OWNER'S & OPERATOR'S GUIDE: E-JET FAMILY

E-Jet family specifications

There are 12 variants of the E-170/-175 and E-190/-195 models available, powered by two main variants of the CF-34. Their specifications are analysed.

The E-170, E-175, E-190 and E-195 are all members of the E-Jet family. Designed from the outset for the regional jet (RJ) market, the four family members provide 70 to 122 seats, with actual numbers depending on cabin configuration. The family is intended to fill the gap between 50-seat RJs and the smallest jetliners, in order to provide airlines with capacity on RJ routes that needed more capacity, or smaller aircraft on jetliner routes at an economic level. The E-Jets family is the first of new generation large RJs or 'right-sized' jets.

The E-Jets have up to 95% commonality in parts and systems across the four main types to reduce rotable inventories and maintenance costs. The flightdeck has 100% commonality for the four models, so they all have cross-crew-qualification, thereby providing flexibility in fleet planning, since additions to the fleet will incur relatively few costs.

The E-Jet family is sub-divided into the E-170/-175 and E-190/-195, with the aircraft being certified as two main types and each with two variants. The smaller E-170/-175 are powered by the CF34-8E engine rated at 14,500lbs thrust, while the larger E-190/-195 are powered by the CF34-10E rated at 18,500lbs thrust *(see table, page 7)*. The -10E has a one-inch wider intake fan than the -8E, and also a three-stage low pressure compressor.

Being certified as two main types means that the E-170/-175 and E-190/-195 each have their own maintenance programmes. The two programmes have a high degree of similarity, however.

Basic features

The E-Jet family was launched in 1999, with the E-170 entering service in the first quarter of 2004. The design efficiencies promised 30% more payload per pound of structural weight compared to similar-sized aircraft.

The E-175 first flew in 2003, with the first delivery made in July 2005 to Air Canada.

The E-170/-175 were followed by the longer E-190/-195 models, which have a larger wing and higher-rated engines.

The E-190 entered service in September 2005 with jetBlue, and the E-195 entered service in December 2006 with Flybe.

Each of the four main E-Jet family models has three variants: the standard (STD); long-range (LR); and advanced range (AR). The AR variant was first introduced on the E-190/-195, and has structural reinforcements that provide greater payload-range performance. The AR changes are now offered on the E-170/-175, with some 2008-built -175LR's being delivered structurally ready for conversion to AR variants in 2009.

The maximum cruise speed for all models is 481kts or Mach 0.82 *(see table, page 7)*. The range varies from 1,700nm to 2,400nm, with the payload increasing from 20,062lbs on the E-170 to 30,093lbs on the E-195. The E-170 and E-175 share the same fuel capacity, as do the E-190/-195 models.

Embraer comments that, although the fuel capacity is the same within each model, the range differs due to higher maximum take-off weight (MTOW). The AR models also have a higher maximum zero fuel weight (MZFW) and slightly higher operating empty weight (OEW).

The E-170/-175 have three payload variants, while the E-190/-195 variants have constant payload *(see table, page 7)*. The cargo capacity in two belly holds also increases from 508.18 cubic feet to 906.17 cubic feet.

Passenger comfort is aided by Embraer's double-bubble fuselage design that promises an increased cabin width at passengers' elbows and shoulders, large cabin windows, and a high cabin ceiling. The aircraft is also configured in a four-abreast seat arrangement, which is popular with passengers. It also aids fast passenger loading and unloading.

In terms of seat capacity, the E-170 carries 70 to 80 passengers, the E-175 carries 78 to 88, the E-190 carries 98 to 114 seats, and the E-195 carries 108 to 122.

Actual seat numbers depend on an operator's seat pitch and other cabin configurations, such as number and size of wardrobes, toilets and galleys.

Time on the ground for any aircraft is wasted money for an operator, so the E-Jets are equipped with integral airstairs at the forward passenger door to aid fast

The four members of the E-Jets family have fly-by-wire flight control systems and identical flightdecks, giving them qualification.

E-JETS SPECIFICATIONS

Aircraft	Engine	Take-off thrust -lbs	MTOW -lbs	MLW -lbs	Maximum payload -lbs	Fuel capacity -lbs	Seats	Range with full payload & LRC -nm	Cargo volume -cu.ft.
E-170 STD	CF34-8E	14,200	79,344	72,310	20,062	20,580	70-80	1,800	508.18
E-170 LR	CF34-8E	14,200	82,011	72,310	20,062	20,580	70-80	2,000	508.18
E-170 AR	CF34-8E	14,200	85,098	73,414	21,693	20,580	70-80	2,100	508.18
E-175 STD	CF34-8E	14,200	82,673	74,957	22,223	20,580	78-88	1,700	604.59
E-175 LR	CF34-8E	14,200	85,517	74,957	22,223	20,580	78-88	1,900	604.59
E-175 AR	CF34-8E	14,200	89,000	75,178	22,840	20,580	78-88	2,000	604.59
E-190 STD	CF34-10E	20,000	105,358	94,798	28,836	28,596	98-114	1,800	799.18
E-190 LR	CF34-10E	20,000	110,892	94,798	28,836	28,596	98-114	2,300	799.18
E-190 AR	CF34-10E	20,000	114,199	97,003	28,836	28,596	98-114	2,400	799.18
E-195 STD	CF34-10E	20,000	107,563	99,208	30,093	28,596	108-122	1,500	906.17
E-195 LR	CF34-10E	20,000	111,972	99,208	30,093	28,596	108-122	1,900	906.17
E-195 AR	CF34-10E	20,000	115,279	100,971	30,093	28,596	108-122	2,200	906.17

turnaround times. This can potentially cut five minutes off turnaround time compared to using an air jetty or ground steps.

The various efficiencies mean that turnaround is expected to take an average of 20 minutes. The boarding process is further assisted by the larger overhead lockers that give, on average, 1.75-2.0 cubic feet of stowage space per passenger. This equates to an increase of up to 0.5 cubic feet (or up to 28%) per seat, compared to that available on each of the E-Jet's equivalent-sized competitors. In particular, the E-190 and E-195 models have stowage space equal to, or better than, older Boeing and Airbus aircraft that are similar, or slightly larger, in size. The cabin, seat and aisle width, and cabin height are all some of the largest available for this size of aircraft, if not the widest of all narrowbodies in some cases.

The E-170/-175 have no overwing exits, which allows more cabin configuration options. Due to the size of the E-190/-195, however, there is a need for two overwing exits. All variants have two full-size passenger-entry doors forward and aft on the port side, and two service doors forward and aft on the starboard side. Doors forward and aft of the cabin can speed up turnaround time.

The E-Jet family has many of the advantages of modern mainline jets. This includes a cruising altitude of 41,000ft, full authority digital engine controls (FADEC), and a fly-by-wire flight control system. The flightdecks of all variants are fully equipped with Honeywell Primus Epic digital avionics and a Dark & Quiet cockpit environment to improve awareness and reduce pilot workloads. The E-Jets will also have an onboard central maintenance computer, which reduces line maintenance costs compared to similar-sized aircraft.

CF34-8E & -10E THRUST RATINGS

Thrust ratings	-8E5	-8E5A1	-10E5	-10E5A1	-10E6	-10E6A1	-10E7
Max take-off	14,510	-	18,820	-	-	-	20,360
Normal take-off	13,420	14,050	17,390	18,820	17,390	18,820	18,820
Max continuous	13,520	-	17,040	-	-	-	-
Take-off flat rating deg C	30	-	30	-	35	-	30
Max temperatures - deg C							
Max take-off	1,006	-	983	-	-	-	-
Normal take-off	965	989	945	983	947	983	943
Max continuous	960	-	960	-	-	-	-

The E-190/-195 will find competition in the spacious Bombardier C Series from 2013, and the Bombardier CRJ-1000 from late 2009. The smaller E-170/-175 will shortly be competing with newer RJs and right-sized jets from Mitsubishi and Sukhoi, which promise more spacious cabins. The E-170/-175 also compete with the older CRJ-700 and -900 models.

The E-Jets, however, are the only family that offer a full range of four models covering 70-120 seats. They are also the first of the new generation of RJs to be in operation and, because they have many of the technological advances of larger aircraft, they are already one of the few aircraft certified to fly into difficult airports such as London City Airport.

Environmentally, the E-Jet is fully compliant with all noise regulations, as well as CAEP/6 gaseous emissions. The margins to CAEP/6 are particularly good on the E-170/-175, ranging from 26.4-97.6% for unburned hydrocarbons, carbon dioxide, nitrous oxides and smoke emissions.

There is a business-jet version based on the E-190, called the Embraer Lineage 1000, which has an extended range and executive seating for 19.

The 12 main airline variants are examined in this guide.

E-170

The E-170 entered service with LOT Polish Airlines in 2005. The STD variant has an MTOW of 79,344lbs, the LR an MTOW of 82,011lbs, and the AR an MTOW of 85,098lbs *(see table, this page)*. While the STD and LR are currently in operation, the AR is not due to be delivered until late 2009/2010. An additional variant, which has the same specifications as other E-170s, but also an increased MTOW of 101,389lbs, will be designated SR as a short-runway variant. This variant is due to be delivered to British Airways CityFlyer in September 2009.

The E-170 will have a maximum fuel capacity of 20,580lbs, which produces a range of 1,800nm on the STD, 2,000nm on the LR and 2,100nm on the AR. This is the case when the aircraft are flown at long-range cruise speed (LRC) and with a full payload.

The E-170, like all of the E-175

The E-Jets provide a combination of attractive cabin layout, short take-off performance and adequate range capability to meet most operator's short- & medium-haul requirements.

variants, is equipped with the CF34-8E rated at 14,500lbs of thrust and has a bypass ratio of 5:1.

In a single-class layout, the E-170 can seat 70 passengers with a 32-inch pitch, 78 passengers with a 31-inch pitch, and 80 with a 29-30-inch pitch. One dual-class configuration can accommodate six first- or business-class seats with a 36-inch pitch and 64 economy seats with a 32-inch pitch, making a total of 70 seats.

Cabin configurations vary according to operator. There is the option of having two galleys, with one at the front and one at the rear, or having one galley at the rear only. There are two toilets, one at the front and one at the rear with the optional addition of one wardrobe. This would be an essential addition for operators that regularly transport business travellers who require space to hang their suit jackets, as a matter of course.

E-175

The E-175 was certified in late 2004, and Air Canada served as the launch customer in 2005. The AR variant recently entered service with some converted from LRs, and some directly from the factory. Although no STD models are in current operation, the STD has an MTOW of 82,673lbs while the LR has an MTOW of 85,517lbs and the AR an MTOW of 89,000lbs *(see table, page 7)*. The maximum fuel capacity is again 20,580lbs with the operating range, under the same conditions as for the E-170, standing at 1,700nm for the STD, 1,900nm for the LR and 2,000nm for the AR. This is a slightly shorter range compared to the E-170, due to an increase in payload and MTOW. The E-175 has the same engine variant as the E-170, which produces the same thrust but with higher MTOW, maximum landing weight (MLW) and maximum payload.

In a single-class layout, the E-175 can carry 78 passengers with a 32-inch pitch, 86 passengers with a 31-inch pitch, and 88 with a 30-inch pitch. A possible dual-class configuration could accommodate six first- or business-class seats with a 38-inch pitch and 72 economy seats with a 31-inch pitch, making a total of 78 seats. Apart from the length, and therefore the additional passenger capacity, the cabin interior is exactly the same as for the E-170.

