The Embraer E2 Jets are third family of aircraft that have been an improvement of an existing family based on re-engining the aircraft with bypass ratio engines to effect a large reduction in fuel burn.

Embraer E2 jets: initial assessment

The Embraer E2 jet family was launched in June 2013 to supersede the E-Jet, or E1, family. The E-Jet family has attracted more than 1,570 firm orders since it was launched in 1999. The E2 family was launched on similar principles to the A320 new engine option (neo) and 737 MAX families. The aircraft are equipped with new-generation, high-bypass ratio engines that provide the aircraft with up to 10-26% lower fuel burn, and the possibility of lower engine-related maintenance costs. The launch of a new family of aircraft also provided the opportunity to make improvements to the airframe and its maintenance programme to reduce airframe- and component-related maintenance costs.

The E2 family has won 240 firm orders. The E2's family features are examined here.

E2 family

The E2 family has three main members: the E175-E2, the E190-E2, and the E195-E2. The E-Jet family has four variants, of which the E-170 has the shortest fuselage and seat capacity. This has not been replaced in the E2 family.

The E175-E2 replaces the E-175, although the E175-E2 is about two-and-a-half feet (0.7 metres) longer than the E-175. The E175-E2 has a standard dual-class seat capacity of 80 *(see table, page 18)*.

The E190-E2 has the same fuselage length as the E-190, and has a standard dual-class seat capacity of 96 *(see table, page 18)*.

The E195-E2 has a fuselage that is almost 10 feet (2.85 metres) longer than its predecessor, the E-195. This gives the E195-E2 a standard dual-class seat capacity of 120. This is equal to four rows of economy seats with a five-abreast seat arrangement, and so 20 seats more than the E-195.

The E2 family therefore has two variants with higher seat capacities than their predecessors. The three E2 family variants also have new wings, with a wider span that provides a higher aspect ratio than the E1 family. This contributes to the E2's improvement in fuel burn, together with the new-generation engines.

The E2 jets are powered by two variants of the Pratt & Whitney (PW) PW1000G engine family. The PW1715G powers the E175-E2. Rated at 15,000lbs thrust, it has a 56-inch diameter fan and a bypass ratio of 9:1 *(see table, page 18)*. This compares with the CF34-8E, which is rated at 14,200lbs thrust and has a bypass ratio of 5:1.

The PW1919G/21G/22G/23G power the E190-E2 and E195-E2. These four variants are rated at 20,860lbs thrust, 22,550lbs thrust, and 23,815lbs thrust *(see table, page 18)*. These variants have a 73-inch fan diameter and a bypass ratio of 12:1. This compares with the CF34-10E that power the E-190 and E-195, which have a bypass ratio of 5.4:1.

The utilisation of the PW1700G/1900G engine on the E2 family has therefore effected a significant increase in engine bypass ratio, which has translated into a lower noise footprint and lower specific fuel consumption (sfc) and aircraft fuel burn. The E175-E2 is expected to have about 10% lower fuel burn than the E-175. The E190-E2 is expected to have a 17.3% lower fuel burn than the E-190, and the E195-E2 will have a 26% lower fuel burn than the E-195. The E190-E2 and E195-E2 will have a larger fuel burn difference than their counterparts in the E1 family, compared to the difference that the E175-E2 has with the E-175. This is explained by the PW1900G having a wider fan and higher bypass ratio than the PW1700G.

The E2 family's weight, passenger payload and seat configuration, operating range, and engine specifications are summarised *(see table, page 18)*.

The E2 family has several main competitors. There is no alternative commercial aircraft family, however, that provides capacity across the 80-120 seats. There are two aircraft programmes with seat capacities close or similar to two members of the E2 family, and there are two other single types with seat capacities close to a single member of the E2 family.

The E175-E2 has several close competitors. The first of the two families partly competing on a seat capacity basis is the Bombardier CRJ family. The CRJ700 has a single-class capacity of 78 and a dual-class capacity of 66 seats. It therefore provides a smaller alternative to the E175-E2, and is closer in size to the E-170.

The CRJ900 has a single-class capacity of 90 seats, and a dual-class capacity of 76. This is almost the same as the E175-E2, but the CRJ900's seat capacity is provided in a four-abreast arrangement.

The second aircraft family to offer two types as alternatives to the E2 family is the Mitsubishi Regional Jet MRJ family. The MRJ70 has a standard single-class seat capacity of 80, and dual-class capacity of 69. This is close to the CRJ700 and E-170.

The first of the E2 jets, the E190-E2, entered into service in April 2018. The aircraft is powered by the PW1900G, which has a bypass ratio of 12.0:1. This will achieve high fuel burn efficiency, and the aircraft is expected to have a 17.3% lower fuel burn than its equal-sized predecessor the E-190 or E190-E1.

