so they will benefit from having a lower level of non-routine requirements than earlier-built aircraft.

One European operator saw the MH required to incorporate SBs on the first C checks drop from 675MH on its first aircraft to 320MH on its third aircraft, even though their build dates were only separated by 12 months. The first aircraft later underwent its first C4 check where SBs only accounted for 105MH.

Engineering orders

The ERJ-145 has not been affected by any major airworthiness directives (ADs). Those ADs that have been issued for the type have generally required inspections using relatively small numbers of MH.

Operators of the ERJ-145 have the option of increasing the design weights of their aircraft. For 145ER/EP/EU variants, SB145-53-0064 increases the maximum zero fuel weight (MZFW) by 250kg and for 145LR/LU variants SB145-53-0068 increases the design weights as follows:

MTOW	22,000kg to 22,600kg
MLW	19,300kg to 19,800kg
MZFW	17,900kg to 18,400kg

For the ERJ-145LR/LU the SB requires the installation of reinforcements to stringers and frames in the central and rear fuselage. These modifications are likely to be performed along with a C2 or C4 check.

Rotable components

Base checks will also involve the removal of a small number of rotable components that have hard times for repair and overhaul. A minority of the rotable units installed on the aircraft are maintained on a hard-time basis. These are mainly safety- and emergency-related items that include escape slides, oxygen bottles and life rafts. There are a small number of system components, such as batteries, that also have hard-time maintenance programmes. These items will be removed during A or base checks. Their repair cycle time may allow the same items to be reinstalled on the same aircraft, while parts with repair cycle times longer than the downtime of the check will have to be exchanged with serviceable units.

Most of the rotables on the ERJ-145 are maintained on an on-condition basis. These will be removed as they fail during line maintenance or A checks, and replaced with serviceable items. As well as hard-timed rotables, base checks will be used to change engines, landing gear sets, the APU and thrust reversers as required. The landing gear overhaul interval is calendar-time and FC-related, while the APU and thrust reversers are maintained on an on-condition basis.

Most aircraft in the ERJ-145 family fleet do not have thrust reversers installed, however, because the aircraft can land satisfactorily on most airport runways. Only aircraft using short runways, such as at London City Airport, need to have thrust reversers fitted. Thrust reversers can be retrofitted through an SB available from Embraer.

Apart from the difficulties of scheduling the removal of on-condition components without an excessive waste of useful life, the difficulty with engine removals is that most are under the Rolls-Royce Total Care programme. An operator therefore cannot send an engine to the shop at its sole discretion. Rolls-Royce has to agree that there are technical grounds for an engine's removal. It is clear that, on a fixed price contract, Rolls-Royce does not want to waste any of the potential on-wing life that can be extracted from the engines.

The relatively small number of hard-timed components means that the MH used for the removal and replacement of rotable components are small in relation to other elements of the base checks.

Interior work

The use of the ERJ-145 for short-haul operations means that work on the aircraft's interior will be relatively minor. The absence of different cabin classes, complex seats and in-flight entertainment

The ERJ-145's base checks typically include routine inspections, non-routine rectifications, interior refurbishment, removal and replacement of rotable components, implementation of engineering orders, and stripping & repainting.

systems greatly reduces the amount of unscheduled maintenance compared with aircraft used for long-haul, widebody operations. Also, while the interiors of long-haul widebody aircraft will be periodically reconfigured to adjust for variations in the different classes of traffic, almost all ERJ-145s will remain in their original configuration throughout their working lives. Even regional aircraft need refurbishment, however, and the C2 and C4 checks provide operators with the ideal opportunity.

Other work

As well as routine inspections, non-routine rectifications, EOs and modifications, interior cleaning and refurbishment, removal and reinstallation of rotable components and interior work, operators have further items to add to the workscope of base checks. These include repetitive inspections that are in addition to the C check task cards, such as: cleaning; engine changes (typically requiring 50MH of experienced labour); changing other large rotables such as the landing gear or APU; clearing deferred defects; and performing OOP tasks. Repetitive inspections are imposed by SBs and ADs, while others are those that an operator's engineering department thinks will improve reliability. OOP tasks are items whose intervals do not match those of the basic A and C checks.

Base check inputs

There are several elements to the base checks. There are three different multiples of C check tasks, and as a result the base maintenance cycle consists of two light base checks and two heavier checks.

C-checks

The lighter checks are the C1 and C3 checks *(see table, page 18)*. These only need the 1C tasks, while the heavier C2 and C4 checks also have the 2C and 4C tasks.

The C1 check needs a routine labour input of 700-800MH, the C2 a further 300-500MH and the C4 an additional 50-100MH. The heaviest C4 check will therefore use 1,050-1,400MH for the routine inspections.

Non-routine rectifications from the 1C tasks add a further 200-400MH, and those from the 2C tasks another 300MH. For the heaviest C4 check, 500-700MH are required for defect rectification, equal to a non-routine ratio of 50%.

Other work consumes an average of 250-300MH for C1 and C3 checks, increasing to 350-500MH for C2 and C4 checks. Incorporating SBs consumes an average of 300-350MH for mature production aircraft (early production aircraft were higher as discussed earlier). Exterior cleaning will add 45MH, and interior cleaning a further 60MH.

This takes the total labour consumption to 1,750MH for the C1 and C3 checks, to 2,650MH for the C2 check, and to 2,700MH for the C4 check. The total for the four checks is therefore about 8,800MH. At a labour rate of $75 per MH, this is equal to $660,000.

It is difficult to estimate typical materials consumption for the C checks, since the data provided by different operators fails to quantify what has been included. Figures for the smaller C1 and C3 checks range from $40,000 to $80,000, although about $50,000 is probably typical. Similarly figures for the C2 and C4 checks range from $50,000 to 110,000, although about $85,000 is not unreasonable. The total consumption of materials and consumables for the four checks is therefore about $270,000.