E-190

JetBlue was the launch customer for the E-190 in 2005 after it was certified in August 2005. Only the LR and AR variants are currently operated, with the AR being the launch customer for the E-190 generally. The MTOW for the STD model is 105,358lbs, while the LR and AR have MTOWs of 110,892lbs and 114,199lbs respectively. This equates to at least a third extra capability compared to the E-170, which is also true for the take-off thrust, MLW, maximum payload and fuel capacity. This is required when it is considered that the E-190 carries at least a third more extra passengers in all configuration options.

The maximum fuel capacity is 28,596lbs, which equates to ranges of 1,800nm, 2,300nm and 2,401nm for the STD, LR and AR *(see table, page 7)*. The range again is calculated with LRC speed and a full payload. This would mean that the E-190 not only carries more passengers, but that the LR and AR can also fly further than the smaller E-170/-175.

The E-190 is powered by a more powerful version of the engine on the E-170. This is the CF34-10E with a take-off thrust rating of 18,500lbs, and a bypass ratio of 5.4:1.

In a single-class configuration, the E-190 can accommodate 98 passengers with a 32- to 33-inch seat pitch, 106 with a 31- to 32-inch seat pitch, and 114 with a 29- to 30-inch seat pitch. If a two-class configuration is required, one option is for eight premium seats with a 38-inch pitch and 86 economy seats with a 31-inch pitch, which totals 94. The E-190 is again very similar to the standard layout of the E-170, but with the addition of more fuselage length, and two overwing exits mid-cabin. A third cabin-crew member would need to be carried in most layouts.

E-195

The E-195 was certified in June 2006 and launched by Flybe. Only the AR and LR variants are currently operated. The MTOW for the STD is 107,563lbs, and 111,972lbs for the LR. The AR's MTOW is 115,279lbs *(see table, page 7)*. The maximum payload is 30,093lbs, with the fuel capacity the same as the E-190's. This results in lower LRC ranges than the E-190, with the STD variant reaching just 1,500nm. The LR has a range of 1,900nm (same as the E-175LR), and the AR can fly for 2,200nm. The engine is the same as on the E-190 and with the same take-off thrust. The cargo capacity is increased to just over 906 cubic feet, which Embraer believes to be more per passenger than available with the 737-600 and A318.

In a one-class layout the E-195 can seat 108 passengers with a 32- to 33-inch pitch, 118 with 31-inch pitch and 122 seats in a high-density layout with 30- to 31-inch pitch. A possible two-class layout could involve eight premium seats with a 38-inch pitch, and 98 economy seats with a 31-inch pitch, making a total of 106 passengers. As expected, the E-195 cabin layout is the same as the E-190, but with additional length. The additional length accommodates a third cabin-crew jumpseat, the option of a second wardrobe and extra passenger seats. AC

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E-Jets fleet summary

The E-Jets family is divided into four main types, of which there are over 500 in operation. The fleet demographics are reviewed.

There are 540 E-Jets in airline operation. The business-jet version, the E-190 Lineage 1000, is not analysed here.

Due to the young age of the aircraft, most E-Jets are still flown by their original operators, or their subsidiaries. Only two aircraft are parked: an E-190LR with Aerorepublica; and an E-170LR with GECAS.

The E-Jets were all launched in June 1999. The first model, the E-170, was delivered to LOT Polish Airlines in March 2005. The launch customer was to be Crossair in Switzerland but, due to re-branding and its acquisition of the collapsed Swiss national airline, this did not happen. The E-175 entered service later in 2005 with Air Canada, and two months later the E-190 entered service with jetBlue Airways. Both airlines remain two of the largest E-Jet operators. The first E-195 was delivered to Flybe in December 2006.

According to the Aircraft Fleet & Analytical System (ACAS), the 540 aircraft in commercial service comprise: 158 E-170s, 119 E-175s, 225 E-190s and 38 E-195s. The E-190 is the most popular model, accounting for 42% of the E-Jets in operation. The E-170 and E-175 account for 29% and 22% respectively, while the E-195 is just 7% of the fleet.

The breakdown of all the E-Jet variants and their general global location *(see table, page 10)* shows that they are particularly popular in North America, which has 54% of the fleet, since they can be used as feeder aircraft to link all the major carriers' hubs. Many of the E-Jet operators are regional feeder and subsidiary airlines of US majors.

There are 46 operators, including: Republic Airlines (71 aircraft), Shuttle America (61), Air Canada (60), jetBlue (38), Compass Airlines (36), US Airways (25), Finnair (20), Virgin Blue Airlines (19) and LOT Polish Airlines (16), COPA Airlines (15), Saudi Arabian Airlines (15), Flybe (14), Aerorepublica (12), Regional (12), EgyptAir Express (11), Azul Linhas Aereas (10) and Grand China Express Air (10). The remaining 29 operators all have fewer than 10 aircraft each.

Air Canada, Azul Linhas Aereas, Cirrus, Finnair, LOT Polish Airlines, nas air, Paramount Airways (India), Regional, Republic Airlines, Royal Jordanian, Shuttle America, TAME and Virgin Blue Airlines all operate more than one type of E-Jet. This allows them to swap aircraft within the schedule and route network, depending on passenger demand, and avoid the cost of maintaining more than one pilot pool.

Fleet forecast

In addition to the 540 aircraft in operation, there is an order backlog for 345 aircraft and options for 313. The majority of backlog aircraft will be delivered over the next three years, with 80 in 2009 and 110 in 2010.

Customers awaiting delivery of large numbers of aircraft are Aeromexico (with a backlog of 7), the Air France Group for KLM Cityhopper and Regional (15), Azul Linhas Aereas (30), British Airways (BA) for BA CityFlyer (11), Air Europa (7), J-Air (8), jetBlue (63), LOT Polish Airlines (12), Baboo (5), nas air (10), Virgin Blue Airlines (5), and Virgin Nigeria (9).

New customers awaiting delivery of the E-Jets include Brazil Rodo Aereo (20), Star Aviation (7), Hainan Airlines (40), Jetscape (8), Lufthansa (25), TACA International Airlines (6), TRIP (5) and US Airways (17).

jetBlue has the largest number of options, with 99, (although this is currently up for discussion), followed by Lufthansa (50), Kunpeng Airlines (45), Azul Linhas Aereas (20) and Brazil Rodo Aereo (20).

Although the E-Jets will face future competition from other new-generation regional jets (RJs) they will remain the only aircraft to offer four different passenger sizes covering all areas of the regional market. They also benefit from flightdeck commonality and the fact that they are the only new-generation RJs already in operation and certified to operate at smaller airports with shorter runways, such as London City Airport. This is one of the main reasons why airlines such as BA (for its London City CityFlyer operation) have chosen the E-Jets over current RJs or are waiting for other new-generation RJs to be delivered. The fact that both backlog aircraft and order options are spread across the world suggests that worldwide demand for these aircraft will continue into the future.

E-170

There are currently 158 E-170s in operation, which equates to 29% of the

The E-Jets have global appeal, and are being used both in regional and mainline operations on all continents of the world.

E-JETS FLEET SUMMARY

Aircraft variant	Africa	Asia Pacific	Europe	Middle East	North America	South America	Variant Sub-Total	Model Sub-Total
E-170 LR	15	13	28	15	77	4	152	158
E-170 STD			4			2	6	
E-175						1	1	119
E-175 AR					36		36	
E-175 LR		3	7	2	70		82	
E-190						2	2	225
E-190 AR	1	24			109	27	161	
E-190 LR		10	26	4	1	21	62	
E-195						1	1	38
E-195 AR				7		5	12	
E-195 LR			24	1			25	
Total	**16**	**50**	**89**	**29**	**293**	**63**	**540**	**540**

fleet with 20 operators. Although Embraer markets three variants, there are only two in operation: the long-range variant (LR) and the standard (STD).

The only four E-170STDs in service are all with LOT Polish Airlines, which was the first to operate the E-170. LOT Polish Airlines has six more E170s, all of which are the LR variant. The average flight cycle (FC) over the past 12 months has been 32-160 minutes. Grand China Express Air achieves as much as 4.5 hours with one of its E-170s. The daily utilisation has been as high as 15 flight hours (FH) per day, but is usually 7-8 FH.

There are 152 E-170LRs currently in operation, with just over 50% in North America. Another 18% are in Europe, 3% in South America, and 9% each in Africa, Asia Pacific and the Middle East.

The largest operator of E-170s is Shuttle America (operating on behalf of Delta and United) with 45 E-170LRs. Republic Airlines is the second largest operator with 31 E-170LRs, followed by Saudi Arabian Airlines (15), EgyptAir Express (11), Finnair (10) and LOT Polish Airlines (10). The remaining airlines operate six or fewer aircraft, and many just have one or two. Shuttle America was bought by Republic Airlines in 2005, making the parent company a large operator, with more than double the number of E-Jets than any other airline.

Another variant, the short-runway version (SR), is planned for delivery to British Airways CityFlyer in September 2009 for use at London City Airport.

E-175

There are 119 E-175s in operation with 10 airlines, representing 22% of the global fleet. The E-175 is most popular in North America, where 106 aircraft are flown. This equates to nearly 90%.

The remaining 12 aircraft are operated in Asia Pacific (3), Europe (7) and the Middle East (2). The largest E-175 operator is Republic Airlines, with 38 aircraft, followed by Compass Airlines with 36, Shuttle America with 16, and Air Canada with 15. The remaining five operators have six or fewer aircraft.

The FC time for the E-175 over the past year has averaged from 85 minutes (with Compass Airlines) to 150 (with Shuttle America). The daily utilisation has been as high as 15FH for some Shuttle America and Compass Airlines aircraft, but is generally just under 7FH.

There are two variants in operation: 36 E-175ARs, all with Compass Airlines (which flies on behalf of Northwest Airlines and Delta), which was the first airline to operate this variant and remains the only one; and the E-175LR, operated by Republic Airlines (which has the largest fleet), followed by Shuttle America (16), Air Canada (15), LOT Polish Airlines (6) and four other operators which each have three or fewer aircraft.

E-190

The global fleet of E-195s consists of 225 aircraft with 24 operators, representing 42% of the total E-jet fleet, and making it the most popular of all the E-Jets. Again, it is popular with North American carriers, which operate 110 E-190s, nearly half the global fleet. South America has 22%, Asia Pacific 15%, Europe 12% and the Middle East 2%.

Air Canada is the largest operator of the E-190 with 45, while jetBlue, the launch customer, has only 38. However, it has an additional backlog of over 60 E-190s, which would make it the largest operator of this model.

The next largest operator is US Airways (25 E-190s), followed by COPA Airlines (15), Virgin Blue Airlines (13) and Aerorepublica (12). The other 18 carriers have fleets of 10 or fewer. The average FC over the past year has been 85 minutes, with Air Canada even getting 135 minutes from one of its E-190s. The daily utilisation has been as high as 15FH with some US Airways and Virgin Blue Airlines aircraft, and 10.5FH with Regional. The fleet average is just under 7FH per day.

There are two variants in commercial operation, the LR and AR, plus two aircraft operated by Embraer in a non-standard configuration.

There are 62 LR variants operated by 13 airlines. The largest operator is Aerorepublica (12 aircraft), followed by Finnair (10), Grand China Express Air (10), Regional (8) and Aeromexico Connect (6). The remaining eight airlines operate four or fewer of this variant in their fleets. The LR is most popular in Europe, which has 26, followed by South America and the Asia Pacific.

There are 161 AR variants of the E-190, making it the most popular variant of all E-Jets. The -190AR represents 30% of all E-Jets and over 70% of E-190s. North America again takes the lion's share of 109 AR aircraft, or 68% of E-190s. South America and Asia Pacific take 15% each of the AR fleet. The largest operators are Air Canada (45 aircraft), jetBlue (38), US Airways (25), COPA Airlines (15) and Virgin Blue (13).

