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FREIGHTER FORECAST 2020-2039

FORECAST THE FUTURE

CFCInsights.com

TWENTY-YEAR

FREIGHTER AIRCRAFT FORECAST

2020-2039

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Executive Summary

Between 2020 and 2039, we forecast the addition of 2,322 jet freighters and 401 feeder aircraft to cater for both growth and retirements of older aircraft. During this period, we expect the world's jet freighter fleet to grow from 1,885 to 2,971 units, and the world's feeder fleet to grow from 243 to 420. Table 1 provides an overview of the key numbers in our long-term forecast.

Our twenty-year forecast is based on an underlying air cargo traffic growth rate of 3.8%. This is 0.1% lower than last year's forecast and considers the effect of a sharp decline in air cargo traffic in 2020 followed by a strong rebound in 2021 and a normal growth trajectory thereafter. While the COVID-19 induced crisis is sending shockwaves through the world economy, we do not think that it will fundamentally change the long-term outlook and lead to a reset of global supply chains. And although the passenger airline business is facing its greatest challenge ever, we find there are opportunities for freighter operators in the short and medium term.

Table 1 - 2020 - 2039 Freighter Forecast Key Numbers

	1Q-20 Fleet	Net Growth	Retired	Total Added	New	P to F	2039 Fleet
Feeders	243	177	224	401	90	311	420
Narrowbody	709	516	585	1101	0	1101	1225
Medium Widebody	569	323	319	642	315	327	892
Large Widebody	607	247	332	579	457	122	854
Total	2128	1263	1460	2723	852	1871	3391

Source: Cargo Facts Consulting Freighter Forecast 2020-2039

Over the next 20 years, we expect to see the retirement of about two thirds of the of the current jet freighter fleet and almost the entire currently active feeder fleet. About half of the of the new and converted aircraft added over the next twenty years will be to replace these retired aircraft and the other half to cater for freight market growth.

Factory-built freighters are forecast to make up 33% of aircraft additions in the jet freighter segment, albeit with large differences across individual categories. Forecast aircraft demand in the narrowbody segment is likely to be met entirely by conversions, whereas we expect the share of conversions in the medium and large-widebody segments to be 51% and 21%, respectively. We foresee 22% of new additions in the feeder segment will be satisfied by production freighters.

The future fleet composition will depend on the choice of aircraft in each segment. While we have a view on which types are likely to feature in each segment, there are some major uncertainties in this regard:

- The future freighter options in the narrowbody jet segment are well-defined with feedstock constraints limiting future conversions of 737-300s/-400s and 757-200s. The future in this segment will belong to converted 737 NGs and A320/321 family. The initial order activity has been skewed towards the 737-800 and later, we will be seeing the A320/A321 units grow. The transition from classics to NGs will depend very much on feedstock pricing and availability. Last year it was the 737 MAX delays holding feedstock back, this year the COVID-19 crisis will potentially free up some of the older 737 NGs.
- While the medium widebody market has been very active of late, there are no new developments on the immediate horizon. The 26-year 767-300F program has no end-date, but feedstock will limit conversion numbers as the last 767-300 passenger aircraft was delivered in 2014. A330 conversions should be available throughout the forecast period, but no announcements have been made on new factory-built freighters in this category, such as the A330-900F or the 787-9F, as of early 2020.
- While the 777-200F program continues to be extremely successful, there has been no firm commitment from Boeing on how long the 747-8F will remain in production. We expect production to cease with the current backlog in 2022, which would be a huge loss for the air cargo business given the unique capabilities of the aircraft. Airbus has been mulling an A350 production freighter but has not officially launched a program. The aircraft would face strong competition from a lower capital cost 777-300ER passenger-to-freighter conversion program. Such a program

was launched by GECAS and Israel Aerospace Industries (IAI) in late 2019 with a target in-service date of 2022.

- The feeder segment continues to seem like a one-horse race, with the ATR 72 set to increase its dominance in this segment, with both converted and production freighters available to operators. Nevertheless, we see potential for further CRJ, Dash 8 300 and 400 deliveries during the forecast period.

The forecast for freighter aircraft demand is sensitive to changes in traffic growth and other parameters. A half percentage point change in long-term traffic leads to a shift in the requirement for approximately 300 jet aircraft and 40 feeder aircraft.

Our forecast also assumes that the historical 50:50 freighter-passenger belly split will move towards a 42.5:57.5 split. If this does not happen, then this would lead to demand for an additional 286 medium and (particularly) large widebody aircraft. Depending on how quickly passenger capacity comes back online after the current crisis, freighters are likely to carry in excess of 50% of all cargo in the short to medium term. Freighters are a critical link in global supply chains.