The total cost for the four checks in the cycle is therefore about $930,000, equal to a reserve of $55 per FH *(see table, page 22)* when amortised over the likely cycle interval of 17,000FH.

Typically operators will undertake some form of major interior refurbishment after five to six years of service. With the ERJ-145 it is possible to carry this out at the C3 check after five to six years, or push it out to the C4 at seven to eight years. This work will include removing and refurbishing: seats; overhead bins; passenger service units (PSUs); bulkheads; ceiling and sidewall panels; toilets; galleys; carpets; and the cargo compartment. Such an extensive interior refurbishment is estimated to use 850MH in labour and $30,000 in materials. At a generic labour rate of $75 per MH the total cost of refurbishment will be $93,750. If interior refurbishment takes place at the C4 check, about every 17,000FH, the reserve will be $6 per FH *(see table, page 22)*.

Stripping and painting is also likely to be performed at the same time. Most operators lack the facilities to carry out external painting, so this is usually outsourced to specialists. A typical cost estimate for the strip and paint of an ERJ-145 is $75,000. Again, assuming painting takes place at the C4 check, about every 17,000FH, this equals a reserve of $5 per FH *(see table, page 22)*.

The total reserve for the base checks, interior refurbishment, and stripping and repainting is therefore about $62 per FH.

Heavy components

Heavy components comprise four categories: the landing gear; wheels and brakes; thrust reversers; and the APU. The installation of thrust reversers is an option on the ERJ-145 family, and the majority do not have them fitted. Thrust reversers can be retrofitted if required.

The landing gear overhaul interval is 20,000FC or 12 years, whichever is reached first. Given the average annual utilisation of 2,000FC, most landing gears will be removed before the 12-year calendar limit is reached. At a typical overhaul cost of $160,000 and exchange

The ERJ-145 has a simple maintenance programme and straightforward requirements, and its maintenance costs are predictable.

fee of up to $50,000, this gives a reserve of about $10 per FC *(see table, page 22)*, equal to about $8 per FH.

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 shipset of brakes is $20 per FC *(see table, page 22)*, This is equal to $16 per FH. Reserves for the wheels and tyres are $18 per FC, equal to $14.4 per FH.

There are two APU choices for the ERJ-145 family: the original Hamilton Sundstrand Model T-40C11; and the newer full authority digital engine controlled (FADEC) T-40C14. Overhaul is on an on-condition basis for both types. For the T-40C11 a typical overhaul cost would be $90,000 and a mean time between overhauls (TBO) would be 4,500 APUH. This gives a reserve of $20 per APUH *(see table, page 22)*. Assuming an APU utilisation of 0.8APUH per FH, this is equal to $18 per FH. Some operators have obtained lower hourly costs from overhaul providers.

For the newer T-40C14 model the overhaul cost will be the same but the mean TBO increases to 8,000 APUH. This gives a much lower reserve of $11.25 per APUH, although the higher figure is used in this analysis.

The installation of thrust reversers is an option on the ERJ-145 family. Many customers have chosen not to have them, and others have deactivated them because of their maintenance costs. Thrust reverser maintenance is on-condition and varies with condition and findings at removal. Although thrust reversers are intended to reduce brake overhaul costs, this is difficult to quantify. The cost of maintaining thrust reversers varies from $5 to $12 per FH.

Rotable components

The ERJ-145 has about 600 rotable part numbers installed, of which 150 are maintained on a hard-time basis, and the remainder on an on-condition basis. The number of components installed on the aircraft is about 1,300, and 900 of these are maintained on an on-condition basis. The remaining 300-400 are hard-timed components, including: hydraulic actuators and valves; pneumatic valves; fuel control units; fire extinguisher components; batteries; and emergency equipment.

Embraer has offered its 'Parts Pool Program' almost from the beginning of the ERJ-145 project. It covers a standard list of more than 500 rotable parts, with options to include larger items such as the landing gear and APU. Failed or hard-time components are removed from the aircraft by the operator and exchanged with serviceable components from Embraer. The latter then arranges for the repair, testing and return of serviceable parts to the inventory. The operator benefits from predictable costs, and avoids the burden of warranty administration and dealing with large numbers of vendors.

As of October 2008, Embraer had 28 customers for the program. Other companies have offered similar programmes, including Celsius Aviocomp (which became part of Saab Aerotech in 2006), which also acts as a supplier to Embraer's Parts Pool Program.

Actual costs for the Parts Pool Program depend on fleet size, utilisation, route network and style of operation. Typical figures would be: $125 per FH for the FH fee covering repair, transport and administration; and $10,000 per aircraft per month for the pool access fee covering the financing of the pool stock, insurance and administration. This equates to $48 per FH.

A fleet of five ERJ-145s operating 2,500FH per year is estimated to need an on-site stock inventory with a value of $1 million. The monthly lease for this stock would be $15,000 shared between the five aircraft, and equal to $15 per FH.

The total for the three elements for the complete rotable support programme will be $188 per FH *(see table, page 22)*.

Engine maintenance

The ERJ-145 family are powered exclusively by the Rolls-Royce AE3007A. There have been several stages in the development of the basic engine. The original AE3007A, with a 7,580lbs take-off rating, was upgraded early on in production to the AE3007A1/1, although both shared the same 1,690 Fahrenheit (F) inter-turbine temperature (ITT) limit and a 7,580lbs thrust take-off rating. This was superseded by the A1/2, which was followed by the definitive A1, which had an increased ITT limit of 1,738F, but again retained the same thrust rating. Both the A1/1 and A1/2 were the result of modification and upgrade programmes early on in the programme.