E-195

The E-195 is the newest of the E-Jets, with 38 in operation, accounting for just 7% of the global E-Jet fleet. All are LR or AR variants, and most are in Europe. The average FC time over the past year has been 85 minutes, and the daily utilisation nearly 7FH. Many of Royal Jordanian's E-195s are doing more than 7FH.

There are just 12 LR variants, in the Middle East and South America. Azul Linhas Aereas and Royal Jordanian have five aircraft each, and nas air two. The AR variant has 25 aircraft, of which one is in the Middle East and the rest are in Europe. The launch customer, Flybe, is the largest operator with 14 aircraft. Air Dolimiti has five and Air Europa four. AC

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E-Jet family fuel-burn performance

The fuel-burn performance of the E-Jet's four variants is analysed on three routes of 207-645nm.

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

Aircraft variants

There are four basic variants of the E-Jets family: the E-170, E-175, E-190 and E-195. The E-170/-175 are certified as one type, and the E-190/-195 are certified as another. Standard models have been used for each of the variants.

All the aircraft variants are powered by CF34 engine family. The E-170/-175 aircraft are powered by the CF34-8EA1, while the E-190/-195 are powered by the CF34-10E. The increase in engine thrust for these two larger aircraft is reflected in their higher maximum take-off weights (MTOW). This goes from about 79,000lbs for the E-170 to just over 105,000lbs for the E-195. 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 E-170 and E-175 and the E-190 and E-195.

There will be many different thrust and MTOW variants used by different airlines. The basic specifications, as pre-loaded in Jeppesen and as stated by the manufacturer, 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. Having said that, the fuel burn used for the analysis of each sector just includes the fuel used for the trip and taxiing. The optimum routes and levels have been used for every flight, except where it has been necessary to restrict the levels due to airspace or airway restrictions and to comply with standard routes and Eurocontrol restrictions.

A taxi time of 20 minutes has been factored into the fuel burns and added to the flight times to provide block times. The flight plans have all been calculated using long-range cruise (LRC). Although other speeds are more likely on shorter routes, LRC has been chosen so that all routes can be equally compared for all variants without the need to adapt payload figures. LRC enables an aircraft to use less fuel per nautical mile, which means longer block times, but this is the economical and operational compromise between fuel consumption and flight times.

The aircraft being assessed are assumed to have a single-class cabin with a full passenger load of 80 on the E-170, 88 on the E-175, 114 on the E-190 and 122 on the E-195. 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 16,000lbs for the E-170, 17,600lbs for the E-175, 22,800lbs for the E-190 and 24,400lbs on the E-195. These are maximum seat capacities for the four variants. Most airlines configure their aircraft with fewer seats than this, but a smaller difference in passenger numbers has only a small effect on resulting fuel burn. The passenger numbers chosen still allow an illustrative comparison of fuel-burn performance to be made.

Route analysis

Three routes of varying lengths were analysed, with tracked distances of 207-645nm. All three routes are between the UK and France, and were picked to examine the fuel burn per seat-mile with increasing mission lengths. All the routes are typical of operators of the E-Jets family, which tend to have average flight cycle times of 1.45 flight hours (FH). All routes have been analysed in both directions, in order to provide a better

The largest E-Jets variants have fuel burn per seat superior to that of the smallest jetliners, while the smaller variants outperform most similar-sized regional types.

FUEL-BURN PERFORMANCE OF THE E-JET FAMILY

City-pair	Aircraft variant	Engine model	MTOW lbs	TOW lbs	Fuel burn USG	Block time mins	Seats	Payload lbs	ESAD nm	Fuel per seat	Fuel per seat-mile	Wind speed kts
SOU-CDG	E-170	CF34-8E5A1	79,178	66,273	523	58	80	16,000	207	6.543	0.032	-5
SOU-CDG	E-175	CF34-8E5A1	82,500	69,471	565	57	88	17,600	207	6.425	0.031	-5
SOU-CDG	E-190	CF34-10E5A1	105,138	89,366	633	57	114	22,800	207	5.551	0.027	-5
SOU-CDG	E-195	CF34-10E5	107,338	92,862	624	57	122	24,400	207	5.116	0.025	-5
CDG-SOU	E-170	CF34-8E5A1	79,178	66,545	539	60	80	16,000	223	6.741	0.032	-29
CDG-SOU	E-175	CF34-8E5A1	82,500	69,762	584	60	88	17,600	223	6.632	0.032	-29
CDG-SOU	E-190	CF34-10E5A1	105,138	89,700	653	59	114	22,800	223	5.724	0.028	-28
CDG-SOU	E-195	CF34-10E5	107,338	93,087	646	59	122	24,400	224	5.297	0.025	-28
EXT-EGC	E-170	CF34-8E5A1	79,178	68,267	749	86	80	16,000	415	9.368	0.023	-2
EXT-EGC	E-175	CF34-8E5A1	82,500	71,581	805	84	88	17,600	415	9.152	0.022	-2
EXT-EGC	E-190	CF34-10E5A1	105,138	91,959	920	83	114	22,800	415	8.071	0.019	-1
EXT-EGC	E-195	CF34-10E5	107,338	95,395	910	84	122	24,400	415	7.461	0.018	-2
EGC-EXT	E-170	CF34-8E5A1	79,178	68,429	794	94	80	16,000	437	9.929	0.024	-23
EGC-EXT	E-175	CF34-8E5A1	82,500	71,710	847	93	88	17,600	438	9.622	0.024	-22
EGC-EXT	E-190	CF34-10E5A1	105,138	92,114	971	90	114	22,800	437	8.514	0.021	-23
EGC-EXT	E-195	CF34-10E5	107,338	95,591	962	91	122	24,400	438	7.886	0.019	-23
BHX-TLS	E-170	CF34-8E5A1	79,178	70,103	967	112	80	16,000	606	12.091	0.020	-2
BHX-TLS	E--175	CF34-8E5A1	82,500	73,490	1,033	111	88	17,600	605	11.737	0.019	-2
BHX-TLS	E-190	CF34-10E5A1	105,138	94,274	1,196	111	114	22,800	607	10.491	0.017	-3
BHX-TLS	E-195	CF34-10E5	107,338	97,717	1,186	111	122	24,400	607	9.722	0.016	-3
TLS-BHX	E-170	CF34-8E5A1	79,178	70,498	1,059	125	80	16,000	676	13.235	0.021	-17
TLS-BHX	E-175	CF34-8E5A1	82,500	73,949	1,136	125	88	17,600	675	12.907	0.020	-17
TLS-BHX	E-190	CF34-10E5A1	105,138	94,778	1,313	121	114	22,800	672	11.513	0.018	-17
TLS-BHX	E-195	CF34-10E5	107,338	98,320	1,315	121	122	24,400	673	10.776	0.017	-17

Source: Jeppesen

picture of each aircraft's fuel burn, and the effect of wind.

The first route to be analysed, and the shortest, is Southampton, UK (SOU) to Charles De Gaulle, Paris, France (CDG). This route has a tracked distance of 207nm on the outbound sector and 208nm on the return sector, and is typical of the routes operated by Flybe. There were headwinds of 5 knots on the outbound sector (which seems to have had no effect on the ESAD, which remains at 207nm), but stronger headwinds of 28-29 knots on the return sector (which meant that the ESAD distances increased to 223-224nm). The winds have had a very small effect on the resulting block times, with block times, for all four variants, being close at 57-60 minutes.

The second route was Exeter, UK (EXT) to Bergerac, France (EGC), which is again a route operated by Flybe. The tracked distance is 415nm on the outbound sector, and a shorter 408nm on the return sector, the difference arising from a longer outbound flight routing due to tracks. The outbound sector had headwinds of 1-2 knots that left the ESAD unchanged at 415nm.

The return sector still had much stronger headwinds of 22-23 knots, meaning that the ESAD increased to 437-438nm, despite a shorter tracked distance. Block times on the outbound sector were 83-86 minutes, and with a 7-9-minute longer block time to 90-94 minutes on the return leg.

The third, and longest, route is Birmingham, UK (BHX) to Toulouse, France (TLS). Again this route is typical of the ones operated by Flybe. The outbound distance is 605nm, which, with a slight headwind of 2-3 knots, allows the ESAD to remain similar at 605-607nm. The return sector has a tracked distance of 645nm, but, due to stronger headwinds of 17 knots, the ESAD increases to 672-676nm.

Fuel-burn performance

The fuel-burn performance of the four E-Jet variants is shown for all three routes, both outbound and inbound. The data also include the associated fuel burn per passenger and fuel burn per passenger-mile for both sectors on each route. The fuel burn increases on all sectors as the power and size of aircraft increase, but this is not necessarily the case for fuel burn per passenger or passenger-mile.

On all six sectors, the fuel-burn performance is similar, with the E-170 always burning the least fuel, followed by the E-175. On all except the inbound sector of the last route (which has very close fuel-burn data for both the E-190 and E-195), the E-195 comes third, followed by the E-190.

The lowest fuel burn per seat can predictably be found on the shorter-length route with the E-195 on the outbound sector. The burn per seat on the same route increases with decreasing aircraft size. So the E-170 has the highest burn per seat in all cases.

The highest fuel burn per seat was, also predictably, on the longest route and on the return sector for the E-170, in particular *(see table, this page)*.

The best indication of fuel-burn performance is burn per passenger seat-mile. For this, the best results overall were found on the longer sectors and the worst on the shorter sectors.

For the first, and shortest, route the best performer was the E-195 with 0.025USG per seat-mile. This was followed by the E-190, then the E-175 and finally the E-170 with 0.032USG per seat-mile *(see table, this page)*.

For the second route, the order remained the same with the E-170 getting 0.023-0.024USG per seat-mile, and the E-195 gaining 0.018-0.019USG per seat-mile.

On the last and longest route, the performance order again remained unchanged. The E-170 used 0.02USG per seat-mile and the E-195 used 0.016-0.017USG per seat-mile *(see table, this page)*. AC

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E-Jets maintenance analysis & budget

The E-Jets family members follow a relatively simple maintenance programme. Maintenance costs are in-line with aircraft of their size and generation.

The Embraer E-Jets are sub-divided between the E-170/-175 and larger E-190/-195. The smaller E-170 first entered service in 2002, while the larger variants started operations later in 2004. The two main type groups are certified as two different aircraft types, and have different landing gears and engines, so they have two separate, although similar, maintenance programmes. Airlines which operate both type groups therefore need to have both maintenance programmes approved.

There are 530 E-jets in operation with airlines: 270 E-170s/-175s, and 260 E-190s/-195s. There are about another 362 on firm order. The aircraft are powered exclusively by the CF34 engine, but the E-170/-175 are equipped with the -8E5 variant, and the E-190/-195 are equipped with the higher-rated -10E5.

The E-Jets have a base maintenance programme of four base checks, with a basic interval of 6,000 flight hours (FH) and 5,000 flight cycles (FC). The fourth check in the cycle therefore has an interval of 24,000FH and 20,000FC. An eighth check at the end of the second base check cycle is heavier than the fourth check.

Most aircraft are operated at annual utilisations of 2,000-2,500FH, so they will have a base check every 25-30 months. On this basis, the earliest-built E-170s will have the first of their fourth base checks coming due in about three years. The fleet leader is an E-170LR operated by Republic Airlines, which has accumulated about 12,800FH and 9,100FC.

E-Jets in operation

The E-170 accounts for the majority of the two smaller variants. The E-170 and E-175 have been selected by airlines to operate in a variety of roles, including regional feeder services for larger carriers, lower-density routes for major airlines, and thinner markets served by small carriers.

