MRJ, Superjet 100 & C Series add to plethora of regional jets.

The 70- to 110-seat market now has up to five contenders. The new aircraft families have been launched to provide new levels of technology over the incumbent CRJ & E-Jets.

The recent addition to the market of the Mitsubishi Regional Jet (MRJ), Sukhoi Superjet100 (SSJ100), and Bombardier C Series gives airlines up to five choices in some seat-size classes in the regional jet (RJ) market.

The upper end of the RJ market can be broadly divided into two groups: 70- to 80-seat aircraft; and 90- to 110-seat aircraft. Prior to the entry of the MRJ, SSJ100 and C Series, these two markets were contested by Bombardier's CRJ product and Embraer's E-Jets. The MRJ and SSJ100 have variants that fit in both markets. The C Series has two basic model sizes. The smaller C110 competes in the larger of the two size categories, while the larger C130 competes in a larger market, directly against types such as the A318, A319 and 737-600.

70- to 80-seat RJs

Actual seat numbers of all aircraft types vary depending on interior configuration. This is affected by items such as the number of toilets and galleys and the space they occupy, and seat pitch.

The CRJ-700 is the smallest aircraft in this category. Its seat capacity is 70 to 78, and it has a maximum take-off weight (MTOW) of 72,750-77,000lbs *(see table, page 5)*. It has a range of 1,434-2,002nm, depending on specification, which is one of the shortest ranges of types in this category.

The aircraft is powered by two General Electric (GE) CF34-8C5 turbofans rated at 12,670lbs thrust, which have a bypass ratio of 5.0:1. The aircraft has a cruise speed of Mach 0.78.

The CRJ-700 is a stretch derivative of the 50-seat CRJ-100/-200, and has the smallest cabin width. Although it has a four-abreast seat configuration like Embraer's E-Jets, the CRJ series has a narrower cabin and consequently narrower seat and aisle width.

The CRJ-700 entered service in 2001, and 263 units are in operation.

Bombardier followed the CRJ-700 with the higher gross weight CRJ-705. Besides having a higher MTOW of 80,500lbs and 84,500lbs, the aircraft also has engines rated at the higher thrust of 13,123lbs and a 200-300nm longer-range capability. The aircraft entered service in 2005, and 16 units are in operation.

Two members of the Embraer E-jets family are the E-170 and E-175, with a longer fuselage and 70-80 and 78-88 seats respectively depending on configuration. The E-170 is therefore similar in capacity to the CRJ-700/-705. The E-170/-175 are aimed at a broader market than the CRJ. While it is used as a regional feeder, the E-170/-175 is also used by major airlines for downsizing from airliner jets such as the MD-87, 737-500/-600 and A318/19. Finnair and LOT Polish are examples.

The E-jets have a wider fuselage and, with the aircraft having the same four-abreast configuration as the CRJ, also have wider seats and aisle. The E-170 has a similar MTOW and range to the CRJ-705 *(see table, page 5)*. The aircraft is powered by the GE CF34-8E, a variant of the CF34-8C5 powering the CRJ-700/-705. The -8E is rated at 13,800lbs thrust and has a bypass ratio of 5.0:1. The aircraft has a cruise speed of Mach 0.75 *(see table, page 5)*.

The E-175 has a longer fuselage, allowing the higher seat capacity. The aircraft also has a higher MTOW of 82,673/89,000lbs and other weights, but otherwise is similar in specification to the E-170. The E-175's larger capacity has made it more attractive than the E-170. There have been 130 firm orders placed for the -175, and 80 are in operation. Firm orders of 315 for the E-170/-175 compare to 322 firm orders for the CRJ-700/-705.

MRJ70

The recently-launched MRJ comes in two basic model sizes. The smaller of these is the MRJ70 with a 70-80 seat capacity. The aircraft has a similar basic configuration as the E-170/-175: a twin-engined, four-abreast cabin design. While some specification weights have yet to be fully defined, the MRJ70 has three MTOW variants of 81,200lbs, 84,700lbs and 88,600lbs. These MTOWs come with three range options of 800nm, 1,270nm and 1,800nm. The aircraft have cruise speeds of Mach 0.78 and Mach 0.82 *(see table, page 5)*.