The first higher thrust development was the AE3007A1P, which was developed for the ERJ-145LR. This engine offered a take-off thrust of 8,338lbs, but retained the ITT limit of 1,738F. For the ERJ-145XR, Rolls-Royce developed the A1E with a further increase in the take-off rating to 8,917lbs, and an ITT limit of 1,778F. For the smaller ERJ-135, Rolls-Royce offered the A3, derated from the A, to a take-off thrust of 7,201lbs for the ERJ-135ER and the A1/3 for the ERJ-135LR, de-rated from the A1 to a take-off thrust of 7,580lbs.

AE3007 in operation

Typical removal intervals for the AE3007A family are 7,000-8,000EFH. At an annual utilisation of 2,500FH and 2,000FC, this is equal to three years' operation.

For its most recent generation of engines, Rolls-Royce has been very successful in signing up its customers for

DIRECT MAINTENANCE COSTS FOR EMBRAER ERJ-145 FAMILY

Maintenance Item	Cycle cost $	Cycle interval	Cost per FC-$	Cost per FH-$
48-hour & 14-day checks	$86,000	1 year		35
A check	34,000	2,000FH		17
Base checks	1,100,000	17,000FH		62
Landing gear	210,000	20,000FC	10	8
Wheels & brakes				30
APU				18
Thrust reversers				5-12
LRU component support				188
Total airframe & component maintenance				**363-370**
Engine maintenance: 2 X AE3007A: 2 X $119 per EFH				238
Total direct maintenance costs:				**600-610**

Annual utilisation:
2,500FH
2,000FC
FH:FC ratio of 1.25:1

its TotalCare (power-by-the-hour) programmes. Some customers have time and material agreements with Rolls-Royce.

Flybe, for example, has a fleet-hour agreement with Rolls-Royce. It is therefore up to Rolls-Royce to build the best engines, while FlyBe is not too concerned with exhaust gas temperature margins and removal intervals. The engine is removed for several reasons, and the shop visit workscope, and engine and life limited parts (LLP) management is defined by Rolls-Royce, although Flybe gets to see it. Flybe has a contractual commitment to get an on-wing interval of 7,000 engine flight hours (EFH) with an average engine flight cycle (EFC) time of 65-70 minutes.

City Airline of Sweden has a higher than average FC time of 1.7FH. Removals of earlier-built engines have been partly caused by the expiry of LLPs with shorter lives, although it aims to have an accumulated time of 20,000EFC at the engine's second removal when most LLPs expire. Most engines are removed due to LLP expiry, as is the case with bmi Regional, which operates at 1FH per FC.

In the airline business sector, 60% of Rolls-Royce engines are in TotalCare programmes, but in the regional business sector (AE3007 primarily) the total is over 95%. As a result the cost of overhauls is less important than the actual cost of being in the TotalCare programme. For a typical smaller operator operating 2,500FH and 2,000FC per year, the cost of TotalCare is likely to be $75 per EFH.

This does not include an allowance or reserve for life limited parts (LLPs).

Life limited parts

The AE3007A series has 26 different LLPs. All the current production parts have lives of 20,000EFC or 30,000EFC.

There are several different part numbers for many of the LLPs, and the earlier ones have lower life limits. This complicates LLP replacement, engine removals and reserves. There are four main groups of LLPs in: the fan rotor; the high pressure compressor (HPC) rotor; the high pressure turbine (HPT) rotor; and the low pressure turbine (LPT) rotor.

The fan rotor includes the fan disc, which has the life of original parts limited to 19,400EFC, but the latest parts have a 20,000EFC life. The forward blade retainer's life is unchanged since the beginning, and life remains at 20,000EFC. The fan drive shaft's original part numbers had a life of 20,000EFC, but latest parts have a life of 30,000EFC.

The HPC rotor has 15 parts. The original HPC-1 disc had a life limit of 12,500EFC. It was subsequently replaced by a new part number with a 20,000EFC life, and then replaced again with another part number with a 30,000EFC life. The remaining 13 HPC discs originally had lives of 20,000EFC, but all but four are now at 30,000EFC limits. The last LLP in the HPC rotor was the coneshaft, which had a target life of 20,000EFC that was reduced by an AD to as low as 2,400EFC depending on part number and engine model. It was subsequently replaced by a new part with a life of 20,000EFC, which in turn was escalated to 30,000EFC for the same part number.

The HPT rotor has had the most LLP problems. The life of the original HPT-1 disc was 8,400EFC. Later parts were increased to 20,000EFC and then 30,000EFC.

Similarly, the HPT-2 disc was initially 10,000FC, then 20,000FC and finally 30,000FC. An emergency AD issued in late 2008, relating to cracking of the HPT-2 disc, has been superseded by AD 2008-26-16.

The initial target life of 20,000FC for the HPT 1-2 Spacer was reduced by an AD to 9,800FC. It was subsequently replaced by a new part with a life of 12,900FC, which in turn was escalated to 30,000FC for the same part number.

The LPT rotor has five LLPs, all of which originally had 20,000EFC lives, but now are all at 30,000EFC. Three of the five are new parts, but two have simply had their lives extended.

These premature LLP life limits led to a large number of early engine removals. Also, while 95% of operators are in TotalCare, not all have included LLPs in their coverage (available as an option). This created a cost burden to acquire the new parts, although offset to some degree against warranty claims on the old parts.