Operators using the aircraft for regional feeding services include Chautauqua Airlines, Republic Airlines and Compass Airlines. Major airlines using the type include Alitalia, Egyptair, Finnair, LOT Polish Airlines, Saudia, South African, Air Canada and Royal Jordanian. Small operators are those such as Baboo, Cirrus Airlines, Fuji Dream Airlines and Hong Kong Express Airways.

Most E-170 and -175 fleets are operated on short sectors with average FC times of 0.9-1.4FH. Annual rates of utilisation are 1,900-2,500FH. The E-175 is operated at longer FC times.

Annual utilisation rates are close at 2,000-2,500FH for Alitalia Express, Egyptair Express, Finnair, LOT Polish Airlines, Saudia and Air Canada. US airline Republic Airlines, which provides feeder services for Delta and United Express, has longer average FC times of 1.35-1.50FH. Shuttle America, which also operates feeder services as Delta Connection and United Express, has FC times of about 1.60FH, one of the longest FC times of all E-Jet operations. Republic Airlines and Shuttle America also have higher annual utilisations of 2,600-3,000FH.

The E-190/-195 have similarly been acquired to operate in a variety of roles, although a few operators are regional airlines, affiliated with larger carriers, using the aircraft for feeder services. The E-190/-195 have mainly been selected to operate thinner routes for major and medium-sized airlines. Examples include Air Canada, COPA, Finnair, Hainan Airlines, jetBlue Airways, Lufthansa, TACA and USAirways.

The E-190 has similar rates of utilisation to the E-170/-175. Most E-190 operations achieve annual utilisations of 2,100-2,600FH and 1,350-1,900FC. Average FC time is about 1.50. Exceptions to this are Air Canada and jetBlue, two of the E-190's largest operators, which both accumulate averages of about 3,000FH per year and have average FH times of 1.80-2.00FH.

While there are 11 E-195 operators, only two have sizeable fleets that have been operating for two or more years. These are Flybe and Royal Jordanian, which have annual utilisations of 2,200-2,600FH and 1,900-2,000FC, and an average FC time of 1.20-1.35FH.

The two main type groups are therefore operated at similar rates of utilisation. Their maintenance costs are analysed here for aircraft completing 2,300FH and 1,800FC per year, at an average FC time of 1.28FH.

Maintenance programme

The E-Jets have a Maintenance Steering Group 3 (MSG3) maintenance programme. "The E-170/-175's maintenance planning document (MPD) is on its fifth revision, having been released in November 2008," explains Mikko Koskentalo, manager marketing and sales at Finnair Technical Services. "The E-190/-195's MPD is on its third revision, which was released in November 2008." Embraer expects to release its next revisions in the third quarter of 2009.

"The maintenance programme includes about 1,400 tasks for the E-170/-175 and 1,200 for the E-190/-195 in average configuration," continues Koskentalo. "The MPD has systems, structural, zonal, high-intensity radiated fields (HIRF)/lightning, and corrosion prevention and control programme (CPCP) inspections."

There are various intervals for these inspection tasks, which are based on multiples of 24 hours, FHs, FCs, calendar hours, and calendar months. These tasks are not pre-packaged into defined maintenance checks in the MPD.

Operators are free to package tasks into line and base maintenance checks, according to their rates of utilisation and FH:FC ratio. Tasks with calendar month intervals are more likely to be included in base checks.

There are several inspections with intervals close to 600FH and multiples of 600FH, and these are grouped into 'intermediate' or 'A' checks by most airlines. Some, such as Flybe, have chosen to equalise the tasks with the lower intervals into smaller line maintenance checks.

There are many inspections with intervals close to 6,000FH, and airlines group these into 'base' or 'C' checks. There are many tasks that have intervals lower than 6,000FH, and so they cannot be grouped into 'base' checks. "We have chosen to add a 3,000FH check package, and group these tasks into a 'B' check. The downtime for this also allows us to complete cosmetic tasks and to catch up with service bulletins (SBs) that cannot be completed during line checks. This

The E-170/-175 and E-190/-195 are certified as two different types, and so have two different maintenance programmes. These are similar, however, with most tasks the same between the two.

interval compares to our annual utilisation of 2,200FH," explains Stefan Kontorravdis, director of engineering at Flybe.

Many system tasks have multiples of 600FH. "Many operators group these tasks into phases or multiples of 600FH," explains Abdel-Aziz Masoud, chairman advisor at Egyptair Maintenance & Engineering. "The 600FH interval is regarded as a Phase 1 interval, and the 6,000FH interval of base checks is regarded as the Phase 10 interval."

Many system tasks have intervals that are a combination of FH and calendar time, usually expressed in months. The task is performed when either the FH or calendar interval is reached first. Tasks related to the landing gear have FC intervals.

Many structural tasks have intervals that are a combination of FC and calendar time. The tasks are performed when either the FC or calendar interval is reached first.

The CPCP tasks have intervals based on calendar time.

The zonal tasks have intervals that are multiples of 6,000FH.

HIRF/lightning inspections have to be performed in the event of the aircraft being struck by lightning. "This is because metal and composite material can separate after being struck by lightning," explains Koskentalo.

The total number of tasks and their intervals varies according to aircraft configuration and operator's maintenance programme. There are up to 730 inspections with FH intervals, 20-40 inspections with combined FH and calendar intervals, 350-430 tasks with FC intervals, about five tasks with FC and calendar intervals, 330-365 tasks with calendar intervals, and up to 10 tasks with FH and FC intervals.

The lowest FH intervals are 100FH, and go up to 40,000FH for the E-170/-175, and up to 30,000FH for the E-190/-195.

The FC intervals range from 600FC up to 40,000FC.

Calendar intervals range from 48 hours up to 240 months.

The FH, FC and calendar tasks with the highest intervals are the base check tasks, which are performed in the heaviest base checks. The FH:FC ratio and annual FH and FC utilisation have to be taken into consideration when packaging tasks into maintenance checks in order to ensure that the inspection intervals are utilised to their highest possible level.

Maintenance checks

Airframe maintenance checks can be split into three groups. These are line checks, A checks and base checks. The workscopes of these checks, and their labour and material inputs are reviewed.

Line checks

The line check maintenance programme in the MPD is simple. It does not have any of the pre-flight or transit checks that are standard for older aircraft types. The smallest line check specified in the MPD is a 48-hour check, which was a 24-hour check in many older aircraft types. The next highest line check for the E-Jets is the 14-day check, which was the weekly check of many older types.

Despite the simplicity of this maintenance programme, operators have added their own checks. Finnair, for example, has added a pre-flight check to its own maintenance programme. "We have a pre-flight check, the 48-hour or 'Service' check of the MPD, and a 'Routine' check with an interval of 120FH or 14 days," says Koskentalo. "We also add some additional line checks so that we can maintain technical despatch reliability (TDR), and also keep a good standard in the interior."

Egyptair's line maintenance programme also differs from the MPD. "The first check in our programme is an after-landing check, which is performed after arrival at base and for stops that last more than four hours. This includes checks on engine oil and fluid levels, and cockpit seats and belts, as well as an external walkaround visual inspection, which checks for physical damage, missing parts, hydraulic fluid leakage, and brake discs. The aircraft technical log, cabin logbook and engine indicating and crew alerting system (EICAS) screens are reviewed for error messages," explains Masoud. "There is also a transit check at outstations where the aircraft stop is less than four hours. This is an external walkaround visual inspection, and aircraft technical log review."

Egyptair's next highest check is the daily check, which has an interval of 48 hours. "This check includes the after-landing check tasks plus several others. These comprise a review of the central maintenance computer (CMC), an oxygen-pressure test, an emergency lighting and battery voltage check, an inspection of the galleys and lavatories, several emergency equipment checks, tyre pressure checks, and navigation light checks," continues Masoud.

"Then there is the weekly check, with an interval of eight calendar days. "Some tasks have to be performed every 100FH or 120FH. Our aircraft operate at about 7FH/8FC per day, so this is equal to 12-14 days," explains Masoud. "These items are included in the weekly check. The tasks in this check include the after-landing check, the daily check and several inspections. The inspections are a full history database download. This encounters downloading of all system

Egyptair is one operator that has substituted jetliners with the E-Jets on some if its routes that have lower traffic densities. The aircraft are operated at high frequencies, and maintain a high level of technical despatch reliability.

faults within the past eight days for further analysis, inspection of the landing gear, brake and tyre assemblies, engine master-chip detector inspections, horizontal stabiliser-ball screw inspection, cargo-lighting and safety-net inspection, passenger emergency equipment, and toilet-waste line cleaning."

A checks

Although there are no pre-defined A checks in the MPD for the E-Jets, there are a large number of tasks that most operators group into a 600FH interval. These packages are generically referred to as 'A' or 'Intermediate' checks by many operators.

The inspections have intervals close to 600FH, or multiples of 600FH. The maintenance programme can also be customised to suit the operators' pattern of operation and rate of aircraft utilisation. The inspection and tasks are mainly system-related tasks of low complexity that require little deep access. They can also be performed overnight, thereby minimising the disruption to the aircraft's operation. Embraer explains that these checks can be performed without the use of a hangar. Most of the tasks have FH intervals, although there are a few with FC and calendar intervals.

In Finnair's case, the Intermediate checks are arranged into a cycle of 10 checks. "The first check in the cycle, the Int-1 check, has an interval of 600FH," explains Koskentalo. "Tasks with intervals from 600FH to 6,000FH are grouped into the 10 Intermediate checks. The second check is the Int-2 with an interval of 1,200FH, and the tenth check is the Int-10 with an interval of 6,000FH. There are some tasks which have intervals that prevent them from being conveniently grouped into one of the 10 packages. These are considered as out-of-phase (OOP) tasks, so they normally have to be packaged with Service checks."

Masoud explains that the A check inspections include: changing oil and fuel filters; cleaning air conditioning and anti-icing filters; visual inspections; serviceability system checks; operational and functional checks; and lubricating flight controls. "There are a few tasks with intervals specified in FC, ranging from 3,000FC to 5,000FC. Bearing in mind our FH:FC ratio of about 1:1, these fall within the cycle of 10 A checks with the full interval of up to 6,000FH."

Kontorravdis explains that Flybe's basic A check interval is 600FH and 500FC. The airline operates its E-195s at about 2,200FH per year at an average FC time of 1.14FH. "We have a system of equalised checks to provide similar-sized workpackages of the tasks that have the basic 600FH interval and multiples of this interval," says Kontorravdis. "These equalised A checks fit in with the downtime provided by an overnight check. We also add some tasks specific to Flybe, as well as some SBs."

Line& A check inputs

Labour and material inputs for annual line maintenance depend on the operator's actual maintenance programme. A generic line maintenance programme can be used, and in this case it is assumed that the programme of checks will include a pre-flight or transit check prior to every departure, a daily or service check once every two days, and a weekly or routine check once every 14 days.

The pre-flight check is not actually part of the MPD, but those airlines that have it comment that labour requirements are relatively low. The check has been included in this analysis for the sake of conservatism, and a labour allowance of 0.5MH has been used. This check will be done at the start of each day. In addition to the routine tasks, it is used to clear any lighter defects that can easily be addressed, so some materials and consumables will be used, in addition to rotables that might get exchanged. A budget of $10 is used to reflect average material and consumable consumption.

The Transit checks follow for the rest of the day prior to each flight. These are usually carried out by the pilots, but an allowance of 0.5MH for labour by line mechanics and $10 of materials and consumables is again used.

The daily check is performed by line mechanics, and a labour consumption of 2.0MH and material consumption of $150 has been used.

A budget of 5.0MH and $200 of materials and consumables can be used for the weekly or service check.