1. Introduction

The latest edition of our 20-year freighter aircraft forecast was prepared during what is turning out to be the worst crisis ever faced by the global airline industry. At the time of writing in the third week of April, global airline flight activity had dropped to about a quarter of its normal levels and close to two thirds of the global airline fleet was parked following travel restrictions and lockdowns to counter the spread of the SARS-COV-2 pandemic. Approximately 50% of global air cargo traffic carried on passenger aircraft, and as such freighter operators have been performing extremely well.

One year does not constitute a trend, but the impact on the world economy is expected to be severe in the short term. Even if we assume an awful 2020, a sharp rebound in 2021, followed by a resumption of the previous growth trajectory, the impacts will be felt over a 20-year period. As such we have included a chapter on the short-term outlook for cargo demand, capacity and aircraft supply. Importantly, we look at what world economic recovery could look like and what this means for the air logistics business. As the crisis evolves we will continue to provide up to date analysis on our Insights platform.

The subsequent chapters cover long term airfreight demand, our analysis and forecast for narrowbody, medium and large widebody and feeder (turboprop and regional jet) freighter fleets. Our airline user analysis provides an overview of how and where freighter aircraft are used. With a large part of the world's freighter fleet consisting of aircraft converted from passenger to freighter configuration, we provide an up to date assessment of the passenger to freighter feedstock situation and outlook. Appendix 2 provides a reference guide with freighter aircraft characteristics for both in-Service and planned cargo aircraft. Appendix 3 contains a summary of each of the most important production and conversion freighter programs.

Our long term forecasts start from the beginning of 2020, and show predicted changes through to the end of 2039, taking into account our assessment of new-build freighter production, passenger-to-freighter (P-to-F) conversion activity, and the retirement of freighters from the existing freighter fleet. The forecasts depict the future fleet evolution in five-year increments through the twenty-year forecast period. Also included is our prediction of the freighter fleet make-up in 2039 by aircraft type, for both the jet freighter and the feeder segments. Both the jet freighter and feeder chapters provide a sensitivity analysis of the impact of changes in traffic growth, freighter productivity, and a shift from freighters to the belly compartments of passenger aircraft.

This report is supplemented with a *Freighter Forecast Tool* and *Feedstock Analysis Tool*. The Freighter Forecast Tool allows subscribers to conduct their own analysis on the impact of changes to key assumptions discussed in the report, while the Feedstock Analysis tool provides customizable detail on the development of passenger to freighter feedstock for different aircraft types. Both tools are hosted on the Cargo Facts Consulting Insights platform (www.cfcinsights.com), which over the past 12 months has developed into a comprehensive analysis platform for the global air logistics business covering the air cargo, express, e-commerce and freighter business.

We trust this report will provide you with valuable independent insights on shaping your freighter aircraft strategy. As always, we welcome your feedback and further questions.

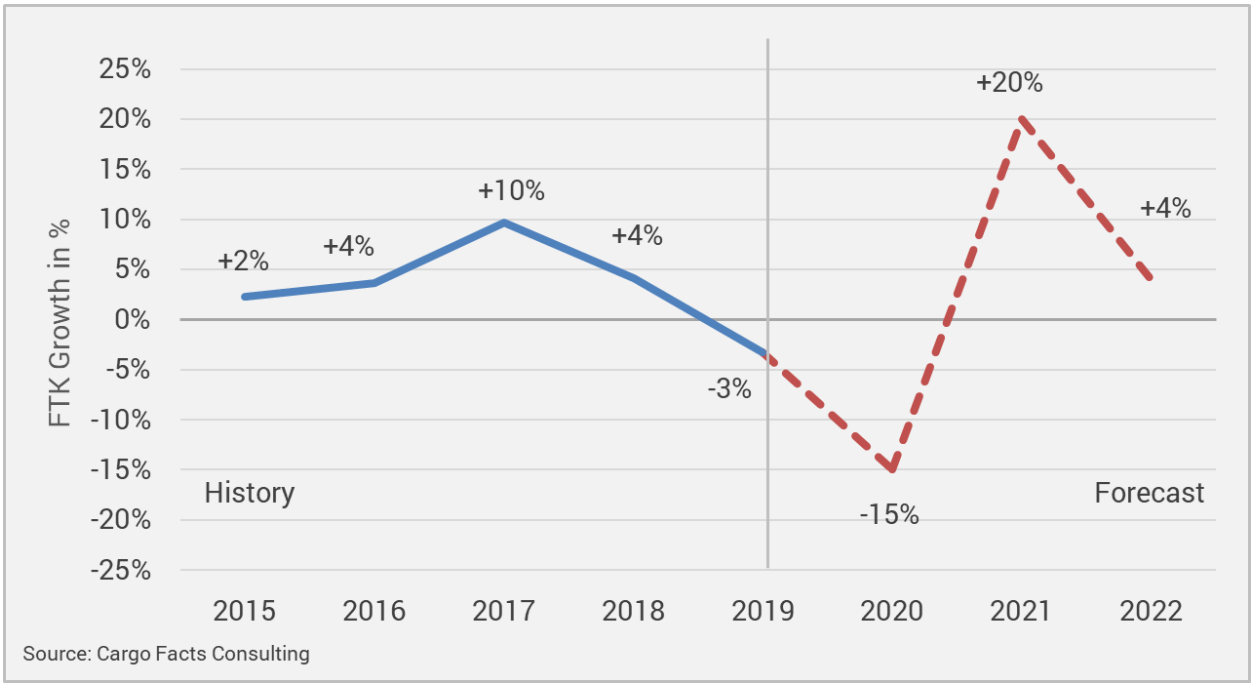
2. The 2020 Crisis and Near-Term Outlook