The list price of the current production standard parts (a total of 26 part numbers and 27 parts, all of which have a life of 30,000FC, except for six part numbers) is $1.4 million. Dividing each individual part cost by its cycle life puts reserves at $50 per EFC for the full shipset. Reserves for LLP replacement depend, however, on the stub life that can be left at replacement. Since typical removal intervals of 7,000-8,000EFH are equal to 6,000EFC, LLP replacement would best take place at the third shop visit and remaining stub lives are likely to be up to 2,000EFC. Assuming the same 10% stub life across all of the LLPs, this would put reserves at $55 per EFC.

When the reserves for engine shop visit maintenance and LLPs are combined the engine's total reserves are equal to $119 per EFH *(see table, this page)*.

Maintenance cost summary

Total maintenance costs are $600-610 per FH *(see table, this page)*.

Costs can be significantly lower for the larger fleet operators, primarily because they will administer their own rotable overhaul and negotiate much lower TotalCare rates with Rolls-Royce. Total maintenance costs nearer to $550 per FH would not be impossible. AC

ERJ-145 family technical support providers

The ERJ-145 family fleet is concentrated in North America and West Europe. Consequently the bulk of technical support providers are in these two continents.

This survey summarises the major aftermarket and technical support providers for the ERJ-145 family of aircraft. It is grouped into seven sections covering the categories of technical support offered by each provider.

1. Engineering Management and Technical Support *(see table, page 24)*;
2. Line maintenance and in-service operational support *(see first table, page 25)*;
3. Base Maintenance *(see second table, page 25)*;
4. Engine Maintenance *(see first table, page 26)*;
5. Spare Engine Support *(see second table, page 26)*;
6. Rotables and Logistics *(see third table, page 26)*; and
7. Heavy Component Maintenance *(see third table, page 26)*.

Some of the technical support providers are listed in most, if not all, of the seven sections and could be termed as 'one-stop-shop' service providers for the ERJ-145 family. This means that they provide most of the technical support services that a third-party customer would require. The following tables show the range of services that these facilities offer.

As the tables show, the maintenance, repair and overhaul (MRO) and other technical support facilities are able to offer a complete range of line and base maintenance services, as well as engine and heavy component maintenance for the ERJ-145 family.

The major maintenance providers include: AAR Aircraft Services; Embraer Service Centre; ExelTech Aerospace Inc; Gameco; OGMA; and FlyBe Aviation Services. The major engine maintenance providers are Rolls-Royce and StandardAero. Due to the financial, personnel, time and tooling costs of certain specialist jobs, none of the facilities are able to offer every single listed capability, but some do come close to doing so.

By 2014, there are likely to be more than 950 ERJ-145s in operation, with potentially another 300 aircraft that are currently placed on order options. The maintenance market will need to continue at current levels and then grow by up to 25% over the next five years if this fleet expansion occurs. This figure does not even take into account the additional maintenance that will be required when the aircraft start to go beyond maintenance maturity. Many ERJ-145s will have increasing maintenance requirements over the coming years as they reach their second heavy check, and start to get beyond their second base-maintenance cycles.

The backlog of ERJ 145 family deliveries amounts to just over 50 aircraft that are destined mostly for existing operators. These therefore already have maintenance contracts in place or, if they are large operators, will have their own maintenance facilities.

There are only two new customers with confirmed orders for the ERJ-145 family: the Royal Thai Army & Navy, and Hainan Airlines in China. There are no new customers on the horizon with firm order options.

Those that were potential new customers have either ceased to operate, or have been bought out by larger airlines. An example of this is British Regional, which was purchased by FlyBe. It subsequently felt that the ERJ-145 family that it inherited from British Regional did not mix with the remainder of its fleet.

Many of the third-party facilities available around the world were once part of an airline, or are connected to, or provide support to one.

The Executive Jet model within the

The main providers of ERJ-145 maintenance and technical support are: AAR Aircraft Services, Embraer Service Center, ExelTech Aerospace Inc, OGMA, Flybe Aviation Services, and Gameco.

ERJ-135/-140/-145 ENGINEERING MANAGEMENT & TECHNICAL SUPPORT

	Outsourced engineering service	Maint records service	DOC & manuals manage	Maint prog manage	Reliability stats	AD/SB orders manage	Check planning	Config & IPC manage	Total tech support
AAR Aircraft Services	Y	Y	Y	Y	Y	Y	Y	Y	Y
Air France Industries / KLM E&M	Y	Y	Y	Y	Y	Y	Y	Y	Y
Alitalia Servizi / Atitech						Y			
Aviation Technical Services (ATS)						Y			
Embraer Service Center				Y	Y				
ExelTech Aerospace	Y	Y	Y	Y	Y	Y	Y	Y	Y
ExpressJet Services		Y							
Flybe Aviation Services	Y	Y	Y	Y	Y	Y	Y	Y	Y
Fokker Services	Y	Y	Y	Y	Y	Y	Y	Y	Y
Gameco	Y	Y	Y					Y	
Goodrich	Y	Y	Y	Y	Y	Y	Y	Y	Y
OGMA				Y		Y	Y		
Rolls Royce (engine related)		Y		Y	Y	Y	Y		Y
Sabena Technic	Y	Y	Y	Y	Y	Y	Y	Y	Y
Samco	Y	Y	Y	Y	Y	Y	Y	Y	Y
StandardAero	Y	Y		Y	Y	Y			
VLM M&E	Y	Y	Y	Y	Y	Y	Y	Y	Y

ERJ-145 family has not been considered in the data below. The market shares, as produced by Aircraft Fleet & Analytical System (ACAS), do not include the ERJ-135BJ Legacy aircraft. In addition, the geographical breakdowns are conducted according to ACAS's view of countries and their relevant world region.

Engine maintenance

The ERJ-145 family, unlike many other aircraft, only has one engine option: the Rolls-Royce (RR) AE3007A. The number of companies that offer maintenance for this engine is not that high, and engine shop facilities are even more rare *(see first table, page 26)*.