The MRJ70 has several features that will allow it to offer lower operating costs than its older generation CRJ and E-Jet counterparts. The first of these is Pratt & Whitney's PW1000G geared turbofan engine, which will be rated at 15,000lbs thrust. PW's geared turbofan provides a

The MRJ is one of two new aircraft families to be powered by Pratt & Whitney's geared turbofan engine. This will provide large improvements in fuel efficiency, maintenance costs, and noise & NOx emissions.

new engine design configuration. Standard two-shaft engines, which include the CF34, have the intake fan and low pressure compressor (LPC) mounted on the same shaft. Higher bypass ratios are achieved by wider fan diameters, and result in improved propulsive efficiency and lower fuel burn. A limiting factor in wider fan diameters is that fan blade tip speeds cannot exceed supersonic levels. A wider diameter fan, therefore, has to turn at a lower rate of revolutions per minute (RPM) than a fan with a smaller diameter. A lower rate of RPMs reduces the compression that the LPC is able to achieve. This in turn means that more stages are required in both the LPC and the high pressure compressor (HPC) to achieve the necessary compression. Larger compressors generally mean that larger and heavier turbines are required. The further limitation here is that the low pressure turbine (LPT), which is mounted on the same shaft as the fan and LPC, also has its RPMs limited. It has to be larger to turn a larger fan and LPC, but this adds weight and can offset the efficiency of lower fuel burns achieved by a higher bypass ratio. The two-shaft configuration therefore starts to reach limitations as bypass ratios are increased.

PW's geared turbofan takes engine design and capability to a different level. Utilisation of a gearbox between the fan and LPC allows the LPC to turn independently of the fan. A higher RPM speed for the LPC and LPT means that they are able to generate more compression and turning power, thereby achieving higher efficiency. This higher level of compression, turning power, and efficiency means that these modules require fewer stages than a conventional two-shaft turbofan of the same thrust rating. This is illustrated by the fact that the PW1000G will have a two-stage LPC and eight-stage HPC. This compares with the 10 HPC stages in the CF34-8C/-8E that power the CRJ-700/-705 and E-170/-175.

This in turn allows larger increases in fan diameter, and therefore higher bypass ratios are possible than with the conventional two-shaft design. The bypass ratio of the PW1000G powering the MRJ70 is expected to be 8.0:1, compared to the CF34-8E's bypass ratio of 5.0:1 *(see table, this page)*. This higher fuel-burn efficiency will certainly lead to higher propulsive efficiency and lower specific fuel consumption (sfc) than achieved by the CRJ-700-CF34-8C5 and E-170/175-CF34-8E designs. Mitsubishi says that it expects the MRJ70 to have 20% lower fuel burn than older generation aircraft with conventional two-shaft engines in the same size class.

The E-175 has a fuel burn of about 950USG on a 650-700nm trip, which is equal to a cost of $2,600 at current fuel prices. A 20% reduction in this fuel burn would mean that the MRJ70 would deliver a saving of about 190USG compared to the E-175, equal to $525 and about $7 per seat at current fuel prices.

70- TO 80-SEAT REGIONAL JET SPECIFICATIONS

Aircraft type	CRJ-700	CRJ-705	E-170	E-175	MRJ70	SSJ100-75
Seats	70-79	74/75	70-80	78-88	70-80	78-83
MTOW-lbs	72,750/ 77,000	80,500/ 84,500	79,344/ 85,098	82,673/ 89,000	81,200/ 84,700/ 88,600	85,585/ 93,210
Range-nm	1,434/ 1,732/ 2,002	1,719/ 1,963/ 1,999	2,100	2,000	800/ 1,270/ 1,800	1,570/ 2,460
Long-range cruise speed-Mach	0.78	0.78	0.75	0.75	0.78	0.78
Engine	CF34-8C5	CF34-8C5	CF34-8E	CF34-8E	PW1000G	SaM146
Thrust-lbs	12,670	13,123	13,800	13,800	15,000	13,500
Bypass ratio	5.0:1	5.0:1	5.0:1	5.0:1	8.0:1	4.4:1