Given that our 20-year forecast was prepared in the middle of the worst crisis to ever have faced the global airline business, we have included a chapter on the evolving supply and demand situation affecting the air cargo business. Subscribers of the report will receive access to additional ongoing analysis as events unfold over the next three to six months via our Insights platform.

2.1 The Demand for Air Freight Capacity in the Short Term

Overall short to medium term air cargo demand will most certainly be affected by the current pandemic induced economic crisis. At this stage we expect a sharp drop in traffic in 2020, followed by a strong recovery in 2021, and a normal trajectory thereafter (see Figure 1).

Figure 1 - Air Freight Traffic History and Forecast 2015-2019 and 2020-2022F



Although actual growth rates may have to be reconsidered as the year progresses, we feel that the basic pattern will remain the same, especially given the level of stimulus being applied to economies around the world.

While the overall consumer demand environment and investment climate is expected to be weak, we expect demand for air cargo capacity to outperform trade, container shipping and the economy overall for the following reasons outlined on the following page:

- While some retail sectors are in lockdown and some industrial sectors (e.g. automotive) have idled or reduced production, supply chains continue to function and require the movement of goods. With up to 90% of passenger lower hold capacity missing on key lanes, demand for freighter capacity is high even despite lower overall demand.
- Currently there are substantial amounts of medical related cargo moving between economies to aid in the response against COVID-19.
- We are seeing many so-called blank sailings in the container shipping industries as companies slow down order activity. As inventory levels dwindle, we are likely to see demand surges for air cargo capacity. Supply chain disruptions are generally good for the air cargo business.
- Lastly, additional e-commerce activity is having a positive effect on the demand for express and intra-regional air capacity. While increased B2C business is not good for express yields overall, it does lead to higher utilization of networks.

2.2 Airfreight Supply in the Short Term

Freighter operators are likely to continue to benefit in the short and medium term even in a depressed environment because so much passenger capacity has been removed from the market. Currently somewhere between 30-40% of cargo capacity worldwide is missing on key intercontinental lanes. Freighter operators have responded with higher utilization and reactivating some parked aircraft. Load factors have also increased and rate levels are elevated.

As of April 2020, the share of the world's freighter fleet that is parked is at historical lows, at about 6%. Most aircraft that can be reactivated have been reactivated. As manufacturers idle production, there is a danger that there will be delays to aircraft set for delivery this year. This includes about 14 767-300F, 16 777-200F and 6 747-8F in 2020 and a similar number of aircraft scheduled for delivery in 2021.

Even conversions may be affected if aircraft inspectors are not able to travel to facilities in China, where most narrowbody and medium widebody conversions take place. This could potentially delay planned redeliveries of aircraft by a number of months. Currently we expect to see redeliveries of about 15-20 widebodies (mainly 767-300s) and between 30 and 40 narrow body freighters (mainly 737s and some A321s).

Some passenger airlines have been operating so called passenger freighter capacity. At the beginning of April, we counted over 40 airlines and more than 140 mainly widebody passenger aircraft that were being

operated in cargo only configuration, with pallets in the bellies and bulk loaded boxes in the passenger cabin. Two weeks later – in the middle of April – we counted 350 passenger aircraft operating on similar missions. These aircraft have been mainly deployed to carry medical cargo and personal protective equipment rather than general freight traffic. In some cases, passenger freighter flights have also doubled up to repatriate citizens. We expect this surge in activity to be short lived as the economics do not justify using passenger aircraft as freighters on long haul routes and only on shorter 2-3h sectors if rate levels remain elevated.