As would be expected, RR is one of the major maintenance providers for the AE3007A engine, and enjoys a market share of 40% of shop visits and engine overhauls. The majority of operators have signed engine maintenance agreements with RR.

RR has facilities around the world in Brazil, Canada and the UK (England and Scotland). Its Canadian facility is particularly prolific, taking 25% of the share on its own. This equates to 424 engines according to ACAS. Nevertheless, RR comes in second to StandardAero, which has nearly 48% of the global market. Again, one of its facilities is particularly busy: its Maryville shop, in the US, takes a huge 46% of the global market share, with 798 engines overhauled.

The only other company that figures in the engine overhaul market share breakdown is OGMA of Portugal, which has only 2% of the market. Nevertheless, it is still a third option for customers, and has overhauled over 34 engines. Any company that has overhauled fewer than 20 engines over the previous year is not mentioned, while 150 engines (over 8%) are listed as having an unknown contractor. Just over 1% of engines is up for tender.

The location and market share for engine overhauls reflects the locations of many of the operators of the ERJ-145 family. North America operates 68% of the fleet and accounts for just over 70% of engine overhauls. Europe operates 14% of the fleet and European shops overhaul nearly 15% of the engines.

There is a similar situation with the overhaul of auxiliary power units (APUs), which is offered by only a few facilities. The market is dominated by the APU manufacturer, Sundstrand, which accounts for a massive 78% of the market. The number of APUs whose maintenance is up for tender, or whose provider is unknown, amounts to 9%, while Revima APU takes nearly 8%. The remaining 5% is shared between StandardAero (Maryville), Honeywell and Empire Aero Center.

Base maintenance

Nearly 70% of base maintenance checks (accounting for 596 aircraft) are carried out in-house. Just over 2% are performed by an unknown contractor, which leaves 28% for third-party facilities.

ExelTech Aerospace in Canada is the largest of these remaining facilities with 10.5% of the C and heavy check market share. AAR Aircraft Services and OGMA are the next largest facilities, each with 4% of the market. Gameco in China has just 2.21%, but this could be due to the current low numbers of the ERJ-145 family being operated in China. These are due to rise in the next few years, however, so Gameco's share may increase accordingly.

Embraer Service Center undertakes a surprisingly small number of C and heavy checks, with only just over 1.5% of the market.

The remaining market is divided between five European facilities, at least three of which can be also classed as in-house providers. Regional (France), FlyBe Aviation Services (UK), LOT Polish Airlines (Poland), Lufthansa Technik (Switzerland) and Pan Europeenne Air Service (France) all share the last 5.5%, in that order.

Asia Pacific

As Asia, or more precisely the Indian sub-continent, does not operate any of the commercial models within the ERJ 145 family, there are no maintenance facilities offering third-party work on the aircraft in the area.

The Asia Pacific, however, has a fleet of 35 aircraft, 31 of which are in China, with the remainder in Thailand and Australia. The only major MRO facility in the area seems to be Gameco in China, which is ideally placed for the additional 40 aircraft that are on order and due to be delivered to China over the next few years. Additionally, ST Aerospace and its subsidiaries are capable of offering some base and light maintenance.

North and South America

The vast majority of maintenance for

ERJ-135/-140/-145 LINE & LIGHT MAINTENANCE SUPPORT

	Maint operations control	AOG support	Line checks	A checks	Engine QEC changes	Engine changes	Landing gear changes	APU changes	Thrust reverser changes
AAR Aircraft Services	Y	Y	Y	Y	Y	Y	Y	Y	Y
Air France Industries / KLM E&M	Y	Y	Y	Y	Y	Y	Y	Y	Y
Alitalia Servizi / Atitech			Y	Y					
Aviation Technical Services (ATS)				Y					
AvMax Group				Y					
Cirrus Technik				Y					
ExelTech Aerospace	Y	Y	Y	Y	Y	Y	Y	Y	Y
ExpressJet Services			Y	Y					
Flybe Aviation Services	Y	Y	Y	Y	Y	Y	Y	Y	Y
Fokker Services			Y	Y	Y	Y	Y	Y	Y
Gameco	Y	Y	Y	Y	Y	Y	Y	Y	Y
Goodrich	Y	Y							
OGMA	Y	Y	Y	Y	Y	Y	Y	Y	Y
Sabena Technics	Y	Y	Y	Y	Y	Y	Y	Y	Y
Samco	Y	Y	Y	Y	Y	Y	Y	Y	Y
ST Aerospace				Y	Y	Y	Y	Y	Y
StandardAero		Y			Y	Y			
VLM M & E		Y	Y	Y	Y	Y	Y	Y	Y

ERJ-135/-140/-145 BASE MAINTENANCE SUPPORT

	C checks	IL &D checks	Composites	Strip/ paint	Interior refurb
AAR Aircraft Services	Y	Y	Y	Y	Y
Air France Industries / KLM E&M	Y	Y	Y	Y	Y
Alitalia Servizi / Atitech	Y	Y	Y	Y	Y
Aviation Technical services (ATS)	Y	Y	Y	Y	
AvMax Group	Y	Y			
Cirrus Technik	Y	Y			
ExelTech Aerospace	Y	Y	Y		Y
ExpressJet Services	Y	Y	Y	Y	Y
Field Aviation	Y	Y	Y	Y	Y
Flybe Aviation Services	Y	Y	Y	Y	Y
Fokker Services	Y	Y	Y	Y	Y
Gameco	Y	Y	Y	Y	Y
Gameco	Y	Y	Y	Y	Y
OGMA	Y	Y	Y	Y	Some
Sabena	Y	Y	Y	Y	Y
Samco	Y	Y	Y	Y	Y
ST Aerospace	Y	Y	Y	Y	Y
VLM M&E	Y	Y	Y	Y	Y

the ERJ-145 family is carried out in North America. This is undoubtedly due to the fact that nearly 70% of all the ERJ-145s in operation are with North American airlines.