The MRJ70 also has several design features that will allow it to provide maintenance cost savings in several ways. The first feature is that the PW1000G will have up to 1,500 fewer airfoils because the engine has fewer stages. As airfoils are some of the most expensive parts in the engine, a reduction in their number will directly reduce engine shop visit costs. The engine is also expected to have a higher exhaust gas temperature (EGT) margin than current generation competing engines. PW's target is for the PW1000G to have 40% overall lower maintenance costs than current equivalent engines. Other benefits of the PW1000G are lower noise emissions, as a result of the higher bypass ratio, and about half the NOx emissions of current engines. The MRJ70 will have a margin of 15.6EPNdB over Chapter/Stage 4 noise levels. NOx emissions are forecast to be about 50% less than required by CAEP VI standards.

The MRJ70 also has several airframe-related features that allow it to deliver maintenance cost savings over current generation aircraft. This includes the use of carbon fibre and composites in the empennage and wing, which will save weight as well as lower corrosion levels.

The aircraft will also have a fly-by-wire (FBW) flight control system. This has the potential to provide savings on the cost of pilot training.

Mitsubishi also claims that the MRJ will provide some of the highest comfort levels in its size class. Cabin width between passengers will be 21 inches; which compares with 20.25 inches for the E-170/-175, and 19 inches for the CRJ. The MRJ will also use a new slim seat, which will give the passenger greater legroom compared to other aircraft at the same seat pitch.

Superjet 100-75

The Superjet International Superjet100 was launched in 2007 and is one of the larger designs of RJs in the 70- to 110-seat classes. The aircraft has a five-abreast cabin layout, and similar configuration to the E-170/-175 and MRJ70. Superjet International is a joint venture between Alenia Aeronautica and Sukhoi.

The smaller variant of the Superjet 100 is the 78- to 83-seat SSJ100-75. This aircraft has an MTOW of 85,585lbs and a range of 1,570nm. The longer-range SSJ100-75LR will have an MTOW of 93,210lbs and range of 2,460nm *(see table, this page)*.

The aircraft is powered by the new Powerjet SaM146, rated at 13,500lbs. This engine is produced by Snecma and NPO Saturn, and has been specifically designed for the Superjet100 family.

The SaM146 is a key feature in allowing the SSJ100 to achieve lower operating costs than current generation aircraft. The engine is a conventional two-shaft design, and has a three-stage

90- TO 110-SEAT REGIONAL JET SPECIFICATIONS

Aircraft type	CRJ-900	CRJ-1000	E-190	E-195	MRJ90	SSJ100-95	C110
Seats	86-90	100-104	98-114	108-122	86-96	98-103	110
MTOW-lbs	80,500/ 84,500	90,000/ 91,800	105,359/ 114,199	107,564/ 115,280	87,300/ 91,400/ 94,400	93,740/ 101,150	118,800/ 127,800
Range-nm	1,350/ 1,593/ 1,828	1,491/ 1,691	2,400	2,200	870/ 1,400/ 1,770	1,590/ 2,390	1,800/ 2,700
Long-range cruise speed-Mach	0.80	0.78	0.75	0.75	0.78	0.78	
Engine	CF34-8C5	CF34-8C5A2	CF34-10E	CF34-10E	PW1000G	SaM146	PW1000G
Thrust-lbs	13,123	14,050	18,500	18,500	17,000	17,500	23,500
Bypass ratio	4.9:1	4.9:1	5.4:1	5.4:1	8.0:1	4.4:1	10.0:1

LPC, six-stage HPC, single-stage high pressure turbine (HPT) and three-stage LPT. The engine will have a fan diameter of 48.2 inches and a bypass ratio of 4.4:1. Superjet International says that together with the SSJ100's airframe design, the SaM146 is expected to give the aircraft 10% lower fuel burn than its nearest competitors. This suggests it will burn about 100USG less than the E-175 on a 650-700nm mission.

The SSJ100-75 is expected to have 35% lower NOx emissions than CAEP IV limits, and 23% lower than CAEP VI limits. The heavier SSJ100-75LR is expected to have NOx emissions that are 30% lower than CAEP IV limits and 18% lower than CAEP VI limits.

The SaM146 also has several features that will make its maintenance costs up to 20% lower than those of current generation engines.

