Embraer launched its next generation RJ family in June 2013. The estimated performance improvements and operating cost savings of the E-Jets E2 are examined here.

E-Jets E2 – An initial assessment

Embraer's E-Jets are currently the best-selling family of regional jets (RJs) in the 60-120-seat category. There are more than 900 E-Jets currently in passenger service with over 60 airlines worldwide, accounting for one-third of the active, western-built, regional passenger aircraft fleet in their size bracket.

Recent years have seen increased competition in the large RJ sector. Bombardier has enhanced its CRJ family of aircraft, while a number of new 'clean-sheet' designs, promising increased efficiency and lower costs, have entered the market. These include the Sukhoi Superjet SSJ100-95, the Bombardier CS100 and the Mitsubishi MRJ family.

Embraer's response to this competition was to launch its second-generation RJ programme: the E-Jets E2.

Derivative or new design?

Embraer has met the challenge of new entrants by deciding to modify its existing product, rather than developing an all-new aircraft.

"We did consider a complete re-design," says Claudio Camelier, vice president of market intelligence at Embraer Commercial Aviation. "In the end we concluded that we could achieve similar operating cost and efficiency improvements to a clean-sheet design by modifying the existing E-Jet product."

The main differences between the E-Jets E2 and their predecessors will be new engines, a re-designed wing, new fourth-generation full fly-by-wire (FBW) controls, a new interior and other systems improvements.

"These changes allow us to offer cost and efficiency improvements while avoiding the inherent risks associated with developing a completely new design," claims Camelier. Bombardier and Mitsubishi have had to push back the introduction of their CSeries and MRJ aircraft due to development delays. In a recent statement Mitsubishi revised the initial delivery date for its MRJ90 from 2015 to the second quarter of 2017. This is only one year before the first E-Jet E2 is due to enter service.

Another key element of Embraer's decision to base the E-Jets E2 family on its current product was the ability to offer flightdeck commonality. The E-Jets E2 will have a new integrated avionics suite, but this will be evolved from the system being used on the current-generation aircraft. "We will have a common type rating between current E-Jets and the E-Jets E2," explains Camelier. "We expect that pilots will need fewer than three days of training to transition between the models, with no need for full flight simulators or high-level flight-training devices. Crew training is an important cost consideration for airlines, so this level of flightdeck commonality should make the E-Jets E2 appealing to current E-Jet operators."

E-Jets E2 specifications

The current E-Jet family consists of the E170, E175, E190 and E195. There are standard (STD), long-range (LR) and advanced-range (AR) variants of each model. The E170/175 and E190/195 are certified as two separate types.

The E-Jets E2 family will consist of the E175 E2, the E190 E2 and the E195 E2. There will be no second-generation variant of the E170. Embraer has not yet decided if it will produce STD, LR and AR variants.

In a standard single-class configuration, the E175 E2 will be one seat row larger than the original E175, while the E190 E2 remains the same size as its predecessor. The E195 E2 will have three more seat rows than the current E195. The E175 E2 and E190/195 E2 will be classified as two separate types.

"The original E170 and E175 are similar in size, and basically address the same market with almost equal operating costs," explains Camelier. "With the E-Jets E2 we have adopted a more balanced size distribution between the models, with about 20% variation in seat capacity between each aircraft. We are covering a bigger market with fewer models. The E175 E2 has been sized as the ideal 76-80-seat, dual-class aircraft for US regional flying."

North America is a primary focus market for RJ manufacturers. Pilot scope clauses in the region can specify the size, type and number of aircraft that regional carriers can operate under the branding of a major airline. In recent years there has been a trend for these scope clauses to be relaxed allowing operations with more large RJs, up to 76 seats in size. Camelier believes this will result in reduced demand for RJs with a dual-class capacity of fewer than 76 seats.

E175 E2

The E175 E2 is expected to enter service in 2020 *(see table, page 8)*. It will seat 80 passengers in a two-class configuration, or up to a maximum of 90 in a high-density, single-class configuration. It will be powered by PW1700G engines, have a maximum take-off weight (MTOW) of 97,731lbs and be capable of carrying a full, single-class passenger payload a distance of 1,920 nautical miles (nm).

The E175 E2 is expected to demonstrate fuel burn and CO2 savings of about 16% per seat compared to its predecessor on a typical 600nm sector *(see table, page 8)*. Design targets for the aircraft include a NOx margin 38% below CAEP 8 standards, and a noise margin of 10 EPNdB below stage IV requirements.