The majority of maintenance facilities in North and South America seem to be independent MRO companies, with only a few facilities being connected to airlines. The airlines that deal with their maintenance in-house, but that also have third-party facilities, are really only ExpressJet and Trans States Airlines. These two airlines alone account for 34% of the global fleet.

The major facilities in North America that are not connected to an airline are those of AAR Aircraft Services and ExelTech Aerospace. The major facilities in South America are the Embraer Service Center and VEM Maintenance & Engineering. In addition, there are the APU and engine facilities of Sundstrand Power Systems (APIC), RR and StandardAero, as well as other smaller providers.

While there are a few major MRO facilities in America that carry out the majority of the global requirements for the ERJ 145 family, there are also many smaller specialist companies, which concentrate on the small areas of maintenance, such as bearings, smaller engine parts, wheels and airframe parts, that the larger companies lack the time or tooling to carry out. The MROs will, where necessary, sub-contract some of their work to these specialist companies in order to ensure that all necessary work is carried out to a high standard and on time. Such specialist firms include: Hawker Pacific, which carries out landing gear maintenance; and Chromalloy, which offers engine maintenance management and a parts repair scheme. There are many component and composite support companies in America. In addition there are very large global companies, such as Goodrich, which specialise in rotables and logistics. Their size means that they are also in a position to offer operators additional services, such as engineering management and technical support.

Europe

The second largest operation of the ERJ-145 family is in Europe, and this is true also of the maintenance locations. The companies that offer third-party maintenance for European aircraft are mostly based in Western Europe, and are split evenly between airline maintenance divisions and independent MROs.

The facilities that are connected to current operators are: Alitalia

ERJ-135/-140/-145 ENGINE MAINTENANCE - AE3007A

	Engine health monitor	Engine maint manage	On-wing engine maint	Engine shop visits	Parts repair schemes
AAR Aircraft Services	Y		Y		
Air France Industries / KLM E&M			Y		
ExelTech Aerospace			Y		
Flybe Aviation Services		Y	Y		
Gameco	Y	Y	Y		Y
Goodrich			Y		Y
OGMA	Y	Y	Y	Y	Y
Rolls Royce	Y	Y	Y	Y	Y
Samco	Y	Y	Y		
StandardAero		Y	Y	Y	Y

ERJ-135/-140/-145 SPARE ENGINE SUPPORT

	On-wing support	AOG services	Short-term leases	Med/long-term leases	Engine pooling
Air France Industries / KLM E&M	Y	Y			
ExelTech Aerospace			Y		
Flybe Aviation Services	Y	Y			
Gameco	Y	Y	Y	Y	Y
OGMA	Y	Y			
Samco	Y	Y			
StandardAero		Y			
Rolls Royce	Y	Y	Y	Y	Y

ERJ-135/-140/-145 ROTABLES & LOGISTICS SUPPORT

	Rotable inventory leasing	Rotable inventory pooling	Repair & doc manage	AOG support	PBH rotables support
AAR Aircraft Services	Y	Y	Y	Y	Y
AvMax Group	Y	Y	Y	Y	
ExelTech Aerospace				Y	
Flybe Aviation Services	Y	Y	Y	Y	Can do
Fokker Services	On system level	On system level	Y	Y	On system level
Gameco			Y	Y	
Goodrich	Y	Y	Y	Y	Y
OGMA			Y		
Rolls Royce (engine relates)	Y	Y	Y	Y	Y
Sabena	Y	Y	Y	Y	Y
Samco			Y	Y	
Turner Aviation	Y	Y	Y	Y	
VLM	Y	Y	Y	Y	Y

ERJ-135/-140/-145 HEAVY COMPONENT MAINTENANCE

	Wheels tyres & brakes	APU test & repair	Thrust reversers	Landing gear	Landing gear exchanges
AAR Aircraft Services	Y			Y	Y
Air France Industries / KLM E&M	Y			Y	
Alitalia Servizi / Atitech	Y				
Cirrus Technik	Y				
ExpressJet Services			Y		
Flybe Aviation Services	Y		Y		
Fokker Services	dormant		dormant	dormant	
Gameco	Y				Y
Goodrich				Y	Y
Hawker Pacific				Y	ERJ 145 -ER & -LR only
OGMA	Y			Y	Y
Revima APU		Y			
Sabena	Y	Y	Y	Y	Y
Samco	Y				Y
Sundstrand Power Systems (APIC)		Y			
VLM	Y	Y	Y	Y	Y

Servizi/Atitech; FlyBe Aviation Services; LOT Polish Airlines; Luxair, Pan Europeenne Air Service; Regional; and Swiss.

Independent MRO facilities in Europe can be found with: Cirrus Technik; Fokker Services Woensdrecht; KLM UK Engineering; Nayak Aircraft Services; OGMA; RR; Sabena Technics; SAMCO Aircraft Maintenance; and Lufthansa Technik Switzerland.

Many of these companies started life as airline engineering departments, but now they are independently operated, stand-alone companies. In addition, companies such as SAMCO, Sabena Technics and FlyBe Aviation Services can offer nearly all maintenance requirements, with the exception of those specialist jobs such as engine maintenance, engine leasing and some heavy component repair and overhaul. OGMA and RR are specialists in engine work, as previously mentioned. Smaller companies may specialise in Europe too. An example is Turner Aviation, which carries out overhaul, modification and repair of aircraft components, systems and avionics.