2.3 Beyond 2020 – What will recovery look like

The prospects for air cargo business in general and specifically for freighter operators over the next 12-24 months will depend both on underlying demand as well as how quickly passenger capacity comes back online. Our assumption is that travel restrictions and a subdued passenger traffic environment will linger longer than a worldwide economic recession. Table 2 provides an overview of how we expect different air cargo markets to perform.

Table 2 - Air Cargo Market Outlook and Freighter Demand over in 2020 and 2021

Segment (share of intl. traffic)	Significance for Freighter Demand	Next 12-24 Months (2020-2021)
General Air Cargo (80%)	Most large widebody and some medium widebody demand	Decline due to lower industrial production. Spikes due to supply chain disruptions. Freighter operators should do well because of loss of passenger capacity.
Express (17% of intl and most domestic traffic)	Feeders through to medium widebodies and about 40% of large widebody fleets	Moderate growth, intercon stronger than domestic. More e-commerce and decline in B2B will depress yields.
Mail (3%)	Some narrowbodies, but almost all international mail traffic moves on passenger services.	Strong growth as a result of e-commerce traffic.
E-Commerce (16% spread across general, express and mail)	Narrowbodies and medium widebodies. Indirect demand for capacity on large widebodies	Strong growth in both domestic, regional and cross border markets.
On-Demand	All types of freighter aircraft ranging from small props and jets, feeders, narrowbodies, medium and large widebodies.	Periodic charter spikes due to inventory forecasting errors and supply chain disruptions during uneven economic restart/recovery

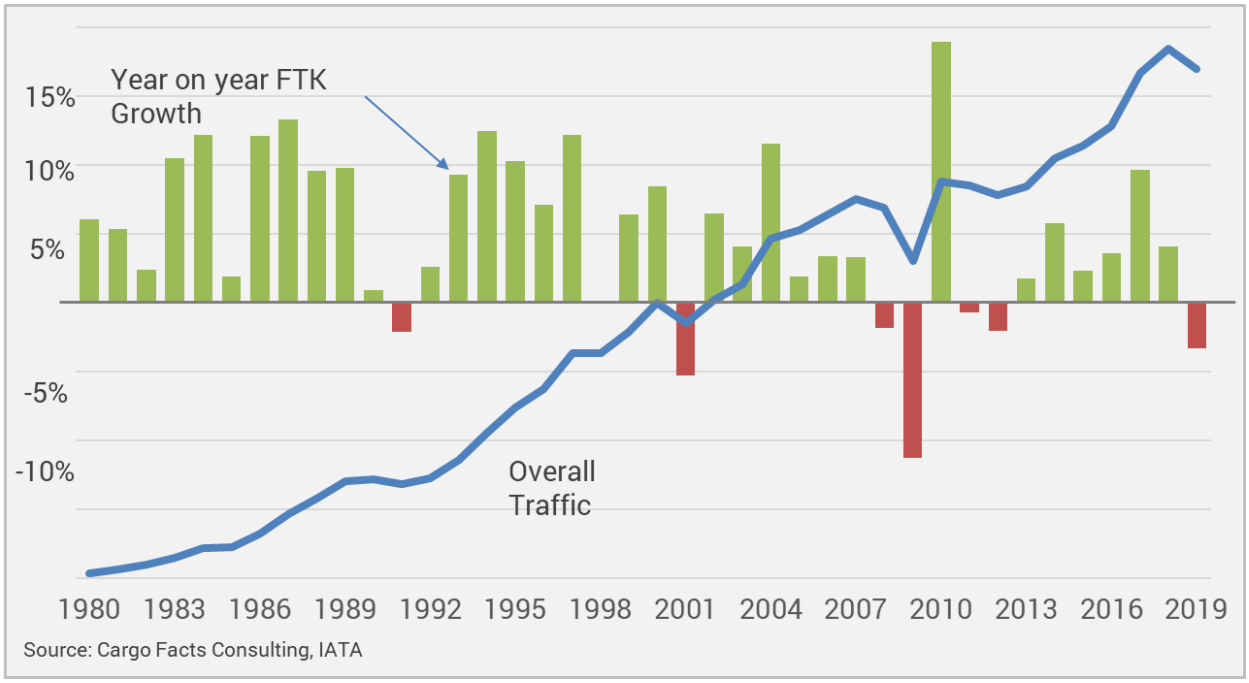
3. Long Term Air Freight Demand

3.1 Global Air Freight Demand since 1980

After six years of uninterrupted group, global air cargo volumes declined by over 3% in 2019. In international markets this decline was almost 4%. This picture, however, hides the fact that e-commerce and express traffic has been growing strongly in important international and domestic markets, including domestic US and China. Most of the weakness in the overall air freight business has been linked to key manufacturing sectors such as the automotive business and ongoing worldwide trade tensions, particularly between the United States and key trading partners. Even without considering the impact of COVID-19, overall demand in growth in 2020 was expected to be moderate.