E-JETS E2 SERIES SPECIFICATIONS

	E175 E2	E190 E2	E190 E2
Two Class Seating	80	97	118
Std Single Class Seating	88	106	132
Max High Density Seating	90	114	144
Economy Layout	2+2	2+2	2+2
Cargo Volume (cu ft)	604	752	1,038
Engine Type	PW1700G	PW1900G	PW1900G
Engine Thrust (lbs)	STD Thrust: 15,000	STD Thrust: 19,000	STD Thrust: 21,000
		High Thrust: 22,000	High Thrust: 22,000
Fan Diameter (inches)	56	73	73
Bypass Ratio	9:1	12:1	12:1
MTOW (lbs)	97,731	125,443	130,954
MLW (lbs)	86,201	109,018	118,498
Payload (lbs)	22,730	28,836	33,400
Range (nm)	1,920	2,800	2,000
Take-off Field Length (ft)	7,349	5,905	6,398
Landing Field Length (ft)	4,429	4,101	4,429
Cruise Speed (Mach)	0.78	0.78	0.78
On Board MTCE computer	Yes	Yes	Yes
Fuel Burn Savings (% per seat) relative to 1st generation EJet	16%	16%	23%
NOx Margin to CAEP 8	38%	42%	39%
Noise Margin to Stage IV (EPNdB)	10	15	13
CO2 Savings (% per seat)	16%	16%	23%
Entry into Service	2020	2018	2019
Firm Orders	100	25	25
Options	0	25	25

Notes:

1). Range based on max single-class pax payload, LRC, typical fuel reserves, 100nm alternate fuel.

2). Fuel burn reduction based on comparison with current E-Jets. Fuel savings are target values for 600nm sector in a dual class config.

3). Orders and options correct as of July 2013.

E190 E2

The E190 E2 will be the first of the next generation E-Jets to enter service. It is currently due for first delivery in 2018. The E190 E2 will accommodate 97 passengers in a dual-class arrangement, or up to 114 in a high-density single-class cabin. It will be fitted with PW1900G engines and have an MTOW of 125,443lbs. The aircraft will be capable of carrying a full, single-class passenger payload up to 2,800nm.

Embraer estimates that the E190 E2 will burn 16% less fuel and produce 16% less CO2 per seat than the original model. It is expected to have a NOx margin 42% below CAEP 8 standards, and a noise margin of 15 EPNdB below Stage IV requirements.

E195 E2

The largest member of the E-Jet E2 family will seat 118 passengers in a dual-class cabin, or up to 144 in a high-density single-class configuration. The E195 E2 will have three more seat rows, and so 12 more seats than the E195.

The E195 E2 will be powered by PW1900G engines, and have an MTOW of 130,954lbs. It will carry a full, single-class passenger payload up to a distance of 2,000nm.

The E195 E2 is expected to burn 23% less fuel and produce 23% less CO2 per seat than its predecessor. Embraer estimates that the aircraft will have a NOx margin 39% below CAEP 8 standards, and a noise margin of 13 EPNdB below Stage IV requirements.

Fleet commonality

The three members of the E-Jet E2 family will have 100% flightdeck commonality. The common type rating between aircraft means that pilots can transition between variants with no extra training.

There will also be a high level of parts commonality between the E-Jet E2 variants. "Based on the Recommended Spare Parts List (RSPL), the expected commonality levels are 100% between the E190 E2 and the E195 E2," claims Camelier. "The expected commonality between the E175 E2 and E190/195 E2 is 73%." This level of commonality would allow operators of multiple variants to minimise their rotable spares inventories and associated maintenance costs.

Efficiency improvements

Embraer believes that the E-Jets E2 variants will realise costs savings over its current RJ family in three main areas: reduced fuel burn, maintenance costs and noise levels.

Some of the main changes that will permit these gains include new engines, a new wing design and full fourth-generation FBW controls.

Engines

Pratt & Whitney (P&W) will be the exclusive engine supplier for the E-Jets E2 family. Embraer joined Mitsubishi, Bombardier and Airbus in choosing the PurePower® PW1000G engine series to power its new aircraft programme. These are a series of high-bypass, geared turbofan engines.

The E175 E2 will have PW1700G engines with a fan diameter of 56 inches and a bypass ratio of 9:1 *(see table, this page)*. The PW1700G will have a standard thrust rating of 15,000lbs.