The larger MRJ90 has single- and dual-class capacities of 92 and 81, making it close in capacity to the E175-E2 and the CRJ900.

The E190-E2 has two close competitors. The CRJ1000, the largest variant of the Bombardier CRJ family, has single- and dual-class seat configurations of 104 and 97 seats, close to the E190-E2's capacity. The Sukhoi Superjet 100, SSJ100, has single- and dual-class layouts of 108 and 87 seats, which also makes it close to the E190-E2.

The E195-E2 has one close competitor, the Airbus A220-100 (formerly the Bombardier CS100). The A220-100 is the smaller of two variants, the larger being the A220-200 (formerly the CS300). The A220 is configured with a five-abreast economy-class layout, giving it a wider cabin and fuselage than the E2 family. The A220-100 has single- and dual-class seat capacities of 133 and 108 seats. This puts it at almost the same seat numbers as the E195-E2, although seat capacity depends on several variable factors.

The E2 family has so far attracted one-sixth of the firm orders won by the E-Jets, or E1 jets, since 1999. The E175-E2 has 100 orders from SkyWest Airlines, which operates as American Eagle, SkyWest, Delta Connection and United Express, providing regional services for American Airlines, Alaska Airlines, Delta Airlines, and United Airlines. The SkyWest aircraft will be configured in a 60-seat capacity, about two-thirds of its potential seat numbers, because aircraft seat numbers are limited by mainline carrier pilot-union scope clauses. The aircraft are due for certification and delivery from 2021.

The E190-E2 has won 86 firm orders. This includes small orders for Norwegian carrier Wideroe and Chinese operator Fuzhou Airlines. The remaining orders for 81 aircraft are from lessors. This includes 42 from AerCap, 27 from Aircastle, and 12 from ICBC Leasing. The first three aircraft have been delivered to Wideroe. The E190-E2 was certified in April 2018 *(see table, page 18)*.

The E195-E2 has 94 firm orders. Like the E190-E2, the majority are from aircraft lessors. Azul Airlines of Brazil has a firm order for 36 aircraft, and Wataniya Airways of Kuwait for 10. AerCap and Aircastle have firm orders for 35 aircraft. The E195-E2 is due for certification in 2019.

Some of the most notable features of the E2 family are its weights, and how these compare to the E-Jets or E1 family. Examination of maximum take-off weight (MTOW) per seat reveals that the E2 jets are generally heavier than most direct competitors. The same applies to operating empty weight (OEW) per seat.

Avionics & connectivity

The E2 family will have a fly-by-wire (FBW) system, which will contribute to its lower OEW, and also to simpler maintenance and fewer deep access inspection and testing tasks.

The E2 family will have CAT III landing capability as standard, and will be capable of future air navigation system (FANS) datalink applications using very high frequency (VHF) radio or Iridium-based L-band satcom communications. The E2 family will have FANS datalink hardware installed on the aircraft. This will allow two applications for controller-pilot datalink communications (CPDLC) messages. One will be for medium-haul routes over oceanic, desert and remote areas that may operate with the system in the future. The FANS capability will also make the aircraft compliant with equipment required for the Single European Sky ATM Research (SESAR) and North American NextGen aircraft operation and air traffic management (ATM) systems.

The E2 family will also have the option of being equipped with tablet-based Class 2 electronic flight bags (EFBs). The aircraft will have an optional wireless server unit (WSU). This will operate as an on-ground, wireless connectivity unit, with both WiFi and cellular systems, according to availability at each airport. The WSU can partly be used to upload and download data to and from the EFB.

Aircraft data

The E2 jets have been equipped with the Honeywell EPIC avionics system. This provides the aircraft with an integrated modular avionics (IMA) architecture that provides all avionics and data communications functions in one unit. It replaces the traditional system of individual avionics boxes operating on ARINC protocols.

"The E2 jets have a databus that connects all of the aircraft's systems. This is referred to as the avionics system control bus (ASCB), and it stores data relating to 40,000 aircraft parameters," says Carlos Barra, director technical support engineering at Embraer Service and Support. "The aircraft's systems have a lot of integration between them, and they are

EMBRAER E2 FAMILY FEATURES & SPECIFICATIONS

Family variant	E175-E2	E190-E2	E195-E2
Date certified	2021	April 2018	2019
Standard single-class seat capacity	88/90	104/114	132/146
Standard dual-class seat capacity	80	96	120
MTOW - lbs	98,676	124,340	135,584
OEW - lbs		72,752	
Maximum structural payload - lbs	23,369	30,203	35,605
Usable fuel - lbs	18,788	29,76-	29,321
Range with full passenger payload	2,017nm	2,931nm	2,655nm
Engines	PW1715G	PW1919G/21G/22G/23G	
Thrust rating - lbs	15,000	20,860/22,550/23,815	
Fan diameter	56 inches		73 inches
Bypass ratio	9:1		12:1

all interconnected via the ASCB. The ASCB is connected to the EPIC integrated modular avionics system and various aircraft systems."

