

The CRJ100/200 series is the only RJ type with active passenger-to-freighter conversion options. Key P-to-F feedstock selection criteria for these aircraft are considered here. Operators should prioritise age and accumulated flight cycles.

# Cherry picking CRJ100s/200s for P-to-F conversion

**R**egional jet (RJ) freighters might appeal to cargo airlines operating certain long-thin sectors, where a narrowbody would provide excess capacity and a turboprop's slower trip times might not satisfy operational requirements.

There are no new-build RJ freighters available, so potential operators in this segment are dependent on passenger-to-freighter (P-to-F) conversion programmes. The only RJ type for which there are active P-to-F conversion options is the CRJ100/200 series.

The most suitable CRJ100 and CRJ200 candidates for P-to-F conversion are identified here.

## Conversion options

There are conversion options available for the CRJ100 and CRJ200.

The only difference between these aircraft is the engine variant.

The CRJ100 and CRJ200 share the same type certificate. They have the same fuselage and wing structure and therefore the same external dimensions. A CRJ100/200 is 87 feet and 10-inches in length, with a wingspan of 69 feet and 7-inches. The CRJ100 and CRJ200 also have the same structure-related maintenance requirements.

When equipped with CF34-3A1 engines an aircraft is certified as a CRJ100. An aircraft powered by the CF34-3B1 variant is certified as a CRJ200. It is possible to exchange the different engine variants between airframes and re-certify the aircraft. For example, CF34-3A1 engines could be removed from a CRJ100 and replaced with the CF34-3B1 variant. This would see the airframe re-classified as a CRJ200.

The CRJ100 entered service in 1992, and according to Flightglobal's FleetsAnalyzer (May 2017) there are 35 active and 48 stored aircraft in passenger configuration. The first CRJ200 entered service in 1996. There are 475 CRJ200s in active passenger service, with 235 in storage.

Two conversion programmes are available for CRJ100/200s. Aeronautical Engineers Inc (AEI) offers a large cargo door (LCD) conversion option, while Cascade Aerospace provides kits for package freighter modifications. Aircraft converted under the AEI programme are given the designation SF, while those modified using the Cascade Aerospace kits are given the designation PF.

## CRJ100/200 SF

AEI launched its Bombardier-licensed CRJ100/200 SF P-to-F conversion programme in 2013. It received a supplemental type certificate (STC) for the conversion from the Federal Aviation Administration (FAA) in October 2016 and has also applied for an STC from the European Aviation Safety Agency (EASA).

The CRJ100/200 SF conversion includes installation of a Class E cargo compartment and an LCD measuring 94 inches X 70 inches on the left side of the fuselage forward of the wing. The conversion also includes a manual Ancra cargo loading system as standard.

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*There are two P-to-F conversion options available for the CRJ100/200 series. AEI's CRJ100/200 SF conversion is the only programme that includes the installation of a large cargo door.*



## CRJ100/200 FREIGHTER SPECIFICATIONS

Aircraft	CRJ100ER SF	CRJ100LR SF	CRJ200ER SF	CRJ200LR SF
MTOW (lbs)	51,000	53,000	51,000	53,000
MZFW (lbs)	44,000	44,000	44,000	44,000
Max structural payload (lbs)	up to 14,870	up to 14,870	up to 14,840	up to 14,840
ULDs	8 ASZ	8 ASZ	8 ASZ	8 ASZ

  

Aircraft	CRJ100ER PF	CRJ100LR PF	CRJ200ER PF	CRJ200LR PF
MTOW (lbs)	51,000	53,000	51,000	53,000
MZFW (lbs)	44,000	44,000	44,000	44,000
Max structural payload (lbs)	up to 15,200	up to 15,200	up to 15,200	up to 15,200
ULDs	N/A	N/A	N/A	N/A

## Notes:

- 1). Max structural payload figures are estimates. These could vary slightly by aircraft owing to different OEWs.
- 2). Payload figures for PF conversion do not account for marginal difference in OEW between CRJ100 and CRJ200.