Nevertheless, long term air cargo growth has followed a positive trend, with only seven out of the past 30 years exhibiting negative growth – during the first Gulf war, in 2001 following the post dot.com bubble recession, during the global financial crisis and on three other occasions over the past 10 years. Figure 2 provides an overview of global air cargo freight tonne kilometres (FTK) growth between 1980 and 2009.

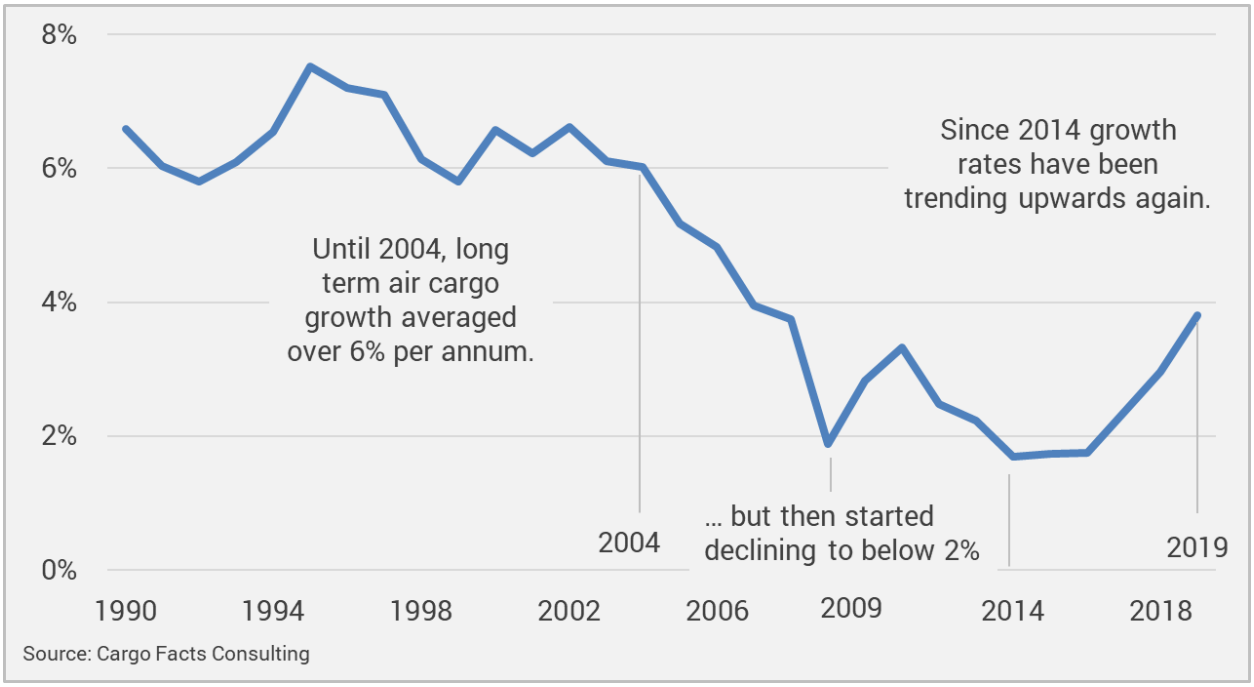
Figure 2 - Air Freight Traffic Growth 1980 - 2019



Although overall air cargo growth has been positive, long term growth rates have been trending downward. Figure 3 highlights how the ten-year moving average growth rate has changed. Until about

2004, long term air cargo growth averaged at about 6% per year, but then started declining to below 2%. Since 2014 growth rates have been trending upwards again, although we expect the decline in 2020 to have a pronounced impact on the average for many years to come.