On the basis of the aircraft completing 2,300FH and 1,800FC per year, the total labour used will be about 1,400MH. This is equal to $105,000 at a labour rate of $75 per MH. Once materials have been included in the cost of the checks, the total annual cost of line checks increases to $150,000. This is equal to a rate of $65 per FH *(see table, page 22)*.

Like line checks, the inputs used by different operators for A or Intermediate checks will vary according to their maintenance programmes. Average inputs for A checks are in the region of 120MH, when rectifications and cabin work are included. Each check will also use about $5,000 of materials and consumables. At the same labour rate, the inputs for the check total about $14,000. Typical utilisation rates of check intervals will be about 500FH, so the A checks will have a reserve of about $28 per FH. An additional $10 per FH can be budgeted for OOP tasks, taking the total to $38 per FH *(see table, page 22)*.

The E-Jets base maintenance programme is comprised of system inspections, with check intervals of 6,000FH and 5,000FC, and structural inspections. These are combined by most operators into a system of four base checks, with a basic check interval of 6,000FH/5,000FC and cycle interval of 24,000FH/20,000FC. The fourth check is usually the heavy check.

Base checks

Base checks include tasks with higher intervals than those described. These form three main groups.

The first of these are mainly system tasks and inspections which have intervals that are multiples of 6,000FH and 5,000FC. There are four main groups: the first with intervals of 6,000FH and 5,000FC; the second with intervals of 12,000FH and 10,000FC; the third with intervals of 18,000FH and 15,000FC; and the fourth with intervals of 24,000FH and 20,000FC.

These groups of tasks are arranged by most operators into block 'C' or 'Base' checks. The first check, with an interval of 6,000FH and 5,000FC, is termed the 'Bas-1' check by some operators, and has just the first group of tasks.

The second, 'Bas-2', check has intervals of 12,000FH and 10,000FC, and comprises the first and second group of tasks. The third, 'Bas-3', check has intervals of 18,000FH and 15,000FC, and comprises only the first group of tasks like the Bas-1 check.

The fourth, 'Bas-4', check has an interval of 24,000FH and 20,000FC. It is the heaviest check, since it comprises the first, second and fourth group of tasks and inspections. This fourth check ends the cycle of the base checks.

There is also a group of additional tasks, which have intervals of 48,000FH and 40,000FC, eight times the interval of the first group of tasks. These come due at the end of the second base check cycle, or the eighth check, the Bas-8 check, which means that this is heavier than the Bas-4 check.

Considering that the average airline utilisation of E-Jets is about 2,300FH and 1,900FC per year, the FH and FC intervals of these system tasks will be reached at about the same time. The 5,000FH interval is equal to about 26 months of operation. Base check intervals are rarely fully utilised, and checks are likely to be completed once every two years. "The four oldest aircraft in our fleet were delivered in the second half of 2005, and they are now going through their Bas-2 checks," says Pekka Helenius, E-Jets programme manager at Finnair Technical Services.

The second and third main groups of base check tasks together form the structural maintenance programme. The second group is the structural tasks which have an initial threshold that starts at 20,000FC and goes up to 40,000FC.

The third group consists of CPCP tasks, which have intervals of 72, 96 and 120 months. "The CPCP tasks are an integral part of the structural maintenance programme, and so the two are performed together," explains Helenius.

"The structural and CPCP tasks are closely linked, and the aircraft is built with corrosion-inhibiting fluids applied on the production line," says Kontorravdis. "The removal and reapplication of these fluids is part of the CPCP requirements."

Combining structural and CPCP tasks depends on operator utilisation. The structural inspections, with a 20,000FC interval, will come due at the same time as the Bas-4 check. This will be about 96 months, which is the same as some of the CPCP tasks. Although the Bas-4 check has not yet come due on any aircraft, it is expected that the structural inspections and CPCP tasks will be combined with the Bas-4 check. One advantage of doing this is that the downtime of the Bas-4 check will allow the most access for the structural inspections.

Consideration has to be given for the CPCP tasks at 72 and 120 months. The 72-month tasks are likely to be combined with the Bas-3 check, if base check intervals are performed every two years. The 120-month tasks are the largest in number, and would come due at the Bas-5 check. However, they are more likely to be included in the Bas-4 check, because they require deep access, which is not possible during the light Bas-5 check, which is similar to the Bas-1 check.

There are also structural inspections with threshold intervals between 20,000FC and 40,000FC. These are likely to come due at various stages between the Bas-4 and Bas-8 checks.

The number of routine tasks that come due in base checks will therefore increase from the Bas-4 check onwards.

Out-of-phase tasks

In addition to the inspections that are included in the line, Int or A-checks, and C or Base checks, there are also several OOP tasks. These are inspections whose intervals do not fit in well with the Int and Base checks. "Examples of OOP tasks are IDG and oil filter changes, which have an interval of 125FH. There are other tasks with intervals of 400FH and 500FH, and we put these in what we call a half-phase check, every 300FH. This is half the A check or basic Phase interval of 600FH," explains Masoud.

Kontorravdis explains that there are many OOP tasks, which are mainly inspections. "These do not have intervals that are multiples of 600FH, and it is possible for operators to package them into previous checks, so they get performed early, or do them on their own as OOP items. Flybe has chosen to amalgamate them into A checks or into a check that we introduced and called the B check, and which is half-way between the base check at 3,000FH."

Base check contents & inputs

The content of base checks clearly includes more than just MPD and maintenance programme inspections, as described. As with all aircraft, the base checks comprise several other elements.

The consumption of labour for the four base checks naturally varies with the routine inspections that come due. These each require 900-1,200MH for the first three base checks, with the second being the largest. The fourth check has a large labour requirement because of the additional structural and CPCP inspections, and can be as high as 5,500MH. This assumes that 120-month CPCP tasks are brought forward and included in the Bas-4 check.

Routine MH for the four checks of the first base check cycle total about 8,700MH.

The first of these additional elements is non-routine rectifications arising from findings due to routine inspections. Routine inspections and non-routine rectifications will form the majority of work performed in the check.

The non-routine ratio is a key factor in the overall size of base checks. These are expected to be low for the first one or two base checks and then increase with age, as is the case with other aircraft.

"We have experienced non-routine ratios of 40-80% in our first base check," says Helenius. "The actual rate depends on how well the aircraft is kept and maintained, but we expect the rate to gradually increase with age."

Like Finnair and many other operators, Egyptair has only had experience with Bas-1 checks. "Our experience with this is a non-routine ratio of about 50%," says Masoud.

At this stage in the E-Jets' life and maintenance cycle, only estimates of likely non-routine ratios can be made. This will be for Bas-3 and Bas-4 checks, with a large number of the fleet now having been through Bas-1 and Bas-2 checks.

Non-routine ratio will typically start at 40-60% for the Bas-1 check, and rise to 60% for the Bas-2 check. The ratios for the Bas-3 and Bas-4 checks are estimated to be 70% and 90% respectively.

MH for non-routine rectifications will be 450-800MH for the first three checks, and be larger at up to 5,000MH for the Bas-4 heck. The sub-total of routine and non-routine MH for the first three checks will therefore be 1,350-1,900MH. The sub-total for the Bas-4 check will be 9,000-10,500MH.

The third main element of base checks involves carrying out inspections and modifications described under airworthiness directives (ADs), modifications described under service bulletins (SBs), and completing engineering orders (EOs). "While there is always a usual amount of SBs required during base checks on the E-Jets, the earlier-built aircraft had to undergo an extensive structural modification programme," explains Helenius. "This meant that our earlier-built E-170s and E-190s required 700-800MH of labour to incorporate these modifications. These were incorporated on the production line of later-built aircraft, so they did not need these modifications in base checks."

One operator has made a provision or budget for as much as 2,500MH to complete all the structural SBs.

Besides these structural modifications, there are always ADs, SBs and EOs that need to be incorporated. The labour inputs required for these will vary according to the ADs that have been issued and their applicability to individual aircraft, and airline policy with respect to incorporating particular SBs.

The E-Jets have been affected by a few ADs. "We have carried out more than 200 modifications on our aircraft," says Koskentalo. "Besides the structural modifications mentioned, we have also made some software and system upgrades."

The CF34 engines powering the E-Jets are divided between the -8E variants powering the E-170/-175, and the -10E powering the E190/-195. Despite the -10Es having a higher thrust rating, the two variants have close maintenance costs.

There have been a few specific SBs that have affected the E-Jets. One of these has been a modification to increase the volume of oxygen for pilot masks from 55 cubic feet to 77 cubic feet.

Another problem has been the need to relocate the drain mast on the belly of the aircraft. The drain was letting dirty water into the air scoop at the fairing for the heat exchanger. An SB was issued to move the drain further aft.

Because of the variation in periodic AD issuance and airline maintenance policy, a typical amount of average labour can therefore only be budgeted for in each base check. Helenius explains that, following the incorporation of the structural modifications, base checks typically use a few hundred MH. A range of 300-400MH has been used for the lower base checks, and 500MH for the Bas-4 check.

A fourth element of base checks will be labour required for additional items that include removing and installing replacement rotable components, clearing defects that have occurred during operation, and some OOP tasks. This again will vary according to each airline's maintenance programme and philosophy. This portion of the check requires 200-300MH.

Interior work can be divided between regular cleaning and refurbishment. A budget of 150MH for regular cleaning in these checks should be used.

Total labour consumption for the three lighter checks is 2,000-2,750MH. Consumption for the Bas-4 check can be 11,000-11,500MH. Total labour for the four checks in the cycle will be 17,500-18,500MH. Charged at a labour rate of $50 per MH, this is equal to $875,000-925,000.

The consumption of materials and consumables varies from $15 to $50 per MH for different elements of the check. Overall material consumption is $55,000-75,000 for the first three checks, and up to $300,000 for the Bas-4 check, taking total consumption over the cycle to $530,000.

The total cost of labour and materials for the four checks in the first cycle is therefore estimated to be $1.5 million with the labour rates used here. Actual check intervals are assumed to be 24 months for ease of maintenance planning as described. This means that the interval between checks is about 4,600FH, compared to the 6,000FH MPD interval. The fourth check will therefore be completed at about 18,400FH, so the reserve for these four checks will be about $79 per FH *(see table, page 22)*.

Refurbishment & painting

Interior refurbishment is treated as an on-condition task by most airlines, although several have established soft times for refurbishing different parts of the interior. The interior includes seat covers, seat cushions, carpets, sidewall and ceiling panels, overhead bins, passenger service units (PSUs), galleys, toilets, and servicing areas.

"We usually dry clean our seat covers once every three or four months. After three cleans they lose their inflammable properties, so we usually have to replace them once a year," says Koskentalo. Similarly, Egyptair replaces its seat covers at every C check, up to every two years.

Removing, reinstalling and dry cleaning a shipset of seat covers will cost about $700. Replacing the shipset will cost about $20,000. On the basis of three cleans and one annual replacement, the amortised cost is equal to about $10 per FH.

Seat cushions will also have to be replaced, and can be done about once every five years. This will cost about $25,000, equal to about $2 per FH.

Carpets will also experience a high rate of wear, although this will vary between operators. Finnair finds that aisle carpets require frequent replacement due to the effects of winter weather. "We replace aisle carpet about once every three months, and other carpet about once a year," says Koskentalo.

Carpet removal and replacement uses about 30MH, and a shipset of new carpet material costs about $2,000. Amortising the two parts over the relevant intervals is equal to $2.00 per FH.

The remaining interior items are maintained by most airlines on an on-condition basis. "We examine the condition of these every base check, and refurbish them to a level so that they last until the next base check," says Koskentalo. "We then plan to do a major refurbishment on these items at the Bas-4 and Bas-8 checks."