The IMA architecture takes advantage of an enhanced avionics standard communications bus (eASCB-D), with four physically segregated buses and a star architecture local area network (LAN).

The aircraft's external connectivity systems and sensors include the inertial reference system, fly-by-wire (FBW) system, radio altimeter, WSU, HF radios, weather radar, and various other sensors. These all feed into the aircraft's IMA and ASCB, which are then interfaced with the flightdeck screens and the multifunction control and display unit.

"All 40,000 of the aircraft's parameters are monitored for the purposes of aircraft management and safety," continues Barra. "The most important 20,000 parameters can be selected, and there are 10,000 that provide very detailed information in relation to the aircraft's systems. These compose about 5,000 maintenance messages. These can be viewed by the flightcrew on the aircraft's central maintenance computer. Moreover, these messages can be customised to provide information in relation to a particular aircraft system."

The E2 jets also have the capacity to record another 3,250 parameters. In addition to this, the aircraft's quick access recorder (QAR) has the capacity to record about 2,000 analogue parameters. This includes parameters used by PW for the PW1000G engine.

The E2 family is also capable of both WiFi and cellular on-ground data communications for downloading aircraft health monitoring and operational data that is stored in the aircraft's QAR.

"The large number of aircraft parameters are monitored, processed and analysed for the purposes of predictive maintenance and improving the efficiency of flight operations," says Barra. "Parameter data can be transmitted to the ground in flight using the aircraft's aircraft communications addressing and reporting system (ACARS) via the usual connectivity systems, such as VHF radio and L-band satcom if installed on the aircraft."

Two categories of data are transmitted in flight. The first is data from the aircraft condition monitoring system (ACMS), and the second is data relating to system faults detected in flight. The crew alerting system means that these can be viewed in flight.

Data that is not transmitted in flight will be transferred to the aircraft operator's flight operations and maintenance IT systems using an on-ground connectivity system that has a high data transfer rate. "The E2 jets have an optional WSU that is provided by Honeywell. All E2 customers have so far taken the option of the Honeywell WSU," explains Barra. "The WSU uses either cellular or WiFi on-ground connectivity links, and so is flexible according to what is available at each airport. The data is downloaded automatically from the QAR via the WSU when the aircraft arrives at the gate. If the WSU is not installed on the aircraft then a solid state disk has to be used, and the data has to be downloaded by a line mechanic."

Embraer also offers a data analysis service. "There are several uses of the data collected from this large number of parameters," says Barra. "Embraer offers the aircraft health analysis and diagnosis (AHEAD) system. This on-ground service monitors the trend of failures and performance of certain parameters and components on the aircraft. It is therefore a health monitoring and a predictive maintenance service intended to prevent likely system and component failures and problems. AHEAD is a real-time service that analyses the data sent during flight. The system is used by the airline's maintenance control centre, and the data is monitored for all aircraft in an airline's fleet. The operations staff view the AHEAD system on screens for the purposes of getting maintenance and fault messages transmitted during flight and sent to the maintenance control and flight operations departments."

The AHEAD system therefore allows the flight operations and maintenance control departments to take actions on the aircraft prior to landing.

There is also the prognostics service, which collects data relating to a large number of parameters for certain components and systems. This is basically a predictive analytics service for the purposes of determining long-term trends in component and system performance.

AHEAD-PRO is a computational web-based platform that continuously monitors the health of the fleet, providing timely maintenance information. The aircraft systems' health condition is systematically assessed. AHEAD-PRO is used to avoid the unplanned or unscheduled maintenance of monitored systems by predicting component and system failures.

The use of AHEAD-PRO also allows airline flight operations and maintenance control departments to plan resources and rectification procedures.

Technical documentation

Another aspect of aircraft management is the provision of technical documents and manuals. All commercial aircraft manufacturers now provide on-line technical documentation services for electronic manuals through their web portals. Embraer provides its FlyEmbraer on-line documentation service to its customers.

These are optional for airlines to use, which have the alternative of hosting the technical documents on their own maintenance and engineering (M&E) IT systems. The service Embraer provides is similar to Boeing's MyBoeingFleet service.

"The documents and manuals for the E2 Jets are provided in iSpec 2200 format and standard generalised mark-up language (SGML) as standard. We can also provide it in extensible mark-up language (XML) if a customer prefers," says Barra. "The FlyEmbraer portal is used to view and manage all documents, as well as the data provided by the AHEAD system.