The E190 E2 will use PW1900G engines. These engines will have a fan diameter of 73 inches and a bypass ratio of 12:1. The PW1900G variant fitted to the E190 E2 will have a standard thrust rating of 19,000lbs, and a high thrust option rated at 22,000lbs.

The E195 E2 will also have PW1900G engines. Although they will have the same fan diameter and bypass ratio of those used for the E190 E2, the larger aircraft's engines will have a higher standard thrust rating of 21,000lbs. The high thrust option is the same as that for the E190 E2, and is rated at 22,000lbs.

The strategy behind the geared turbofan is that it will reduce fuel burn by increasing propulsive efficiency. The propulsive efficiency of an engine depends on the ratio of the exit speed of the accelerated air mass, compared to the forward speed of the aircraft. The closer

Embraer took the decision to develop a derivative of the first generation of E-Jets. The E2 generation will provide reductions in cash operating costs from a 16% or 23% lower fuel burn, and lower engine- and airframe-related maintenance costs.

the two speeds, the higher the propulsive efficiency. Accelerating a larger mass of air by a small amount by using a wider intake fan leads to a higher propulsive efficiency.

"In traditional jet engines the fan and low pressure compressor (LPC) have to operate at the same revolutionary speed," explains Camelier. "This means that neither is able to turn at its optimum speed. The PurePower® PW1000G series of engines includes a reduction gear between the fan and LPC. This allows the fan to spin at lower speeds, permitting a larger fan diameter and higher bypass ratio." The result is a larger amount of air being accelerated more slowly, leading to higher propulsive efficiency and lower fuel burn.

The resulting lower exit speed of the accelerated air also reduces noise levels when compared to existing engines. Embraer believes this will lead to lower noise-related fees, and allow airlines to take more direct flight tracks and request curfew extensions. The manufacturer claims that this could provide up to a 3% reduction in cash operating costs.

The geared turbofan engines may also reduce engine-related maintenance costs. Embraer is targeting a 15% reduction in overall maintenance costs with the E-Jets E2 family. About half of these savings are expected to come from the new engines. Embraer claims that they will spend longer time on-wing than current powerplants. In addition, the gear mechanism permits the LPC and the low-pressure turbine (LPT) which drives it, to optimise their efficiency by turning at higher revolutions. This means that the same amount of pressure can be generated with fewer engine stages and airfoils. Fewer stages can translate to lower maintenance costs.

Embraer admits that the geared turbofan design has some disadvantages. "It is a heavier engine than those used on the current E-Jets," explains Camelier. "This is mainly a result of the gear system and the larger fan. Some of this extra weight is offset by the fewer stages in the compressor. The greater propulsive efficiency provided by the engine's design more than overcomes the additional weight penalty."

Wing design

The E-Jets E2 will have a new wing design. Their wings will have a higher aspect ratio than the current E-Jet family.

The aspect ratio takes into account a wing's length and width. The longer and thinner the wing, the higher the aspect ratio. A higher aspect ratio can lead to less induced drag and reduced fuel burn.

The E-Jets E2 will have raked wing tips. "A raked wing is the optimum solution for maximising aerodynamic efficiency for aircraft of the size and characteristics of the E-Jets E2," claims Camelier.

4th generation fly-by-wire

Embraer has built on its experience with previous systems on the original E-Jets to design full FBW controls for the E-Jets E2.

Although the FBW system on the current E-Jets controls the roll spoilers, it does not power the ailerons. On the E-Jets E2 all of the primary flight controls will be FBW.

"The new generation FBW will allow the E-Jets E2 to fly with a more aft centre of gravity (C of G) position," claims Camelier. "In flight, the lift generated by an aircraft's wings is balanced by an opposing force provided by the stabiliser to maintain an optimum angle-of-attack. When the C of G is further aft, the negative lift generated by the stabiliser can be smaller, resulting in less drag and lower fuel burn."

The further benefit if a FBW system is fewer maintenance tasks to calibrate the flight control system.

Airframe maintenance

About 50% of the E-Jets E2 family's expected maintenance savings will come from reduced airframe inspection requirements.

The current E-Jets have a Maintenance Steering Group 3 (MSG3) maintenance programme. This permits airlines to organise maintenance tasks into line and base checks, according to their rates of utilisation.