Figure 3 - Ten Year Moving Average Air Cargo Traffic Growth 1990 - 2019



3.2 Long Term Global Air Freight Outlook

To support our freighter forecast, we prepare long-term air cargo traffic forecasts under different scenarios. While our base case predicts a long-term air traffic growth rate of 3.8%, we find that scenarios of between 2.2% and 5.0% appear realistic. This is slightly lower than last year's forecast as we consider the long-term impact of the current pandemic induced economic crisis. Specifically, our twenty-year forecast has been prepared to take into account an expected 15% drop in worldwide air cargo volumes in 2020, followed by a 20% rebound and a normal trajectory thereafter. This is consistent with the situation observed following the 2007/2008 global financial crisis. The overall long-term effect of such a scenario is about 1 year of lost growth over a 20 year period. As such, our underlying 20 year traffic forecast has dropped from 3.9% to 3.8%. In comparison, our baseline traffic forecast is somewhat less optimistic than recent Boeing and IATA forecasts and matches the latest Airbus forecast. Table 3 provides a comparison of our most recent forecast with others produced over the past one and a half years.

Table 3 - Cargo Facts Consulting vs Other Traffic Forecasts

Forecast	Baseline	Range	Date Published
Cargo Facts Consulting 2020 – 2039	3.8%	2.2% - 5.0%	April 2020
Cargo Facts Consulting 2019 – 2038	3.9%	2.6% - 5.0%.	April 2019
Cargo Facts Consulting International Express 2020 – 2024	5.0%	n.a.	November 2019
Cargo Facts Consulting US Domestic Express 2020 – 2024	1.2%	n.a.	November 2019
Cargo Facts Consulting Intra EU Express 2019 – 2024	3.4%	n.a.	November 2019
IATA 2019 – 2028	4.2%	n.a.	March 2019
Boeing 2018 – 2037	4.2%	3.7% - 4.7%	October 2018
Airbus 2019 – 2038	3.8%	4.3% (belly) 2.8% (freighter)	September 2019

Overall, we expect express and e-commerce demand to outpace general cargo growth in both the medium and the long term. Our Air Express Market Outlook (published in November 2019) and Global E-Commerce Logistics Outlook (published in September 2019) provide more detail on the current state of play and expected developments in each of these business segments.

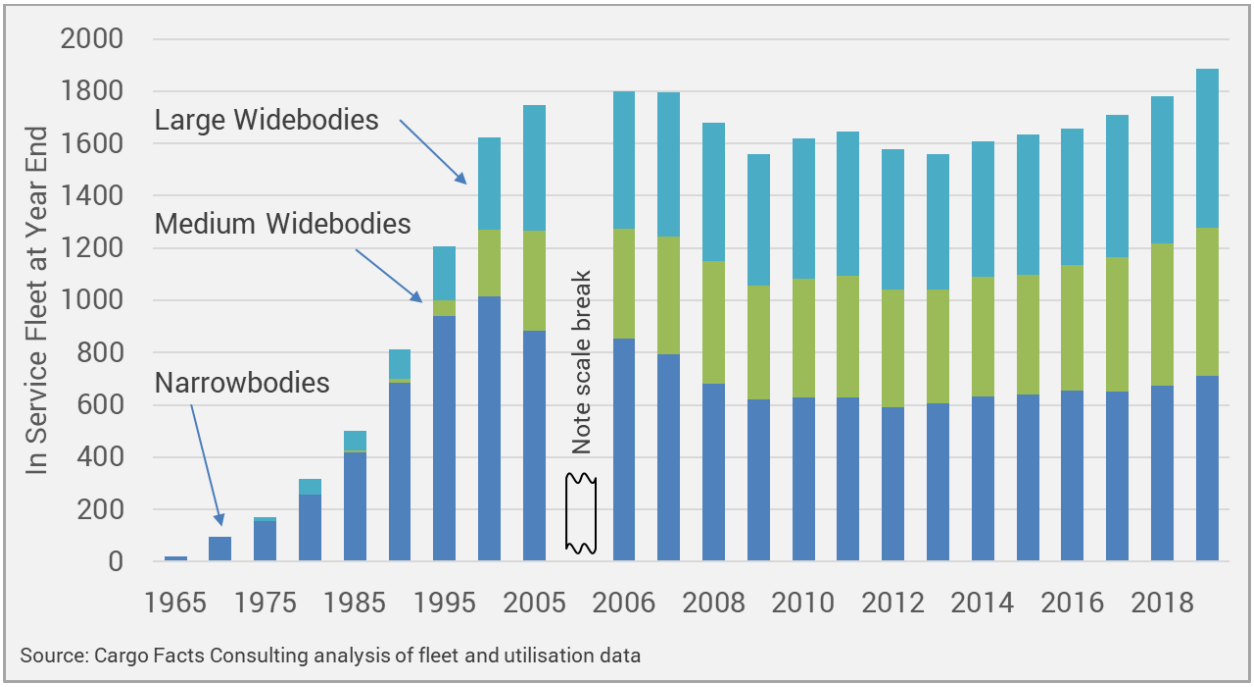
At this point in time it is too early to estimate whether the current crisis will have a lasting impact in term of reorganization of global supply chains towards a greater degree of regionalization. While the recent political environment has favored higher levels of protectionism, supply chains and markets have and continue to remain global.