The restoration of the panels, bulkheads, bins and PSUs may use 100-200MH at the Bas-4 check. Refurbishment at the Bas-8 check may use about 800MH and $4,000. Refurbishment of galleys, toilets and servicing areas at the Bas-8 check may use about 400MH and $5,000. The total cost of this, amortised over the Bas-8 check interval, will be equal to a reserve of about $2 per FH.

The final element of refurbishment is aircraft stripping and repainting. This will use about 1,200MH and $10,000-15,000 for paint, taking the total cost to $70,000. If aircraft are repainted once every six years, the reserve will be $5 per FH.

The total reserve for interior refurbishment and stripping and repainting will be $21 per FH *(see table, page 22)*. About $12 per FH of this cost is related to the refurbishment and replacement of seat covers and cushions.

Heavy components

Heavy components comprise the landing gear, wheels and brakes, and the auxiliary power unit (APU).

The landing gear overhaul life varies across the E-170/-190 variants, ranging from 30,000 cycles/12 years for the E-170/-175, to 20,000 cycles/eight years for the E-190/-195. Given the average utilisation of 1,800FC per year the majority of landing gear overhauls will take place when the calendar limits are reached. The estimated overhaul cost for the E-170/-175 gear is $207,000. A typical overhaul reserve is therefore $10 per FC *(see table, page 22)*, equal to $8 per FH. The estimated overhaul cost for the E-190/-195 gear is $259,000. A typical overhaul reserve is therefore $18 per FC *(see table, page 22)*, equal to $14 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 wheels, brakes and tyres is $50 per FC for the E-170/-175, equal to $39 per FH and $70 per FC for the E-190/-195, equal to $55 per FH *(see table, page 22)*.

The APU is a Hamilton Sundstrand Model APS 2300 and overhaul is on-condition. A typical overhaul is estimated to cost $147,500 and the average time before overhaul (TBO) to be 6,700 APU hours (APUH). This gives a reserve of $22 per APUH *(see table, page 22)*. Assuming an APU utilisation of 0.8APUH per FH this is equal to $18 per FH.

Rotable components

Considering the relatively small size of the E-170/-190 fleet it, is surprising that no fewer than three companies are offering rotable overhaul programmes for it. They are all fundamentally similar, covering most of the rotable parts with the exception of the larger items, the landing gear and APU. Failed or hard-time components are removed from the aircraft by the operator and exchanged for fresh components provided by the service provider. The latter then arranges for the repair, testing, and return of serviceable parts to the inventory. As well benefiting from having predictable costs, the operator avoids the burden of managing warranty administration, and having arguments with a large number of vendors.

Unsurprisingly, the most established of these providers is Embraer itself. The company's Parts Pool Program, which was developed for the earlier ERJ-145 family, has been extended to the E-170/-190 and has been selected by a large number of operators.

In November 2008 Lufthansa Technik became the second player in this market when it announced that National Air Services, of Saudi Arabia, would be the launch customer for its Total Component Support (TCS) service for the E-190. Lufthansa Technik offers TCS across the whole range of Airbus and Boeing products, as well as the Bombardier CRJ series and the Q400. This builds on Lufthansa Technik's earlier co-operation with LOT Polish Airlines on the Embraer 145 and E-Jet. The two companies signed a co-operation agreement in 2004, whereby Lufthansa Technik is responsible for component repair, and LOT Polish Airlines provides the logistic support. In addition to these two fleets, Lufthansa Technik will undoubtedly support the 30 E-190/-195s that have been ordered by Lufthansa itself.

The most recent entrant is US-based Barfield, a part of the Sabena Technics Group. In June 2009 the company announced that it had been selected by TACA of El Salvador to provide full repair and overhaul support for the rotable components on its fleet of 11 E-190s.

The actual costs for these three

DIRECT MAINTENANCE COSTS FOR E-170/-175 & E-190/-195

Maintenance Item	E-170/ -175	E-190/ -195
Line & ramp checks	65	65
A check	38	38
Base checks	79	79
Interior refurbishment & stripping/repainting	21	21
Landing gear	8	14
Wheels & brakes	39	55
APU	18	18
LRU component support	209	209
Total airframe & component maintenance	**477**	**499**
Engine maintenance:		
2 X $153-180 per EFH	306-360	
2 X $136-156 per EFH		272-312
Total direct maintenance costs:	**783-837**	**771-811**

Annual utilisation:
2,300FH
1,800FC
FH:FC ratio of 1.28:1

competing programmes depend on fleet size, utilisation, route network and style of operation among other criteria. Typical budgets for new aircraft are estimated to be $115/FH for the FH fee covering repair and overhaul, and $15,000 per aircraft per month for the pool-access fee covering the financing of the pool stock, insurance and administration (equating to $78/FH).

A fleet of five E-170/-190 family aircraft operating 2,300FH per year is estimated to require an on-site stock inventory with a value of $1 million. The monthly lease cost for this stock would be about $15,000 shared between the five aircraft. This would be equal to about $16 per FH.

The total for the three elements is therefore $209 per FH *(see table, this page)*.

Engine maintenance

The E-170/-190 family is powered exclusively by engines from the General Electric (GE) CF34 family. The E-170-175 are powered by variants of the CF34-8E, while the E-190/-195 are powered by variants of the higher-rated CF34-10E.

It is not widely appreciated that, although they are both members of the CF34 family, there is no commonality between the CF34-8 and CF34-10. The CF34-8 was a derivative of the CF34-3 which powered the Canadair CRJ200. It retained the same architecture but incorporated a larger fan and a new ten-stage compressor derived from the F414 military engine.

For the even greater thrust required by the CF34-10, General Electric used the architecture of the CFM56 rather than the CF34. The compressor is based on the CFM56-7B. The retention of the CF34 designation was more to do with branding than engineering.

CF34-8E5

There are two engine variants available for the E-170 and E-175: the CF34-8E5 and the CF34-8E5A1. They are physically identical and differ only in the normal take-off thrust rating and the maximum allowable take-off temperature *(see table, this page)*.

All these engines are maintained on-condition, but a typical interval for the first shop visit of a CF34-8E5 is about 11,500 engine flight hours (EFH). Subsequent shop-visit intervals will be lower at 7,500EFH. The first and second shop visits are estimated to cost $700,000, but the third will be more expensive at an estimated $1,000,000. Over the three shop visits the cost per EFH will be $91/EFH.

The CF34-8E has 23 different life limited parts (LLPs), and all the current-production parts have a projected ultimate life of 25,000EFC. However the current life limits vary from 11,500EFC up to 25,000EFC (only 13 of the 23 LLPs having so far reached the projected ultimate life). GE, however, has guaranteed to meet the 25,000EFC limit. In the event that the LLP is removed, because the limit has not been extended, then GE will compensate the operator the difference. The list price of the current production-standard parts is approximately $1.65 million. Dividing each individual part cost by its ultimate cycle life puts the LLP reserve at $66/EFC.

Reserves for LLP replacement, however, depend on the stub life that can be left at replacement. Based on the projected ultimate component lives, and assuming an annual utilisation of 2,300FH/1,800FC, LLP replacement will not be a factor until the third shop visit. Assuming that the third shop visit takes place at 26,500EFH/20,740 cycles, then the stub life left in the LLPs at replacement is likely to be in excess of 15%, so a more realistic LLP reserve would therefore be $80/EFC.

CF34-8E5A1

The equivalent shop-visit intervals for the higher-rated -8E5A1 will be about 9,500EFH and 6,500EFH. Therefore although the shop visits are estimated to cost the same as those for the -8E5, the reserve per EFH will increase from $91/EFH for the CF34-8E5 to $107/EFH for the -8E5A1.

The CF34-8E5A1 has the same LLPs as the -8E5 and, with the exception of the components in the high pressure turbine (HPT), all the current production parts have a projected ultimate life of 25,000EFC. The seven HPT LLPs have a projected ultimate life of only 20,000EFC. The current life limits of the components in the HPT, however, are only 6,000EFC. Dividing each individual part cost by its ultimate cycle life puts reserves at about $70/EFC, but again this fails to take into account the stub life that will be left at replacement.

Based on the projected ultimate component lives, and assuming an annual utilisation of 2,300FH/1,800FC, LLP replacement will not be a factor until the third shop visit. Assuming that the third shop visit takes place at 22,500EFH/17,600 cycles, the stub life left in the LLPs at replacement is going to be about 9% for the LLPs in the HPT, but almost 30% for the remaining LLPs. A more realistic LLP reserve would therefore be $94/EFC. It is clear that the lower 20,000-cycle life of the LLPs in the HPT will have a significantly negative impact on the operating cost of this engine.

There is little difference in overall maintenance costs between the E-170/-175 and E-190/-195. The larger aircraft have higher heavy component costs, but this is offset by slightly lower engine maintenance costs.

CF34-10E5 in operation

There are no fewer than five engine variants available for the E-190 and E-195: the CF34-10E5, E5A1, E6, E6A1 and the E7. They are physically identical, and the difference between them is in the take-off thrust rating, flat-rating temperature and the maximum allowable take-off temperature *(see table, page 22)*.

All these engines are maintained on-condition, but a typical interval for the first shop visit of a CF34-10E5 is about 18,000EFH. Second and third shop-visit intervals will be lower at about 12,000EFH and 10,000EFH respectively. The first shop visit is estimated to cost in the region of $850,000, but the second and third will be more expensive at $1.4 million and $1.3 million respectively. Over the three shop visits the cost per EFH will be $89/EFH.

On all the CF34-10E variants the LLPs have a projected ultimate life of 25,000EFC. The list price of the current production-standard parts is approximately $1.4 million. Dividing each individual part cost by its ultimate cycle life puts the LLP reserve at about $56/EFC. Again, reserves for LLP replacement depend on the stub life that can be left at replacement.

Based on the projected ultimate component lives and assuming an annual utilisation of 2,300FH/1,800FC, LLP replacement will not be a factor until the second shop visit. Assuming that the second shop visit takes place at 30,000EFH/23,480 cycles, then the stub life left in the LLPs at replacement is likely to be approximately 6%, and a more realistic LLP reserve would therefore be $60/EFC.

CF34-10E6

The equivalent shop-visit intervals for the higher-rated -10E6 will be about 17,000EFH, 10,500EFH and 9,000EFH. The first shop visit is estimated to cost in the region of $850,000, but the second and third will be more expensive at $1.35 million and $1.25 million respectively. Over the three shop visits, the cost per EFH will be $95/EFH.

Based on the projected ultimate component lives, and assuming an annual utilisation of 2,300FH/1,800FC, LLP replacement will not be a factor until the second shop visit. Assuming that the second shop visit takes place at 27,500EFH/21,520EFC, then the stub life left in the LLPs at replacement is going to be about 14%, and a more realistic LLP reserve would therefore be $65/EFC.

CF34-10E7

The equivalent shop-visit intervals for the higher-rated -10E7 will be about 13,000EFH, 7,000EFH and 6,000EFH. The first shop visit is estimated to cost in the region of $700,000, but the second and third will be more expensive at an estimated $1.0 million and $950,000 respectively. Over the three shop visits the cost per EFH will be $102/EFH.

Based on the projected ultimate component lives, and assuming an annual utilisation of 2,800FH/2,200FC, LLP replacement will not be a factor until the third shop visit. Assuming that the third shop visit takes place at 26,000EFH/20,350 cycles, then the stub life left in the LLPs at replacement is going to be approximately 18%, and a more realistic LLP reserve would therefore be $69/EFC.

Maintenance cost summary

Perhaps surprisingly, there is not a great difference between the total maintenance costs for the E-170/-175 and the larger E-190/-195. This is mainly because the E-190/-195 has slightly lower engine maintenance costs than the E-170/-175.