Those countries that operate the aircraft are well supported with maintenance companies. In fact, there is probably a greater choice of maintenance provider for the ERJ-145 family in Europe than in North and South America, even though the majority of work is completed in America.

Middle East and Africa

Like Asia, the Middle East has no commercial models of the ERJ-145 in operation. Even though the Executive variants are operated there, there are nevertheless no major maintenance facilities in the Middle East for the ERJ-145 family.

Africa has 11 aircraft actively operated, but there are no major maintenance companies offering support in the area.

South African Airlink, which operates five ERJ-135s, does much of its own maintenance in-house, but all its engine shop work is completed by RR's UK facility.

If an aircraft encounters problems in areas that have no maintenance cover, such as Asia, Africa, or the Middle East, many of the major global MROs would be able to assist the operator by sending out the relevant personnel and parts. Airlines with their own maintenance department would also be able to do this, if not already partly done, to cover their network. AC

ERJ-135/-145 aftermarket & values

The ERJ-135/-140/-145 fleet is now mature, and first-tier operators have begun to phase the aircraft out of service. The used market for ERJ-145 family aircraft has begun to become active in recent years. Probable large fleet reductions by American Eagle or ExpressJet will saturate the market.

The Embraer ERJ-145 was the first aircraft in a family of 37-50-seat regional jets. The ERJ-145 accounts for most of the fleet, while its smaller derivatives, the ERJ-135 and ERJ-140, are niche aircraft, developed almost solely to bypass the scope-clause restrictions imposed on the major US operators.

The definitive Embraer ERJ-145 was launched in 1992. In September 1996 Continental Express ordered 25 aircraft plus 175 options. A total of 275 aircraft (245 ERJ-145s and 30 ERJ-135s) were delivered to Continental Express, which later became ExpressJet.

Despite the order from Continental Express and later commitments from American Eagle, most of the US market had already been captured by Bombardier's CRJ.

Embraer won orders from Chautauqua Airlines, Mesa Airlines and Trans States Airlines. Limited opportunities in the US spurred Embraer on to other markets. Nearly all the major European airlines that ordered 50-seat regional jets from 1997 onwards selected the ERJ-145. These included Alitalia, British Midland, British Regional Airlines, Brymon, Crossair, LOT Polish Airlines, Luxair and PGA - Portugalia.

Despite the emphasis on markets outside the US, Embraer also launched two derivatives dedicated to circumventing the scope clause restrictions faced by its two major customers, American Eagle and Continental Express. The 37-seat ERJ-135 was launched in 1997, and the 44-seat ERJ-140 in 1999.

The ERJ-135 had some limited success in developing a market for 30-seat jets and a total of 122 were built (excluding Legacy business jet derivatives) compared with 687 ERJ-145s. The Embraer ERJ-140 was less successful with only 74 built, all for operation either with or on behalf of American Eagle.

ERJ-145

Of the 687 ERJ-145s delivered from the Embraer production line (excluding two undelivered prototypes), 594 or 86% remain with their original operators. These same operators have added another 45 aircraft, or 7% of the total, from the used market. Trading of the remaining 7% has been fairly consistent over the past 10 years, with a fairly limited supply of aircraft balanced by equally limited demand.

The ERJ-145 has been fortunate in that none of the big US fleets, which account for over 70% of the total fleet, have come on to market. The biggest threat to this stability was the prospect of a large proportion of ExpressJet's fleet (the world's largest ERJ-145 operator with 244 aircraft or 35% of the total) coming available. In December 2005 Continental announced that it would be withdrawing 69 of the ERJ-145s flown by ExpressJet under its capacity purchase agreement with ExpressJet. ExpressJet, which leases all its aircraft from Continental, chose to retain the aircraft and find them new applications. ExpressJet began its own scheduled operation, ExpressJet Airlines, and dedicated part of its fleet to developing a charter business. It also agreed to fly 10 aircraft for Delta Air Lines.

In June 2008 Continental and ExpressJet reached agreement on a new seven-year capacity purchase agreement. This resulted in the return of 39 of the 69 ERJ-145s to Continental's operations, as well as the withdrawal of the 30-strong ERJ-135 fleet. In return, ExpressJet accepted a reduction in the block-hour rates that it charged Continental. The rentals on the balance of 30 ERJ-145s that were operated at ExpressJet's own risk were reduced and they were all dedicated to charter operations.

All independent scheduled flying and the operations for Delta ceased in September 2008.

The second largest fleet belongs to American Eagle. In May 2008 the airline announced plans to withdraw 35-40 unspecified regional jets, as well as its Saab 340 fleet. In July 2008 the airline wrote down the value of its ERJ-135 fleet, and it appears safe to assume that the 39 ERJ-135s will be disposed of and that the ERJ-145 fleet is relatively secure.

Chautauqua Airlines operates the third largest fleet of 62 aircraft, all of which are in active service.

The fourth largest operator Trans States began a gradual reduction of its fleet during 2008. Five aircraft have been returned to lessor GECAS and placed with Aerolitoral, while at least three more are being returned to ECC Leasing.

Mesa Airlines, the smallest of the US fleet operators, has not been so fortunate. In March 2008 Delta Air Lines terminated its contract with the Mesa subsidiary Freedom Airlines for the operation of 34 ERJ-145s, claiming that the operator was not meeting specified completion rates. In May 2008, Mesa won a preliminary injunction preventing Delta from terminating the contract and the aircraft are currently in operation pending Delta's appeal. Prior to winning its successful injunction, Mesa stated publicly that the loss of Delta's business would force it into Chapter 11 bankruptcy protection.