There are a number of required inspections with intervals of about 600FH and multiples of 600FH, and most airlines will group these into 'intermediate' or 'A' checks. There are also many tasks with intervals of about 6,000FH, and airlines will most likely group these into 'base' or 'C' checks. These intervals are now being increased to 750FH for A checks and 7,500FH for C checks.

The E-Jets E2 will also have an MSG 3 maintenance programme, but the main groups of tasks will have their intervals extended further to 850FH and 8,500FH.

Structural maintenance inspection intervals will also be extended. Structural tasks have an initial inspection threshold of 20,000-40,000FC on the original E-Jets. All structural airworthiness limitation item tasks will have an initial inspection threshold of 40,000FC for the E-Jets E2. This means they will not come due until the aircraft have been operating for about 20 years. Corrosion prevention and control programme (CPCP) inspections will be distributed in the second and fourth base checks, equivalent to 17,000FH and 34,000FH.

It has yet to be confirmed whether the

REGIONAL AIRCRAFT FLEET, IN SERVICE AND ON ORDER

	Two-Class Seating	Maximum Seating	Entry into Service	Order Backlog	Options
MRJ70*	70-74	78	Unknown	0	0
MRJ90	81-85	92	2017	165	160
CS100**	108	125	Unknown	63	41
ARJ21	78	90	Unknown	122	70
	Two-Class Seating	**Maximum Seating**	**In Service**	**Order Backlog**	**Options**
E170	70	78	176	7	3
E175	76	88	155	148	287
E190	97	114	464	87	73
E195	106	124	123	19	0
CRJ-700	66	78	331	15	3
CRJ-900	79	90	236	49	44
CRJ-1000	93	104	34	36	18
SSJ100-95	87	98	13	132	35
ATR72		74	458	256	179
Q400		80	393	36	25

*EIS for the MRJ70 is currently unknown. Some MRJ90 orders have conversion option to MRJ70.

**EIS for CS100 is unknown.

Fleet data and orders correct as of July 2013.

E-Jets E2 will have fewer overall MPD tasks than the current-generation aircraft.

With more FBW controls replacing traditional systems for aileron control, there is a possibility that fewer systems inspection and calibration tasks will be required for flight controls.

There will be little change in the main fuselage structure between the original E-Jets and the E-Jets E2. The current structure is mostly aluminium, with 10% made up of composite materials. In comparison, about 70% of the fuselage of Bombardier's CSeries aircraft will be composite. This could mean that the CSeries will have fewer structural inspections requirements than the E-Jets E2.

The e-enabled aircraft

"In general the E-Jets E2 will be a more e-enabled aircraft for maintenance, flight operations and passenger entertainment," claims Camelier.

Embraer will supply the E-Jets E2 with an improved, on-board, central maintenance computer (CMC). "The CMC on the current E-Jets is designed to help troubleshooting," says Camelier. "It has data recording and transmission functions. Health monitoring is done on the ground using Embraer's AHEAD-PRO product, which is an aircraft health analysis, diagnosis and prognostics system."

The CMC for the E-Jets E2 will be re-designed to increase fault-reporting detail, and improve report formatting. It will have more memory, a faster fault-recording rate, and improved report transmission capabilities.

Embraer is not currently disclosing whether the new CMC will have a dedicated on-board interface, or how many remote access points in the outside of the aircraft will be provided for portable maintenance computers.

For operational connectivity, Embraer will offer the option of an installed Class 2 electronic flight bags (EFBs) for its E-Jets E2. The manufacturer already provides flight operations EFB software applications, including aircraft performance, weight and balance, and operations manuals.

"Cabin connectivity options for the E-Jets E2 are still being evaluated, but we expect an evolution from the current-generation aircraft, which already offer PC power outlets and wireless internet options," says Camelier.

Interior

Several interior refinements are planned for the E-Jets E2. "The new cabin design with have a fresh look and feel," claims Camelier. "It will be more durable, easier to reconfigure and have more hand luggage capacity than the current E-Jets." The re-designed cabin will have new, slim seats that will be lighter and provide more leg room. It will also benefit from LED lighting and larger overhead bins.

Target market

Embraer is not only targeting the regional market with its E-Jets E2. "The E-Jets are a very flexible tool with a wide range of applications," says Camelier. "Currently 54% of E-Jet operators are regional carriers, 28% are full-service airlines and 18% are low-cost carriers (LCCs). The E-Jets E2 will serve the 70–130-seat market."