Despite the greater thrust and the higher cost of overhaul of the CF34-10, its longer shop-visit intervals result in an overhaul cost per EFH comparable with the CF34-8E5. Moreover, the list price for the LLPs on the CF34-10 is actually less than the CF34-8 at $1.4 million compared to $1.65 million. As a result, the higher-rated CF34-8E5A1 suffers the highest cost of all, because it has the shorter shop-visit intervals, the most expensive LLPs and the lowest LLP life.

The total maintenance cost for the two smaller members of the family is $783-837 per FH for the E-170/-175, and $771-811 per FH for the E-175 *(see table, page 22)*. The difference is mainly due to the increased cost of maintaining the higher-rated engines. The E-190/-195 have higher heavy-component-related costs, which offset their lower engine maintenance costs.

The total costs are particularly low for the E-190/-95 considering their size. This is one major element that makes the aircraft appealing compared to the smallest jetliners, whose maintenance costs are about $300 per FH higher. Although the maintenance costs are relatively high for the E-170/0175, the aircraft nevertheless remain economically attractive. AC

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E-Jet family technical support providers

The E-Jet family has a fleet that is predominantly in North America and Europe. Therefore, the majority of support is found in these two areas.

This survey summarises the major aftermarket and technical support providers for the Embraer E-Jet 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 25)*;
2. Line maintenance and in-service operational support *(see first table, page 26)*;
3. Base Maintenance Support *(see second table, page 26)*;
4. Engine Maintenance *(see first table, page 27)*;
5. Spare Engine Support *(see second table, page 27)*;
6. Rotables and Logistics *(see third table, page 27)*;
7. Heavy Component Maintenance *(see fourth table, page 27)*.

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 E-Jets. This means that they provide most of the technical support services that an airline customer would require. The tables show the range of services that these facilities are capable of offering.

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

The major maintenance providers include: ExelTech Aerospace, Aveos Fleet Performance and Embraer. The major engine maintenance providers include GE Engine Services and Aveos Fleet Performance. 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.

By the end of 2012, there are likely to be over 800 E-Jets in operation, with potentially another 300-plus aircraft that are on order. The maintenance market will need to continue at current levels, and then grow by about 35% over the next three years if the expected fleet expansion does occur. The oldest E-Jet is just five years old, and the maintenance market growth does not include the increased requirements that will be needed over the coming years as the E-Jets mature and more heavy base checks come due.

The backlog of E-Jet deliveries amounts to nearly 350 aircraft that are destined for all areas of the world. Existing operators will already have maintenance contracts in place with third-party facilities or in house, but the maintenance of those aircraft going to new operators, however, will need to go to tender. This will be where a lot of the growth could be seen, as more third-party operators, both airline-connected and independent, start to offer capabilities around the world.

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

The Executive Jet model (of which there is currently only one being operated) within the E-Jet family has not been considered in the data below. The market shares, as produced by Aircraft Fleet & Analytical System (ACAS) for the month of June 2009, do not include this model. The geographical breakdowns are conducted according to ACAS's view of countries and their relevant world region.

Engine maintenance

The E-Jet family has just the one engine option for each aircraft model: the CF34-8E for the E-170 and E-175; and the CF34-10E for the E-190 and E-195 models. Although the engine is part of a family that is maintained by many facilities, there is still a limited choice of MRO facilities that cover these engine variants.

As would be expected, General

Although the E-Jets fleet is likely to climb to about 900 active aircraft, the technical support market is still likely to be limited to OEMs and a few independent maintenance providers.

E-JET FAMILY ENGINEERING MANAGEMENT & TECHNICAL SUPPORT

Facility	Outsourced engineering service	Maintenance records service	Documentation & manuals management	Maintenance programme management	Reliability statistics	AD / SB orders management	Check planning	Config IPC management	Total tech support
Aveos Fleet Performance Inc.							Production planning		Y
Egyptair Maintenance & Engineering	Y	Y	Y	Y	Y	Y	Y	Y	Y
Embraer Services (Nashville)	Y	Y	Y	Y	Y	Y	Y	Y	Y
Embraer Maintenance Center (Brazil)	Y	Y	Y	Y	Y	Y	Y	Y	Y
Embraer Service Center) (Fort Lauderdale, France & Singapore)	Y	Y	Y	Y	Y	Y	Y	Y	Y
ExelTech Aerospace	Y	Y	Customer supplied	Y	Y	Y	Y	Y	Y
Finnair	Y	Y	Y	Y	Y	Y	Y	Y	Y
Flybe Aviation Services	Y	Y	Y	Y	Y	Y	Y	Y	Y
Fokker Services / Stork	Y	Y	Y	Y	Y	Y	Y	Y	Y
Goodrich	Y	Y	Y	Y	Y	Y	Y		Y
Lufthansa AERO Alzey									Y
Lufthansa Cityline	Y	Y	Y	Y	Y	Y	Y	Y	Y
Lufthansa Technik									Y
MTU Maintenance						Engine only	Engine only	Engine only	Engine only
Nayak Aircraft Services	Y	Y	Y	Y	Y	Y	Y		
OGMA	Y	Y	Y	Y	Y	Y	Y	Y	Y

Electric (GE) takes the majority of the engine overhaul market. Its engine shop in Strother, USA, alone has just over 48% of the share, which according to ACAS equates to over 500 engine shop visits to date. If those figures are combined with those completed at its headquarters and Welsh engine shop, the result is that GE holds nearly a 58% market share.

As the aircraft fleet grows and more engines require shop visits, and the number of facilities with capabilities grows, it will be interesting to see how this figure changes. Having said that, GE has large facilities all over the world, so it is likely to continue to take a large portion of the market.

StandardAero, which pushed GE into second place with engine overhauls for the Embraer ERJ-145 family, is an expert on the Rolls Royce AE3007 *(see ERJ-145 family technical support providers, Aircraft Commerce, December 2008 / January 2009, page 23)*. According to ACAS, Standard Aero has only had three engine shop visits from E-Jets in recent times, despite also being CF34 experts. This is quite possibly because it predominantly deals with corporate jets. Also, while it does maintain the -1, -3 and -8 models of the CF34, it does not yet have capability for the -10, and GE (Strother) has cornered the US market. StandardAero could well increase its market share over the coming years.

The next largest market share is taken by a group made up of contracts that are unknown or are for tender. This amounts to nearly 30% of recent market share.

The next individual company is Aveos Fleet Management, which accounts for 11% of the engine overhaul market. Lufthansa Technik takes the next biggest share of the market, when both its main shop and that at Lufthansa A.E.R.O. Alzey are combined.

As previously mentioned, there are and will continue to be a growing number of choices for operators as the E-Jets fleet grows. This is because many engine shops are developing their CF34 capabilities to include the -8E and -10E series. This is true of MRO companies such as MTU and Lufthansa Technik, as well as airline maintenance departments.

For the APU market, about half of APUs are maintained by Sundstrand Power Systems in the US. The other half are maintained in-house by airlines or are up for tender.

Base maintenance

The base maintenance market is divided into light and heavy checks. The figures differ between the two checks, but the order that the facilities fall into generally stays the same.

There are still a number of operators that undertake their base maintenance in house, with nearly a quarter of light checks and 19% of heavy checks being completed this way (equating to 91 and 117 aircraft respectively). There are 10% of light checks and 15% of heavy checks for aircraft with maintenance contracts up for tender, or completed by an unknown facility.

ExelTech Aerospace is by far the most prolific of the remaining third-party facilities. It has taken 27% of the market share for both checks, and comes close to being a one-stop-shop when it comes to E-Jet maintenance.

As well as maintaining engines, Aveos Fleet Performance also undertakes a large amount of airframe maintenance, assisted by the number of E-Jets in the Air Canada fleet. For both checks, it has gained 12.5% of the market. This means that facilities in Canada have nearly 40% (190 aircraft) of the base maintenance market share.

Embraer itself has performed about 12% of base maintenance checks at its Nashville, USA facility. There are other MRO facilities, as seen in the tables, that undertake maintenance on the E-Jets, but they all contribute less than 4% each, with many doing less than 1% (about five aircraft) each of base check maintenance.

These figures will change over the next year or so as the global fleet increases and more facilities increase their capabilities and capacity. This could well be true of companies such as Flybe, which is increasing its E-195 fleet. At the same time Flybe is reducing its 737 and BAE146 fleet, meaning that there will be an increase in E-Jet capacity at Flybe Aviation Services.

North and South America

North America is the largest operator of E-Jets with 293 aircraft (54%), while South America has only 12% of the

E-JET FAMILY LINE & LIGHT MAINTENANCE SUPPORT

Facility	Maint. Op. control	AOG support	Line checks	A checks	Engine QEC changes	Engine changes	Landing gear changes	APU changes	Thrust reverser changes
Aveos Fleet Performance Inc.		Y	Y	Y	Y	Y	Y	Y	Y
Egyptair Maint. & Engineering	Y	Y	Y	Y	Y	Y	Y	Y	Y
Embraer Services (Nashville)	Y	Y	Y	Y	Y	Y	Y	Y	Y
Embraer Maint. Center (Brazil)	Y	Y	Y	Y	Y	Y	Y	Y	Y
ExelTech Aerospace	Y	Y	Y	Y	Y	Y	Y	Y	Y
Finnair	Y	Y	Y	Y	Y	Y	Y	Y	Y
Flybe Aviation Services	Y	Y	Y	Y	Y	Y	Y	Y	Y
Goodrich	Y	Y							Y
Lufthansa Cityline	Y	Y	Y	Y	Y	Y	Y	Y	Y
MTU Maintenance		Y			Y	In co-operation with partner			
OGMA	Y	Y	Y	Y	Y	Y	Y	Y	Y

global fleet according to ACAS's June 2009 data. Again, many of the operators have in-house maintenance facilities, but there are also a growing number of other MRO facilities offering E-Jet maintenance. This is aided by the vast E-Jet fleet that is already flown in the North American area.

As mentioned previously, Aveos Fleet Performance and ExelTech Aerospace are facilities in North America that have a large share of the market. Both are considered independent MROs, although Aveos Fleet Performance started as the maintenance department for Air Canada.

Other independent MRO facilities in North America include AAR, Certified Aviation Services, Empire Aero Center, First Wave MRO Inc., and Goodrich.

As well as maintaining their own fleets, many operators offer third-party maintenance capabilities to others. These companies include US Airways.

There are 63 aircraft currently being operated in South America, but again, like in the Asia Pacific area, the maintenance market is not large, even though the aircraft is a South American product. The main facility is in fact Embraer's Maintenance Center in Brazil. With this and many large MRO facilities in North America, the South American fleet is well catered for.

Europe

Although Europe has the second largest E-Jet fleet, it has just 16.5% of the global fleet. There is a relatively good choice of facilities for both engine and airframe maintenance, although none of them currently work on the large numbers that are seen by Aveos, ExelTech and GE in North America.

The vast majority of European facilities are in fact developed from airline maintenance departments and include Alitalia, Finnair, Flybe, LOT Polish Airlines and Lufthansa. This is directly connected to the fleet that those airlines have chosen to fly in recent years. OGMA and SR Technics are two of the few independent facilities that offer E-Jet maintenance.

Standalone engine maintenance is offered by GE in Wales and by MTU in Germany, the latter being an independent facility.

The growth of the E-Jet fleet within Europe could well see capacity and capability growing within those facilities that already offer the service, but also among more of the independent facilities and new operators, such as British Airways. Nearly 100 new aircraft will be delivered to Europe alone over the coming years, which emphasises this point.