As the CRJ100 and CRJ200 have the same fuselage structure they offer the same cargo volume when converted into freighters. A CRJ100/200 SF can hold up to eight unit load devices (ULDs) with base dimensions of 62 inches X 88 inches. There are no optimised containers available matching these specifications, but VRR Aviation has produced a design proposal for the ASZ container, which has the required base dimensions and a height of 67.9-inches. A CRJ100/200 SF loaded with eight ASZ containers would offer a cargo volume of 1,356 cubic feet (cu ft). According to AEI, the ASZ container will enter production once an order for it is placed, which AEI expects by the end of 2017. VRR has also designed the PSA pallet with base dimensions optimised for the CRJ100/200 SF. When loaded with eight PSA pallets a CRJ100/200 SF would offer a cargo volume of 1,800 cu ft. AEI says that the PSA pallet is available now.

A CRJ100 SF would offer a typical structural payload of up to 14,870lbs, while a CRJ200 SF would have a payload of up to 14,840lbs (see table, this page).

AEI has received 54 commitments for its CRJ100/200 SF P-to-F modification, eight of which have already been converted to firm orders. It has completed the prototype conversion of a CRJ200 for launch customer IFL Group, and this aircraft is due to enter service imminently.

“The CRJ100/200 series is a solid, well-built aircraft that was designed with the potential for freight carriage in mind,” says Robert Convey, senior vice president of sales and marketing at AEI. “Unlike most of our conversion programmes there is no need to reinforce the floor structure with the CRJ100/200 series. I believe that we will end up converting in excess of 100 aircraft.”

### CRJ100/200 PF

Cascade Aerospace has developed

Package Freighter (PF) conversion kits for the CRJ100/200 series. These PF kits include airworthiness certification, technical publications, parts and modification instructions. The STC has obtained EASA and Transport Canada certification.

The CRJ100/200 PF conversion kits can be bought from Cascade Aerospace or Bombardier and installed by a third party. The PF modification features the installation of a Class E cargo compartment, but unlike AEI's CRJ100/200 SF programme it does not include the addition of an LCD. This means the size of freight that can be loaded in a CRJ100/200 PF is governed by the dimensions of the existing passenger entry and cargo doors.

A CRJ100/200 PF provides a bulk cargo volume of up to 1,722 cu ft and a structural payload of up to 15,000lbs.

*Aircraft Commerce* was unable to identify how many CRJ100/200 PF kits have been sold in total, but there are currently two active CRJ100 PFs, six active CRJ200 PFs and one CRJ200 PF in storage. Canadian-headquartered leasing and maintenance, repair & overhaul (MRO) specialist Avmax is the world's largest lessor of CRJ100/200 aircraft. It has converted five CRJ200s to PF status so far, all of which have been leased.

### Airframe selection

Operators may wish to consider a number of selection criteria when identifying potential CRJ100/200 series P-to-F conversion candidates, including: the age and acquisition cost, engine variant, weight specifications, accumulated utilisation, fleet commonality and maintenance condition.

### Age and cost

In most P-to-F modification programmes, feedstock aircraft are 15-20

years old when they undergo conversion. Dual P-to-F feedstock selection requirements relating to acquisition cost and remaining economic life typically become optimised when aircraft enter this age window.

When an aircraft is less than 15 years old it will normally remain in demand with passenger carriers, which will see it maintain higher market values. As it ages, it may be phased out of passenger service, which will lead to a subsequent reduction in residual values. In some cases market values will drop to levels at which P-to-F conversions make economic sense.

Aircraft older than 20 years will probably have suitable acquisition costs for P-to-F conversion, but may not have sufficient remaining economic utilisation for an investor to realise the desired return on investment. It is not unusual for operators to expect at least 15 years' utilisation from a freighter after it has undergone a P-to-F modification or even up to 20 years' post-conversion usage. Feedstock aircraft that are older than 20 years are less likely to have enough utilisation remaining in terms of flight hours (FH) or flight cycles (FC) to meet these requirements. This may be due to design service limits or utilisation thresholds related to time-consuming and expensive ageing maintenance requirements.

Convey believes that 15-20 year-old airframes will account for most CRJ100/200 SF conversions. This analysis will only consider aircraft that are 20 years or younger as suitable future conversion candidates.

As well as the optimum conversion age window, operators will also want to identify the potential 'on ramp' cost of bringing a CRJ100/200 series freighter into service. This is the sum of the acquisition and conversion costs, plus any maintenance-related expenditure.