4. Jet Freighter Fleet Analysis and Forecast

4.1 Fleet Evolution and Recent Developments

Overall, the world's in-service jet freighter fleet grew by almost 6% last year, despite a drop in world air cargo traffic of over 3%. The largest increase was in the large widebody fleet which saw overall aircraft numbers increase by 7%, compared to around 5% for the narrowbody and medium widebody fleets.

Figure 4 - Jet Freighter Fleet Evolution 1965 - 2019



As of the first quarter of 2020, there were a total of 1,885 jet freighters in operation ranging from Bae146s through to 747-8Fs. This includes 709 narrow body freighters (mostly 737s and 757s), 569 medium widebody freighters (mostly A300s, 767s and A330s) and 607 large widebody freighters (mostly 747s, 777s and MD-11s). Table 4 provides an overview of the jet aircraft included in each category.

Turboprop and regional jets operating in freighter configuration are included in a separate chapter (5). Note that our fleet tally and forecast do not include special purpose aircraft such as the AN-124 and IL-76, as these generally do not operate in scheduled cargo networks.

Despite overall weak demand in 2019, the share of the world's freighter fleet that is parked remains at historical lows. In fact, as in 2019 several previously parked older generation aircraft were brought back in service.

Table 4 - In Service Jet Freighter Fleet, Q1 2020

Narrowbody	Medium Widebody	Large Widebody
< 85,000 lbs (< 40 tonnes)	*85,000 – 180,000 lbs (40 - 80 tonnes)*	*> 180,000 lbs (> 80 tonnes)*
709 (+5%) Total Units	**569 Total Units (+5%)**	**607 Total Units (+7%)**
11 BAe 146	4 A310-300F	16 MD/DC-10-30/-40
27 DC-9, 16 MD-80	9 A300B4, 163 A300-600	113 MD-11
14 B737-200	38 A330-200F, 3 -200P2F	179 B777
32 B727-100/-200	3 A330-300P2F	6 747-200F
122 737-300, 145 737-400	58 B767-200	48 747-400SF/BCF
6 B737-700, 20 B737-800	168 767-300F	155 B747-400F/ERF
5 TU-204C	109 767-300BCF/BDSF	90 B747-8
311 757-200	14 MD/DC-10-10	

Source: Cargo Facts, Cargo Facts Consulting analysis of fleet, transaction and utilisation data

High feedstock values for newer generation aircraft, low fuel prices as well as pending STC approvals have slowed the transition from older to newer generation types in the ***narrow body*** segment.

- The 737-700 fleet increased by 2 units and the 737-800 fleet by 11 units to a total of 6 -700s and 20 – 800s. Redeliveries are likely to accelerate now that Israel Aerospace Industries (IAI) has received its STC for the 737-800 conversion. Pemco is expected to receive its STC for the 737-700 conversion in the first half of 2020.
- So far there have been no A320/A320 conversions redelivered to customers, but we expect to see the first aircraft with operators this year. In February 2020, EFW received EASA certification for its A321-200P2F. 321 Precision is also expected to receive its STC in 2020, with C3 to follow in 2021. EFW and C3 A320 certification are expected to take place in late 2020/ early 2021.
- Aided by low feedstock prices and customer demand, the MD-80 freighter fleet increased from 6 to 16 units in the last 12 months.

- The number of in-service Bae 146 freighters increased by four units with the transfer for aircraft form WDL in Germany to Pionair in Australia. Furthermore, the number of in-service DC-9 units increased by six aircraft, and two additional 737-200s were returned to active service. Meanwhile the 727 fleet declined by 11 aircraft.
- Even with dwindling feedstock numbers, the 737-400 remains immensely popular with operators and the last 12 months saw the in-service fleet increase by 10 units. The number of 737-300 declined marginally by 3 units. Currently there are a total of 267 737-300/400 in operation.
- The 757-200 remains the most popular aircraft in this segment, with numbers increasing marginally by four units to 311.

Feedstock values have also had an effect on capacity additions in the ***medium widebody*** segment.