"The main point of FlyEmbraer is for airlines and operators of Embraer aircraft to author and edit maintenance task cards,

The E2 Jets family has several features that will provide maintenance cost reductions over the E1 family of aircraft. These include longer airframe check intervals, and engine LLPs with uniform lives of 25,000EFC.

and some of the technical manuals in relation to their approved maintenance programme (AMP)," continues Barra. "The ability to author and edit comes from airlines creating their own routine task cards to be added to maintenance planning document (MPD) tasks, but also to edit MPD maintenance tasks. An alternative is for operators to create their own maintenance task cards in their M&E and content management systems (CMS), and then upload them to FlyEmbraer. This refers to routine task cards, but non-routine task cards can be written and edited the same way."

Another use of FlyEmbraer is for the authoring of engineering orders (EOs), or in-house modifications. "This can be an in-flight entertainment (IFE) installation or another type of aircraft interior modification that airlines often write internally, and get approved by their local airworthiness authority," says Barra. "Again, these could be written internally, and then uploaded to FlyEmbraer. Another alternative is for Embraer to write the EO for the airline."

With technical documents and manuals kept in electronic format, and written in iSpec 2200 format and in SGML/XML language comes the ability to perform maintenance with an all-electronic task card system. "The FlyEmbraer system allows the electronic task cards held in an airline's account to be transferred remotely to the facility where airframe maintenance checks are being performed. The task cards can therefore be viewed on electronic devices, such as tablet computers for the purposes of performing paperless maintenance," says Barra. "The completed electronic maintenance task cards, and the associated data can then be transferred to the operator's M&E system for the purposes of electronic storage."

Airframe maintenance

The E2 family has an airframe maintenance programme with check intervals that are one-third longer than those of the E1, or E-Jets, family.

The E1 family had two MPDs, one for the E-170 and -175, and one for the E-190 and E-195. The A checks have basic intervals of 750FH and a base check interval of 7,500FH. The base check programme has a cycle of four checks, with the fuel check cycle having an interval of 30,000FH. This is equal to 150 months or 12 years of operations at typical rates of utilisation.

Unlike the E1 jets, the E2 family will have a single MPD.

The E2 family has a programme of A checks at 1,000FH intervals, and base checks at 10,000FH intervals. There are multiples of 10,000FH tasks. These are mainly system tasks. The 10,000FH limit is equal to three to four years of operation at typical rates of utilisation.

There are also structures tasks with intervals of 7,500FC for external inspections, and 15,000FC for internal inspections. This last group of tasks has inspections that require deep access.

There are also inspections for the corrosion prevention and control program (CPCP). The two inspection limits are eight and 16 years. This requires the complete removal of the aircraft's interior because of the access required. These are therefore best combined with the second and fourth base checks, which will also have the 7,500FC and 15,000FC structural inspections included.

These intervals should therefore generate a base airframe check cycle of four base checks with intervals of 10,000FH. Checks will be performed about every three years, and the second and fourth checks in the cycle will include deep access, internal structural inspections, and CPCP inspections that also require deep access. The base check cycle should therefore be completed about every 12 years.

Engine maintenance

A large portion of total maintenance costs will be engine-related. The PW1715G powering the E175-E2 is smaller than the PW1919/21/22/23G powering the E190-E2 and E195-E2.

The PW1715G has the smaller 53-inch diameter fan, plus two low pressure compressor (LPC), eight high pressure compressor (HPC), two high pressure turbine (HPT) and three low pressure turbine (LPT) stages. The engine achieves a bypass ratio of 9.0:1.

The engine has six life-limited parts (LLPs) in the fan and LPC module, four LLPs in the LPT module, 11 parts in the HPC module and six parts in the HPT module; a total of 28 LLPs. These include seals. The 2018 list price for a shipset of LLPs is about $4.0 million, and target life limits of all parts is 25,000EFC. This will result in a reserve for all parts of a minimum of $160 per engine flight cycle (EFC), on the basis that the parts fully utilise their target life limits. A shipset of LLPs will need to be changed after 10-12 years of operation, given likely rates of utilisation for the E2 jets.

The PW1900G is the larger engine. It has a 73-inch diameter fan, so it is able to achieve a higher bypass ratio of 12.0:1. The engine has three LPC stages, eight HPC stages, a two-stage HPT that is standard for the PW1000G family, and a three stage LPT.

Like the PW1700G, the PW1900G has a shipset of 28 LLPs that have target lives of 25,000EFC. Again, these have a 2018 list price of about $4 million, which on the simplest level will result in a reserve of about $160 per EFC. - *CW* AC