AEI's CRJ100/200 SF conversion has a current list price of \$1.85 million, but it

was not possible to identify the cost of acquiring and installing Cascade Aerospace's PF kit.

Convey estimates that the cost of putting a CRJ100/200 series aircraft through a heavy maintenance visit at the time of conversion could be up to \$500,000. He does, however, point out that AEI and its touch labour conversion partners have, as yet, not performed such checks on the CRJ100/200 at the time of conversion.

Since it was not possible to confirm precise maintenance costs, this analysis will not attempt to estimate total on-ramp costs for CRJ100/200 freighters.

It is, however, possible to estimate potential acquisition and conversion costs for CRJ100s and CRJ200s in half-life maintenance condition. When converted to SF status under AEI's STC, total acquisition and conversion costs for typical feedstock-age CRJ100s could be \$2.35-2.55 million depending on the variant (see table, page 114). For feedstock-age CRJ200s, the acquisition and conversion cost could be \$2.95-4.05 million.

### Engines

It has already been established that the only difference between a CRJ100 and CRJ200 is the installed engine

variant. Some operators might prefer aircraft certified as CRJ200s due to the several slight operational advantages that the CF34-3B1 can provide over the CRJ100's CF34-3A1 engines.

The CF34-3B1 offers a higher temperature 'flat-rating', and better specific fuel consumption, climb thrust and hot and high performance than the CF34-3A1.

"The precise variant of CRJ100 or CRJ200 series aircraft is designated by the engines," says Rick Pollock, business development manager, aircraft leasing, Americas, at regional aircraft leasing specialist Avmax. "Any gains realised by operating an aircraft with CF34-3B1s, rather than CF34-3A1s, may be minimal in the typical freighter environment. You could therefore argue that CRJ100s and CRJ200s are equally suitable for P-to-F conversions. The only reason a cargo carrier may prefer the CRJ200 is if a high percentage of its flying involves serving hot and high airports, or frequently needs to operate the aircraft at its maximum take-off weight (MTOW)," adds Pollock.

Convey believes that more CRJ200s will be converted in the long term, but points out that this is partly due to the number of aircraft certified as CRJ200s significantly exceeding the number of active and stored CRJ100s.

The performance advantage offered

by the CF34-3B1 is unlikely to be enough for the engine variant, and therefore the certified aircraft model series, to be considered a key feedstock selection criterion for most potential CRJ100/200 cargo operators. It is possible, however, that some carriers with niche operating requirements will prefer the CRJ200.

It should be noted that prospective operators will have the flexibility to acquire an aircraft certified as a CRJ100 and have it re-certified as a CRJ200, provided they can source CF34-3B1 engines in the right condition at the right price.

This analysis considers the CF34-3A1-powered CRJ100 and CF34-3B1-equipped CRJ200 to be equally suitable feedstock candidates for P-to-F conversion.

### Weight specifications

The same MTOW and maximum zero fuel weight (MZFW) options are available for the CRJ100 and CRJ200, since they share the same structure. Two sub-variants of the CRJ100/200 series are available. They can be certified as extended range (ER) or long-range (LR) variants.

CRJ100/200 ER aircraft have an MTOW of 51,000lbs, while LR aircraft have an MTOW of 53,000lbs. All

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## ESTIMATED ACQUISITION &amp; CONVERSION COSTS FOR HALF-LIFE CRJ100S/200S

Aircraft	MTOW (lbs)	Engine	Aircraft Age	CMV (\$-millions)	Conversion cost AEI SF P-to-F (\$-millions)	Acquisition & conversion cost (\$-millions)
CRJ100ER	51,000	CF34-3A1	17 years	0.50	1.85	2.35
CRJ100ER	51,000	CF34-3A1	20 years	0.50	1.85	2.35
CRJ100LR	53,000	CF34-3A1	16 years	0.70	1.85	2.55
CRJ200ER	51,000	CF34-3B1	15 years	1.75	1.85	3.60
CRJ200ER	51,000	CF34-3B1	20 years	1.10	1.85	2.95
CRJ200LR	53,000	CF34-3B1	15 years	2.20	1.85	4.05
CRJ200LR	53,000	CF34-3B1	20 years	1.40	1.85	3.25

CMV Source: Oriel

Notes:

1).CMVs are for aircraft in half-life maintenance condition with half-life engines. CMVs provided for available aircraft vintage within typical 15-20 year conversion window.