The re-sized E175 E2 is well-suited to regional operations, including hub-and-spoke feeder services in the US. The launch customer for this aircraft is SkyWest Inc, a holding company that owns SkyWest Airlines and Express Jet Airlines. These regional airlines operate feeder services on behalf of major US carriers including Delta Air Lines, United Airlines, American Airlines, US Airways and Alaska Airlines.

SkyWest Inc already has 40 E175s on order for SkyWest Airlines. "The E175 E2 is a natural addition to our current order for the E175," says Brad Rich, president of SkyWest Inc. This reinforces Embraer's claim that the second-generation aircraft will appeal to existing E-Jet operators. "We chose the E175 E2 based on extremely compelling

Embraer has selected the PW1000G for the EJets E2 family. This has the combined effect of allowing the aircraft to be stretched and provide more capacity, and reduce fuel burn up to 23% over their predecessors.

economics, Embraer's excellent customer support, and its demonstrated commitment to continual improvement of its product," adds Rich. SkyWest Inc has yet to decide which of its regional airlines will operate the E175 E2.

Embraer believes the E190 and E195 E2 aircraft will complement operations with larger narrowbodies. "Market trends relating to the next-generation narrowbodies are seeing the bulk of orders placed for the larger variants, such as the A320neo and 737 MAX 8," says Camelier. These aircraft seat about 180 passengers in a single-class cabin. With standard single-class capacity of 106–132 seats, the E190 and E195 E2 have the potential to fill a gap in the market. "The E190 and E195 E2 are good aircraft for full-service airlines and LCCs looking to add new routes or extra frequencies on existing city-pairs, or to operate mid-demand-density routes where the extra capacity of larger narrowbodies is not required," suggests Camelier. "The E-190 and E-195 E2 offer similar comfort levels and costs per seat to narrowbodies, but with lower trip costs."

The competition

"Embraer is the leader in its segment in terms of market share by orders," says Camelier. "We expect the E-Jets E2 to help maintain this leadership in the 70-130-seat jet category.

"The closest competitors to the E175 E2 in the 70–90 seat market are the CRJ700 and 900, MRJ90, ARJ21, ATR72 and Q400," adds Camelier. "The closest competitors to the E190 E2 and E195 E2 in the 90–130 seat segment are the CS100, SSJ100, and CRJ1000. We do not see the CS300 as a direct competitor, because it is larger than the E195 E2."

The capacity and orders for the main competitors in the E-Jet E2 size category are summarised *(see table, page 12)*.

Embraer has already secured 150 firm orders and another 50 options for the E-Jets E2 family *(see table, page 12)*.

There are 100 E175 E2s on order backlog, all of which are destined for SkyWest Inc. The aircraft in the 70-90-seat category with the most outstanding orders is the ATR72. Turboprops can offer cheaper operating economics than RJs, but the advantages are generally limited to short routes, particularly those under 300nm *(see The fuel burn performance & costs of turboprops versus RJs, Aircraft Commerce, June/July 2013, page 13)*. To optimise efficiency, turboprops have to sacrifice speed. On routes beyond about 350-400nm most turboprops become uncompetitive with RJs. As these distances are exceeded, an RJ's greater speed can increase its overall productivity by allowing it to fit more rotations into a daily schedule than would be possible with a turboprop. This allows the RJ operator to spread costs over more flights resulting in lower costs per available seat mile (ASM).

There are 25 E190 E2s and 25 E195 E2s on order, with a further 25 options taken out for both types. All 50 orders and 50 options were placed by International Lease Finance Corporation (ILFC). The aircraft in the 90-130-seat category with the most outstanding orders is the SSJ100-95.

Summary

Embraer's conservative strategy to re-engineer its popular E-Jet family, rather than design an entirely new aircraft, looks to have its benefits. It will reduce the operating costs of an already proven design by improving fuel burn performance, lowering noise levels and reducing maintenance requirements. Embraer also avoids the potential complications and delays that can occur when developing a clean-sheet aircraft. Existing E-Jet operators might see it as a lower risk than adopting new, untried types. The ease with which flight crews will be able to transition from the current E-Jets to the second-generation aircraft will be particularly appealing.

One potential drawback to Embraer's conservative approach with the E-Jets E2 is comparable maintenance requirements to other new aircraft. Some of the new competing designs, such as the CS100, will have a higher percentage of composite materials in their fuselage structures. This in turn might lead to a need for fewer structural maintenance inspections and potentially lower maintenance costs. AC