While the engine has the same basic architecture as the CFM56, the SaM146 will have about 20% fewer stages. The SaM146 has 30% fewer HPC stages than the CF34. While it is not yet clear what the life limits will be for the engine's life limited parts (LLPs), these are expected to have uniform lives of 20,000 engine flight cycles (EFC) when the engine enters service in the second half of 2009.

The SSJ100 also employs several technologies for it to achieve some reductions in airframe-related maintenance costs. The aircraft will use carbon fibre or composite materials to make it lighter than current generation aircraft, and provide a lower incidence of corrosion. Like the MRJ, the SSJ100 will have an FBW flight control system. It will also have electronic landing-gear extension and retraction, and braking systems. These will also contribute to the aircraft's high maintainability and weight-saving features.

Superjet International has also revealed several features of the SSJ100's maintenance programme. Based on an expected annual average level of aircraft utilisation of 3,200 flight hours (FH) and average flight cycle (FC) time of 1.4FH, airframe- and component-related maintenance costs have been estimated.

The programme will include daily and weekly checks. The A check interval will be 750FH, with tasks at multiples of this interval. The C check interval will be 24 months, with multiples as high as 96 months (eight years) of this interval. There is also the structural inspection at 12 years and multiples thereof. The landing gear overhaul interval will be at 20,000FC, equal to eight or nine years of operation.

The line checks of daily, weekly and A checks are estimated to have a direct cost, for direct labour and materials, of $45 per FH. Reserves for C checks and the structural inspection check are estimated at $39 per FH, taking total airframe-related costs to $84 per FH.

Reserves for landing gear, auxiliary power unit (APU) and other components are estimated at $7.6, $9.8 and $106.7 per FH respectively. This takes the total for components to $124.1 per FH. Total airframe and component costs are $208 per FH.

The SSJ100 will have a similar seat width to the MRJ, while the SSJ100's aisle is almost three inches wider. The 2009 list price for the SSJ100-75 is $26.4 million, while the -75LR's list price will be $27.0 million. This compares to $33.2 million for the CRJ-700, $31.5 million for the E-170, and $33.5 million for the E-175.

90- to 110-seat RJs

The CRJ-900, a stretch variant of the CRJ-700/-705, is the smallest aircraft in this category. Bombardier launched a further stretch variant of the CRJ, the CRJ-1000, in early 2007.

The CRJ-900 has a capacity of 86-90 seats, MTOWs of 80,500lbs and 84,500lbs, range of 1,350-1,828nm, and cruise speed of Mach 0.80. The aircraft is also powered by the same CF34-8C5 that powers the CRJ-700 series, and is rated at 13,123lbs thrust.

As a stretch of the CRJ-700, the CRJ-900 has the same seat and aisle widths. The CRJ-900 has a won a total of 250 firm orders. The aircraft's larger customers include Air Nostrum, Comair, Lufthansa Cityline and Skywest.

The CRJ-1000 is a 3-metre stretch of the CRJ-900. Seat capacity is 100-104 seats, and the aircraft has MTOW options of 90,000lbs and 91,800lbs. The aircraft has a range capability of 1,491nm and 1,828nm, a cruise speed of Mach 0.78, and is powered by the GE CF34-8C5A2 rated at 14,050lbs thrust. The CRJ-1000 allows Bombardier to provide an interim aircraft before the entry into service of the C110. The CRJ-

The C Series will compete with the 10-seat smaller SSJ100-95. Besides larger size, the C110 will be powered by Pratt & Whitney's geared turbofan, the PW1000G. This could provide the C110 with a fuel burn advantage.

1000's current list price is $43.2 million. The CRJ-1000 has won 39 firm orders, with Adria Airways and Brit Air as the major customers.

The E-190 and E-195 are the two larger counterparts of the E-170 and E-175. The E-190 and E-195 are stretch versions and have seat capacities of 98-114 seats and 108-122 seats respectively.

The E-190 has MTOW options of 105,359lbs and 114,199lbs, a range of 2,400nm, and cruise speed of Mach 0.75.

The longer E-195 has MTOW options of 107,564lbs and 115,280lbs, a range of 2,200nm, and a cruise speed of Mach 0.75. Both aircraft are powered by the GE CF34-10E rated at 18,500lbs. They have a bypass ratio of 5.4:1.