CRJ100s and CRJ200s have an MZFW of 44,000lbs. The only difference between ER- and LR-certified aircraft is that the LR variant has a longer range, due to its higher MTOW. “A CRJ100/200LR provides more than 300nm of additional range compared to an ER variant when operating with the same payload,” explains Delio Petohleb, director of sales, asset management group, Bombardier Aerospace.

CRJ100/200 series aircraft can be re-certified from ER to LR status without the need for structural modifications via an original equipment manufacturer (OEM) service bulletin (SB). Interested parties should contact Bombardier for further details, including costs.

Cargo operators tend to prioritise payload over range. The only marginal payload difference between the CRJ100/200 series fleet relates to a fractional disparity in operating empty weight (OEW) between CRJ100s and CRJ200s. A set of CF34-3A1 engines for the CRJ100 weighs about 30lbs less than two CF34-3B1s, so the typical OEW for a CRJ100 ER/LR aircraft is 30lbs less than that for a CRJ200 ER/LR. This translates to a 30lbs payload advantage for the CRJ100 ER/LR. This payload difference is too insignificant to be a defining factor in the feedstock selection process.

This analysis considers ER and LR variants of the CRJ100/200 series to be equally suitable P-to-F conversion candidates, since there is no difference in available payload between the two specifications, and there is flexibility to upgrade from ER to LR status if required. It is, however, acknowledged that some operators may prefer LR aircraft due to niche operating requirements.

“Potential cargo operators that need the LR’s extra range may avoid CRJ100/200 ER feedstock, since these will incur additional SB costs to be modified to LR status,” says Petohleb.

“LR variants have been more popular in passenger service, but it is quite

possible that operators in the freighter segment may not need the extra 2,000lbs of MTOW that an LR offers, either due to freight loading considerations or shorter sector lengths,” says Pollock.

### Accumulated utilisation

The CRJ100/200 series has an economic operational life of 80,000FC. There are no life extension options available beyond this threshold.

Petohleb estimates that the average annual utilisation for a converted CRJ100/200 freighter would most likely be 600-800FC per year when operating in a regional cargo feeder role.

This analysis assumes that potential CRJ100/200 freighter operators would expect up to 20 years’ post-conversion utilisation from their aircraft. A CRJ100/200 freighter with an average annual utilisation of 800FC would operate up to 16,000FC over a 20-year period.

From a utilisation perspective, the most suitable CRJ100/200 feedstock candidates are, therefore, those that have accumulated 64,000FC or fewer at the time of conversion. These aircraft should provide up to 20 years of service before reaching their economic life limit.

### Fleet commonality

Operators that intend to source multiple aircraft may place particular emphasis on the importance of fleet commonality when selecting CRJ100/200 feedstock for P-to-F conversions.

Such operators could potentially reduce future maintenance costs by choosing a fleet of ‘sisterships’. Sisterships are groups of the same aircraft variant that have been operated in the same environment by a single operator, using uniform procedures and quality standards. They typically have the same components and modification status.

Selecting sisterships can reduce costs

by avoiding the need for multiple spares inventories, and any maintenance issues related to managing aircraft with different components or modification statuses.

### Maintenance condition

Maintenance considerations are another important factor in the feedstock selection process.

Most operators combine P-to-F conversions with a heavy maintenance input. This optimises aircraft downtime, since the conversion process and maintenance visit both require deep access and the removal of all interior items. The removal of passenger cabin interior items can consume a significant number of man-hours (MH). Combining the conversion and maintenance check reduces the potential duplication of these MH-consuming access tasks and reduces the time the aircraft is out of service.

Potential CRJ100/200 freighter operators may therefore aim to identify feedstock aircraft that are approaching a heavy maintenance inspection.

“Each task in the CRJ100/200 Maintenance Planning Manual (MPM) has an individual inspection interval,” explains Paul Draper, planning manager at Avmax. “The intervals are FH, FC or calendar based. There are a few that have a combination of the three.

“Despite this, many operators still group inspections into blocks and refer to them as A and C checks,” adds Draper. “The C check interval is 5,000FH, while the A check interval is 500FH. Some operators equalise A checks into 250FH intervals, but this is uncommon.

“At typical levels of utilisation, most passenger operators end up performing C checks every two years,” explains Draper.