The biggest players in the ERJ-145 market are ECC Leasing and GECAS. ECC Leasing is a 100%-owned subsidiary of Embraer, dedicated to managing the manufacturer's portfolio of used aircraft. These are typically early deliveries financed by BNDES, the National Development Bank of Brazil, or aircraft that have been taken back by Embraer in trade against new aircraft.

GECAS acquired a large ERJ-145 portfolio by buying aircraft with leases attached. Since the original leases are coming to an end, it is becoming increasingly involved in the used market.

Apart from these two organisations, two UK companies, Airstream International and Skyways Aviation, have been involved in the majority of the remaining ERJ-135 and ERJ-145 transactions. The largest single fleet of aircraft to become available was Flybe's. It acquired a fleet of 28 with its acquisition of BA Connect from British Airways in March 2007. Of these, 16 aircraft were owned and 12 were leased. Nine were leased from RBS and three from ECC Leasing. A deal was struck with Universal Asset Management of the USA to acquire the 16 owned aircraft under a sale and leaseback structure. Aircraft Solutions is the company that has been set up to manage these 16 aircraft.

Aircraft Solutions and its marketing agent Airstream have sold four aircraft to

The biggest threat to the ERJ-145's market stability is a retirement of some of ExpressJet's fleet. The airline is the single-largest operator of ERJ-145s, with 244 aircraft.

Dniproavia of the Ukraine. They have leased four to the start-up airline Athens Airways of Greece, and one aircraft each to Andalus Lineas Aereas of Spain and bmi Regional of the UK. Similarly, RBS has so far placed five of its nine aircraft with Dniproavia, while ECC Leasing has leased two of its three, also to Dniproavia. This leaves a total of 11 Flybe aircraft to be placed. The airline has announced plans to retire its last ERJ-145 in October 2009.

ERJ-145 owners are fortunate that three operators have taken most of the used aircraft that have come on to the market. Aerolitoral of Mexico, operating as Aeromexico Connect, took delivery of five aircraft direct from the factory, but it has now built its fleet up to 33 by taking aircraft from the used market. It has leased aircraft from a wide variety of sources, including Chautauqua Airlines, ECC Leasing, GECAS, RBS and Swiss.

Dniproavia has acquired 11 former Flybe aircraft, four from Aircraft Solutions, two from ECC Leasing and five from RBS. On a smaller scale bmi Regional has steadily expanded its fleet to the current total of 14, plus four ERJ-135s.

As a result of the fairly even balance between supply and demand for the type, pricing and lease rates have been reasonably steady. There has been a slow decline over the years but nothing particularly dramatic. Most recent sales activity has been for early generation EU/EP variants, and has seen pricing of $9-10 million. Lease rates have recently dipped below the $100,000 level for the first time.

How long this situation will continue depends on whether demand continues to match supply. Certainly more aircraft are likely to come on to the market in the near future. There are the 11 remaining Flybe aircraft that will become available during 2009. In December 2008 Alitalia announced that it is selling its entire fleet of 14 ERJ-145s, while the continued operation of the 34-strong fleet at Mesa is still subject to the legal appeal from Delta Air Lines.

ERJ-135

Nearly all airline sales were to existing ERJ-145 operators, although the type also found a niche as a corporate/government shuttle. Of the 122 ERJ-135s delivered, 116 remain with their original operators. The three largest customers were all in the US. These are American Eagle (40), Continental Express/ExpressJet (30) and Chautauqua Airlines (15). There are also small European fleets.

Trading of the ERJ-135 has clearly been quite limited, but five transactions took place in 2008. In January bmi Regional added to its fleet by purchasing a single aircraft originally delivered to failed operator JetMagic. In June, Chautauqua Airlines sold two aircraft to Aircraft Leasing Services of Kenya. Two aircraft returned to ECC Leasing by Chautauqua Airlines in July were subsequently sold on to the Brazilian Air Force.

Despite the apparent rise in activity, the outlook for the type seems doubtful following decisions by all three of the large US operators to phase it out. The largest fleet belongs to American Eagle, which in May 2008 announced plans to withdraw 35-40 unspecified regional jets. In July 2008 the airline wrote down the book value of its ERJ-135 fleet, and it appears reasonable to assume that it will dispose of the 39 ERJ-135s. The June 2008 agreement between the second largest operator ExpressJet and Continental has allowed the return of 39 ERJ-145s to Continental's service, but the entire fleet of 30 ERJ-135s is being withdrawn.

Disposals from the third US fleet operator, Chautauqua Airlines, have been more active. An amended contract with Delta Air Lines is phasing out the operation of 15 ERJ-135s from September 2008 at a rate of two aircraft per month.

Compared with the more active ERJ-145 market, it is difficult to establish market pricing and lease rates for the ERJ-135. The few transactions that have taken place have mainly been sales to non-airline operators. Recent pricing for outright sales has been quoted as high as $10 million. With the prospect of the number of stored aircraft outnumbering the active fleet by 2:1, however, pricing at such levels is unlikely to be seen again.

ERJ-140

The third and final ERJ-145 family variant was the ERJ-140, which was developed specifically to circumvent the scope clause restrictions at American Eagle. Only two customers took delivery of this variant: American Eagle (59) and Chautauqua Airlines (15), which has operated the aircraft under contract to American since they were delivered.

Although American has announced that it will be retiring 35-40 regional jets in May 2009, these will almost certainly be ERJ-135s so the future of the ERJ-140s appears secure for now. In October 2008 Chautauqua Airlines agreed a new ERJ-140 contract with American that will see the fleet reduced to 13 from June 2009. The two remaining aircraft will continue to be paid for by American as spare aircraft.

Clearly pricing and lease rates for this variant are academic given the limited market. AC