The E-190 has won 410 firm orders, while the E-195 has won 87. The largest customers are jetBlue, Air Canada and USAirways.

MRJ90

The MRJ90 is the larger variant of the MRJ family, at eight feet longer than the MRJ70. Its features include: a seat capacity of 98-103; MTOW options of 87,300lbs, 91,400lbs and 94,400lbs; a range of 2,200nm; and cruise speeds of Mach 0.78 and 0.82.

Like the MRJ70, the MRJ90 will be powered by the PW1000G, rated at 17,000lbs thrust. This is expected to give the aircraft 20% lower fuel burn than current generation aircraft. The E-190 has a fuel burn of about 1,100USG on a 650-700nm trip, so the MRJ90 may burn 220USG less. This would provide a saving of $605 at current fuel prices.

The MRJ90 would also benefit from the same maintenance cost reduction features that the MRJ70 will gain from the PW1000G. The MRJ90 is expected to have noise emissions 17.4EPNdB lower than permitted Chapter/Stage 4 levels. NOx emissions are forecast to be 50% less than required by CAEP VI.

The MRJ90 will have the same features so that it can offer the same savings in airframe maintenance costs as the MRJ70.

Superjet 100-95

The SSJ100-95 is the larger SSJ100 variant, longer by eight feet than the -75, and with a seat capacity of 98-103. The basic -95 has an MTOW of 93,740lbs and range of 1,590nm. The longer-range variant, the -95LR has an MTOW of 101,150lbs and range of 2,390nm. Both variants have a cruise speed of Mach 0.78.

The SSJ100-95 will have the same SaM146 engine as on the -75, and will be rated at 17,500lbs thrust. As with the SSJ100-75, the -95 is expected to have about 10% lower fuel burn compared to older generation similar-sized aircraft. The SSJ100-95 may therefore burn 100USG less than the E-190 on a 650-700nm mission.

The SSJ100-95 will also have lower NOx emissions than CAEP IV and VI limits of a similar magnitude that the -75 will have. The SSJ100 will also have similar benefits in engine- and airframe-related maintenance costs. Airframe- and component-related maintenance costs will be the same as those described for the -75 model.

C Series

The Bombardier C Series was launched in July 2008 following an order from Lufthansa for up to 60 aircraft.

The aircraft has a five-abreast cabin configuration similar to the SSJ100. The C Series' cabin is six inches wider internally than the five-abreast DC-9 and Fokker 70/100, and six inches narrower than the six-abreast 737.

There are two C Series models, and the C110 is the smaller of the two with a standard capacity of 110. The C110 will have two MTOW options of 118,800lbs and 127,800lbs, and range options of 1,800nm and 2,700nm.

The C Series will be powered by the PW1000G, and so receive similar reductions in fuel and engine-related maintenance costs to the MRJ. The PW1000G will be rated at 23,500lbs for the C110, and is expected to give the C110 20% lower fuel burn than similar-sized current generation aircraft. The E-190 and E-195 burn 1,100USG and 1,160USG on a 650-700nm mission. This suggests that the C110 could have a 220-230USG lower fuel burn, providing a saving of $606-630 at current prices. The PW1000G will also provide the C110 with similar savings in engine-related maintenance costs that it will provide for the MRJ family.

The PW1000G will also allow the C110 to meet Chapter/Stage 4 noise emissions levels by a margin of about 20 EPNdB, and will have NOx emissions about 50% lower than CAEP VI standards.

The C110 will also use lightweight materials, many of which are not currently in use with commercial aircraft. These materials will mainly comprise carbon fibre, with the clear intention of reducing hull weight and lessening the incidence of corrosion in the airframe. The C Series will have a maintenance programme of extended check intervals, which will be 750FH for A checks and 7,500FH for C checks. Another main feature will be the use of integrated avionics, which will allow circuit boards rather than individual black boxes to be replaced following failure of components. This feature will not only save weight, but also save the cost of maintaining an inventory of rotables. Overall, Bombardier is aiming to achieve a maintenance cost 25-30% than the E-190/-195. AC