It is likely that CRJ100/200 freighters would be bridged on to the low utilisation maintenance programme (LUMP). “The LUMP must be applied to any aircraft that operates fewer than

1,500FH per year in accordance with maintenance review board (MRB) requirements,” says Draper. “Due to the average utilisation of cargo operators, it is likely that most CRJ100/200 freighters will be maintained under the LUMP. The LUMP moves a large number of the 5,000FH and 10,000FH inspection tasks to intervals of 48 and 96 months. This will result in heavy check inspections taking place at 48-month intervals.”

One particular maintenance consideration that potential CRJ100/200 freighter operators should be aware of relates to structural inspection tasks that come due when an airframe has accumulated 40,000FC. These fatigue damage (FD) tasks require deep access and potential operators might be concerned about associated MH requirements and any costs linked to associated non-routine rectifications.

“The FD tasks require the removal of the passenger cabin interior and all flight controls,” says Draper. “About half the tasks have a 40,000FC repeat interval, while the rest are manageable during the routine inspection cycle as part of a block check.”

According to Bombardier, seven CRJ200 aircraft have undergone the 40,000FC inspection with a minimum amount of findings. This suggests the inspection should not be a major concern for potential freighter operators.

Avmax’s Draper agrees, and suggests that the FD tasks should be manageable if incorporated within existing heavy maintenance inspections.

“The FD tasks that come due at 40,000FC need a fair amount of access, but if this is scheduled with a C check the additional access is not excessive by any means,” says Draper. “If the FD tasks are performed as a standalone event out-of-phase with a heavy check, it is estimated they will require 1,280MH. This is for a passenger-configured aircraft, with 985MH for access and 295MH for inspections. Access requirements are far smaller for a freighter due to the simplified interior, with no seats, overhead bins or galleys to remove.” If the FD tasks are performed during a scheduled C check the required access MH will clearly be significantly reduced. Avmax estimates that avoiding the duplication of access would reduce the

time required to complete the 40,000FC FD tasks by 250MH for a passenger-configured aircraft.

Avmax has put three CRJ200s through the 40,000FC inspections so far. “Non-routine findings resulting from the 40,000FC FD inspections have been low for the three aircraft that have reached this utilisation threshold so far,” says Draper. “On average they have required fewer than 200MH to rectify. We have found corrosion on airframes converted to freighters, but this was during standard heavy checks as a result of the calendar-based structural and corrosion prevention control programme (CPCP) inspections.”

This analysis does not consider the 40,000FC fatigue inspection threshold to be a defining factor in the CRJ100/200 feedstock selection process, although operators should clearly understand the additional maintenance requirements and costs that could be incurred.

Operators also need to be aware of any outstanding Airworthiness Directives (ADs) or SBs affecting CRJ100s and CRJ200s. *Aircraft Commerce* was not made aware of any ADs or SBs that could



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## CRJ100/200 SUITABLE FUTURE CONVERSION CANDIDATES

Aircraft variant	15-20-years-old May 2017	All aircraft May 2017
<b>CRJ100</b>		
CRJ100ER Active	20	20
CRJ100ER Parked	25	25
CRJ100LR Active	5	5
CRJ100LR Parked	1	1
<b>Total</b>	<b>51</b>	<b>51</b>
<b>CRJ200</b>		
CRJ200ER Active	81	129
CRJ200ER Parked	62	86
CRJ200LR Active	86	338
CRJ200LR Parked	78	139
<b>Total</b>	<b>307</b>	<b>692</b>
<b>All Aircraft</b>		
Active total	192	492
Parked total	166	251
<b>Total</b>	<b>358</b>	<b>743</b>

## Notes:

- 1). Fleet data source: Flightglobal Fleets Analyzer. Fleet data correct as of 3rd May 2017.
- 2). All aircraft column figures include airframes up to a maximum of 20-years-of-age.
- 3). Figures show all aircraft with fewer than 64,000FC.

make certain airframes less suitable conversion candidates.

## Suitable aircraft

The two principal selection criteria to consider when selecting CRJ100 or CRJ200 feedstock candidates for P-to-F conversion are the aircraft's age and its accumulated FCs.

Individual operator preferences will determine the priority assigned to other selection criteria; such as the engine variant, weight specification and fleet commonality.