E-JET FAMILY BASE MAINTENANCE SUPPORT

Facility	C checks	Heavy checks	Composites	Strip / paint	Interior refurb.
Aveos Fleet Performance Inc.	Y	Y	Y	Specific areas only	Y
Egyptair Maintenance & Engineering	Y	Y	Y	Y	Y
Embraer Aircraft Maintenance Services (Nashville)	Y	Y	Y	Y	Y
Embraer Maintenance Center (Brazil)	Y	Y	Y	Y	Y
Embraer Service Center) (inc. Fort Lauderdale, France & Singapore)	Y	Y			
ExelTech Aerospace	Y	Y	Y		Y
Finnair	Y	Y	Y	Y	Y
flyBe Aviation Services	Y	Y	Y	Limited areas only	Y
jetBlue Airways					
Lufthansa Technik				Y	Y
OGMA	Y	Y	Y	Y	

Asia Pacific

The greater Asia Pacific region accounts for just 9% (or 50 aircraft) of the global E-Jet fleet. As such there are currently limited maintenance options for E-Jets based in Asia Pacific. The facilities that do have capability will be on a small scale at the moment, or will just deal with in-house maintenance. Operators may have in-house maintenance facilities, but few also offer third-party capabilities to others.

Mandarin Airlines does a fair amount of its own maintenance in house, but it does not offer third-party maintenance. Instead, it has an agreement with China Airlines to do some of its base maintenance checks. China Airlines' capabilities, as well as others such as

Paramount Airways, could improve as the E-Jet fleet in the area grows.

More than 50 additional E-Jets will be delivered to the Asia Pacific over the coming years. Within this number, Hainan Airlines alone has a backlog of 40 aircraft to be delivered over the next three years.

Middle East and Africa

The combined E-Jet fleets of Africa and the Middle East amount to just over 8% of the global fleet, with 16 aircraft in Africa and 29 in the Middle East. With such low current numbers, it is predictable that there are no facilities currently offering E-Jet cover, other than within the maintenance departments of the major airlines of the regions that operate this aircraft.

The operators with maintenance departments offering third-party capabilities include EgyptAir (EgyptAir Maintenance & Engineering) and Royal Jordanian (JorAMCo), the former coming relatively close to being a one-stop-shop.

New E-Jets in the regions will account for 17 aircraft in the Middle East and 14 aircraft in Africa. Only two of the operators already have the type, so there are potentially four new maintenance contracts to be awarded. One of those new operators will be South African Airlink in 2011, so maintenance is very likely to be completed in house. This could mean that South African Airlink covers southern Africa, while EgyptAir covers northern Africa and JorAMCo deals with the Middle East, although Goodrich has a small capability from its offices in Dubai.

If an aircraft encounters problems in areas that have no maintenance cover, such as some regions of Asia, Africa and 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 done, to cover their network.

Summary

Although the E-Jet fleet is set to reach about 900 aircraft, the technical support market looks likely to remain a specialist one served by a few providers. The fleet will remain focused with a relatively small number of airlines. The technical support market will mainly be divided between Embraer, GE, some independent airframe and engine shops, and the larger airline maintenance and engineering departments. AC

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E-JET FAMILY ENGINE MAINTENANCE

Facility	Engine health monitoring	Engine maint. Management	On-wing engine maintenance	Engine shop visits	Parts repair schemes
Aveos Fleet Performance Inc.			Y	Y	Y
Egyptair Maintenance & Engineering	Y	Y	Y		
Embraer Services (Nashville)	Y	Y	Y		Y
Embraer Maintenance Center (Brazil)	Y	Y	Y	Light repairs	Y
ExelTech Aerospace			Y		
Finnair	Y	Y	Y		
Flybe Aviation Services		Y	Y	Mgt & workscope approval	Limited
GE Engine Services	Y	Y	Y	Y	Y
Goodrich					Y
Lufthansa AERO Alzey	Y	Y	Y	Y	Y
MTU Maintenance	Y	Y	Y	Y	Y
Nayak Aircraft Services	Y	Y			
OGMA			E170/175 only		

E-JET FAMILY SPARE ENGINE SUPPORT

Facility	On-wing support	AOG services	Short-term leases	Medium/long-term leases	Engine pooling
Egyptair Maintenance & Engineering	Y	Y			
Embraer Services (Nashville)	Y	Y			
Embraer Maintenance Center (Brazil)	Y	Y			
ExelTech Aerospace		Y			
Finnair	Y	Y	If available	If available	If available
Flybe Aviation Services	Limited to line & base EMM tasks				
GE Engine Services	Y	Y	Y		
Lufthansa AERO Alzey	Y	Y	Y	Y	Y
MTU Maintenance	Y	Y	Y	Y	Y

E-JET FAMILY ROTABLES AND LOGISTICS

Facility	Rotable inventory leasing	Rotable inventory pooling	Repair & document management	AOG support	PBH rotables support
Egyptair Maintenance & Engineering	Limited support	Limited support	Limited support	Limited support	Limited support
Embraer Services (Nashville)	Y	Y	Y	Y	Y
Embraer Maintenance Center (Brazil)		Y	Y	Y	Y
Embraer Service Center (Fort Lauderdale, France & Singapore)		Y	Y	Y	Y
ExelTech Aerospace				Y	
Finnair	Y	Y	Y	Y	Y
Fokker Services / Stork	On system level	On system level	Full cap.	Full cap.	On system level
Goodrich	Y	Y	Y	Y	Y
Lufthansa Technik	Y	Y	Y	Y	Y

E-JET FAMILY HEAVY COMPONENT MAINTENANCE

Facility	Wheels, tyres & brakes	APU test & repair	Thrust reversers	Landing gear	Landing gear exchanges
Egyptair Maintenance & Engineering	Y		Y		
Embraer Services (Nashville)	Y		Y	Y	Y
Embraer Maintenance Center (Brazil)	Y			Y	Y
Embraer Service Center (Fort Lauderdale, France & Singapore)	Y	Y		Y	Y
Finnair	Y			Under study	Under study
Flybe Aviation Services	W&T only				
Fokker Services / Stork	Dormant cap.		Dormant cap	Dormant cap	
Goodrich			Y		
Lufthansa Technik	Y			Y	Y

E-Jets aftermarket & values

The E-Jets are still young and in high demand from operators. There are few aircraft available on the market and few transactions of used aircraft have been completed.

The E-170 model is the more popular of the two smaller family members, accounting for 193 orders, plus two unsold prototypes. The largest market for the E-170s has proven to be in North America (76 in total), although this has been very concentrated. In fact 25% of all the E-170s ordered have been delivered to a single customer, Republic Airlines. The balance have been sold in Europe (38 aircraft), Africa/Middle East (37), Asia (19), Australasia (6) and South/Central America/Caribbean (3). The other 14 aircraft were delivered to lessor GECAS.

GECAS ordered 50 E-170s in June 2000, but the operating lease market has not developed as expected and, in the end, only took delivery of nine aircraft. Four were leased to LOT Polish Airlines, and a further four went to Hong Kong Express, although these four were returned to GECAS in 2007 and subsequently placed with AirNorth (1) and SkyAirWorld (1) both of Australia, and Kenya Airways (2). The two 'used' aircraft delivered to Kenya Airways were followed by a third aircraft delivered direct from Embraer, but again on lease from GECAS. In April 2008 Aldus Aviation, a new leasing company, bought eleven of the GECAS fleet of E-Jets, and another three in October. Not all 14 aircraft have been identified, but the total includes two E-170s with LOT Polish Airlines, and five E-190s with Aeromexico (2) and Regional (3). GECAS also added two more E-190s through a sale and leaseback with Virgin Blue.

Apart from GECAS and Aldus Aviation, the only other lessors are ECC Leasing and Jetscape. The Embraer subsidiary ECC Leasing has four of the six prototype aircraft in its portfolio. These are currently leased to Cirrus of Germany (1), Paramount Airways of India (2) and SATENA of Colombia (1). Jetscape has a single E-170 leased to AirNorth of Australia. Aside from the four prototype/development aircraft that have been leased out by ECC Leasing, there have been relatively few 'used' transactions for the E-170.

The list price of the E-170 is $31.5 million, but the Republic aircraft have been offered at $20 million. Market lease rates are $180,000 per month.

E-175 market

The E-175 has not achieved the same widespread market acceptance as the smaller E-170. The majority of the E-175s have been ordered for the North American market (105 in total). The balance have been sold in Europe (16), South/Central America/Caribbean (6), Africa/Middle East (2) and Asia (1). The remaining five aircraft were delivered to GECAS.

Three of the GECAS aircraft are leased to Paramount of India, and the remaining two aircraft are leased to LOT Polish Airlines. The only other lessor is ECC Leasing, which has aircraft leased to Cirrus of Germany (1) and TRIP Linhas Aereas of Brazil (1).

Apart from various short-term leases, there have been no 'used' transactions, and there are currently no E-175s on the market. Market lease rates are estimated at $200,000 per month.

E-190 market

The E-190 has become the most popular model, accounting for 443 sales and constituting over 60% of the current backlog. The majority of E-190s have been ordered for the North American market (191 in total). The balance has been sold in Europe (68), Asia (55), South/Central America/Caribbean (52), Africa/Middle East (23) and Australasia (18). The other 34 have been ordered by ECC Leasing, GECAS and Jetscape.

GECAS has ordered a total of 24 aircraft, all but one of which has been delivered. Lessees comprise Aeromexico (4), Aerorepublica (7), Mandarin Airlines (7), National Air Service (3) and, until its recent failure, Sky Air World (2). Availability from GECAS is limited to the two former Sky Air World aircraft, although even these are believed to be earmarked for Republic Airlines and its Air Midwest operation.

Jetscape placed an order for 10 E-190s, with options on a further 10 and purchase rights on yet another 10. To date only one has been delivered (a second was converted into an order for the E-170 and delivered to Air North), but, in addition to the aircraft ordered from the manufacturer, Jetscape has bought four more E-190s, two in a sale-and-leaseback transaction with Aeromexico, and a further two purchased from JetBlue and leased to Azul of Brazil.

There are only two E-190s on the market, both recent deliveries to TACA of El Salvador and being offered by Airfleet Resources. Jetscape has nine outstanding deliveries for delivery from 2010.

The list price of the E-190 is $37.5 million, but TACA was believed to be looking for $31.5 million for their aircraft. Market lease rates were close to $300,000 per month, but the most recent transaction, involving jetBlue leasing two of its aircraft to Azul, is believed to have been at a rate of around $250,000.

E-195 market

The E-195 is the least popular of the E-Jets having achieved a total of only 111 orders. The E-190 has been four times more popular with 443.

The E-195 has completely failed to penetrate the North American market. The majority of the E-190s have been sold in Europe (51) and South America (51) with Africa/Middle East accounting for the remaining two. The remaining seven aircraft have been ordered by GECAS. Lessees comprise Montenegro Airlines (2), National Air Service (2) and Royal Jordanian (3).

There are no E-195s on the market, although at least one operator is known to be offering aircraft. The list price of the E-195 is US$ 39.50 million, but the Globalia aircraft were being offered at around $31 million. Lease rates of $260,000 per month are being offered.

Summary

The E-170 and -175 have found their largest market as a replacement for 50-seat regional jets in North America and Europe.

The E-190 and E-195 have found a niche as a replacement for the previous generation of 70-100 seaters. This is particularly true in Europe, where they have replaced Alpi Eagles Fokker 100s, BA Cityflyer's Avro RJ100s, Flybe's BAE 146s, KLM's Fokker 100s, Lufthansa's BAE 146/RJs and Montenegro Airlines' Fokker 100s. In the rest of the world they have found a further niche as the equipment for the low-cost carriers Azul, jetBlue, NAS Air and Virgin Blue. AC

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