*Aircraft Commerce* has applied the two priority selection criteria to the current active and stored fleet of CRJ100s and CRJ200s, based on each airframe's current age and accumulated utilisation. The accumulated utilisation figures used in this analysis are based on data retrieved from Flightglobal's FleetsAnalyzer on 3rd May 2017.

The fleet can initially be filtered according to each airframe's accumulated FC. Aircraft that have accumulated 64,000FC or less are considered the most suitable candidates for conversion. None of the active or stored CRJ100s or CRJ200s are close to reaching this FC threshold. This means none of the current fleet can be eliminated as conversion candidates based on accumulated utilisation alone.

The fleet is then filtered according to the aircraft's age. Airframes that are 20 years old or younger are considered to be the most suitable conversion candidates. This rules out 50 older airframes comprising 32 CRJ100s and 18 CRJ200s.

There are 51 CRJ100s and 692 CRJ200s that meet the priority feedstock selection criteria, and are therefore considered suitable for conversion (*see table, this page*). These aircraft have been split into separate CRJ100 and CRJ200 fleets to help buyers identify the candidates most suited to their individual requirements. Some of the largest passenger operators are also highlighted to help identify the potential for fleet commonality.

The following feedstock summary identifies aircraft that are within the typical conversion window of 15-20 years of age. It also highlights younger airframes, since these could become suitable P-to-F feedstock in the future. The fleet numbers account for both active and stored aircraft.

### CRJ100 candidates

There are 51 active and parked CRJ100s that meet the two priority selection criteria. This includes 45 ER aircraft and six LR variants.

The largest operator of these CRJ100s is SkyWest Airlines (10 aircraft), with six active and four parked CRJ100ER airframes. The next largest operator is Rusline (9), with six active CRJ100ERs, two active CRJ100LRs and one CRJ100ER in storage.

All 51 CRJ100s identified already fall within the typical conversion age range.

There are 14 active and stored CRJ100s that could operate 800FC per year for 20 years without exceeding the 40,000FC threshold, thereby avoiding the 40,000FC FD inspections. These include

12 ER and two LR variants. The largest operator of this sub-group is Cem Air with two ERs and a single LR variant.

### CRJ200 candidates

There are 692 active and parked CRJ200s that satisfy the two priority feedstock selection criteria, including 215 ER airframes and 477 LR variants.

The largest operators of qualifying CRJ200 airframes are all based in the US. SkyWest Airlines has the largest total fleet (173), which includes 32 active and 13 parked CR200ERs and 126 active CRJ200LRs with a further two in storage. The next largest fleets are those of Endeavor Air (133), Air Wisconsin (66), ExpressJet Airlines (39) and PSA Airlines (35).

The largest CRJ200LR fleets are operated by; Endeavor Air (130), which has 53 active and 77 stored aircraft; SkyWest Airlines (128), with 126 active and two parked aircraft; and Air Wisconsin (61), with 53 aircraft in service and a further eight in storage.

The largest CRJ200ER fleets are operated by SkyWest Airlines (45), which has 32 active and 13 parked airframes; and ExpressJet Airlines (37), with 29 active aircraft and eight in storage.

There are 307 active and parked CRJ200s that fall within the typical conversion age range. This includes 143 ER variants and 164 LR aircraft. The largest fleets are those of SkyWest (61), Endeavor Air (34), Air Wisconsin (23) and ExpressJet (23). It should be noted that all 34 of Endeavor Air's 15-20 year old CRJ200s are in storage.

US-based regional carriers have been increasingly removing 50-seat RJs from service in favour of larger 70-seat aircraft following a relaxation in mainline pilot scope clause agreements (*see An evaluation of the large regional jet market, Aircraft Commerce, February/March 2017, page 18*). Nearly half of the conversion-age CRJ200 fleet is therefore in storage. These aircraft could represent a good feedstock opportunity for operators looking to enter the RJ freighter market in the next few years. There should also be no shortage of fleet commonality opportunities.

There are 255 active and stored CRJ200s (61 ER and 194 LR variants) that are 20 years old or younger, and could operate up to 800 FC per year for 20 years without needing the 40,000FC FD inspections. Endeavor Air is by far the largest operator of aircraft in this sub-group, with 46 active and 48 stored CRJ200LRs and one ER variant in storage. - NMP 

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