- The 767-300 freighter fleet grew by 17% from 237 to 277 units. This included an additional 21 production freighters and 19 conversions.
- Meanwhile the A330-200P2F saw only a single redelivery to Egyptair, the sole customer for the type. DHL Express took redelivery of an additional two A330-300P2F and expects to receive a further unit in the first half of 2020, bringing its total to four. So far, no other customers have made commitments to further A330 conversions, partly due to the continued popularity of the 767-300, for which feedstock continued to be available at the right price. As feedstock becomes scarcer and A330 feedstock becomes cheaper, we expect a shift to more A330 conversions.
- The number of A300-600 in service declined by six units as a result of Uni-Top airlines shutting down operations, but otherwise this type continues to remain popular and we do not expect to see many retirements in the near term as the average fleet age is still fairly young.
- Meanwhile, a number of older generation type were parked or retired – this includes 5 A310-300F, one A300B4 and 6 MD-10-10Fs that were retired from the FedEx fleet. The number of 767-200 in operation, however, increased by two units.

Activity in the ***large widebody*** segment is currently being driven by the 777-200F, but also by the reactivation of several previously parked aircraft:

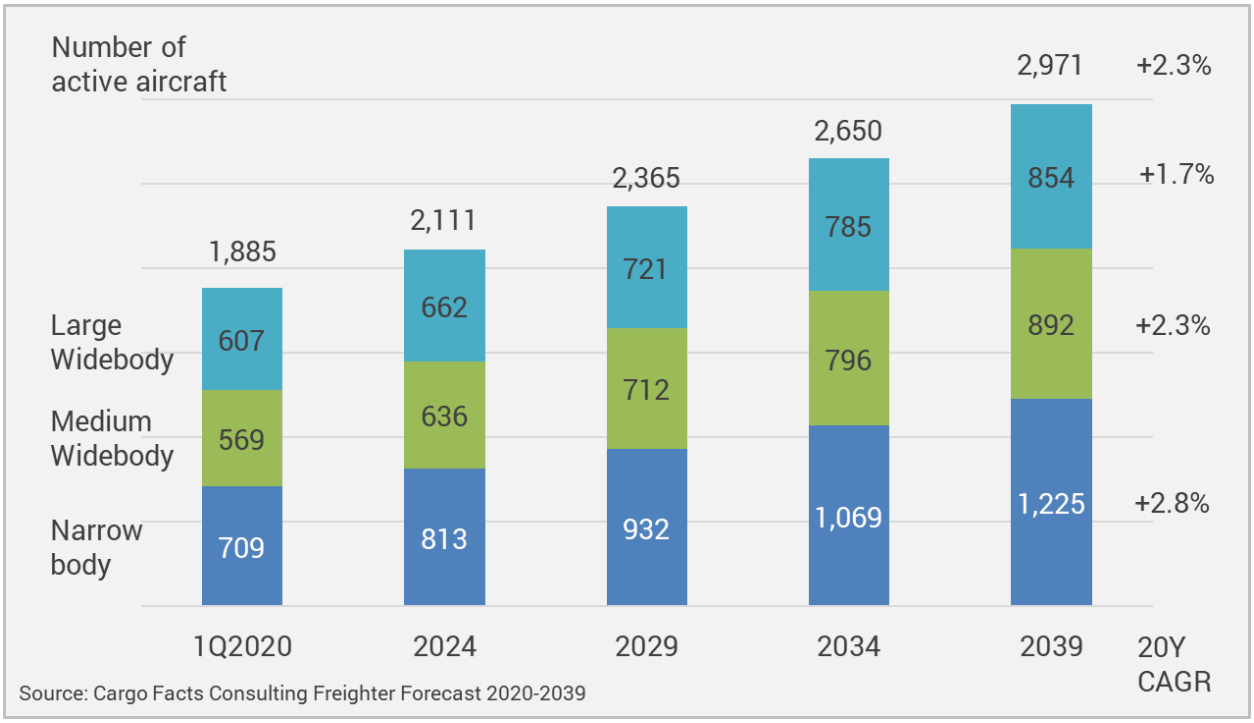
- The number of 777 freighters in operation increased by 18% or 27 units to a total of 152 aircraft.
- An additional 7 747-8F were delivered bringing the in-service fleet to 90 units. The remaining backlog for this type is 17 aircraft and at this stage we estimate that the 747-8 program will end in 2022.

- The number of MD-11Fs in service declined by four aircraft in net terms as both Lufthansa Cargo and FedEx parked aircraft of the type. UPS meanwhile, has picked up some of the ex-Lufthansa units and put these back into operation.
- Four 747-400F/ERF and three 747-400BCF and 6 747-200Fs were reactivated over the last 12 months. There are very few 747 freighters that are currently parked.

4.2 Twenty Year Jet Freighter Forecast

Over the next 20 years we expect the world's jet freighter fleet to grow by about 65%, from 1,885 units today to 2,971 units at the end of 2039 (Figure 5).

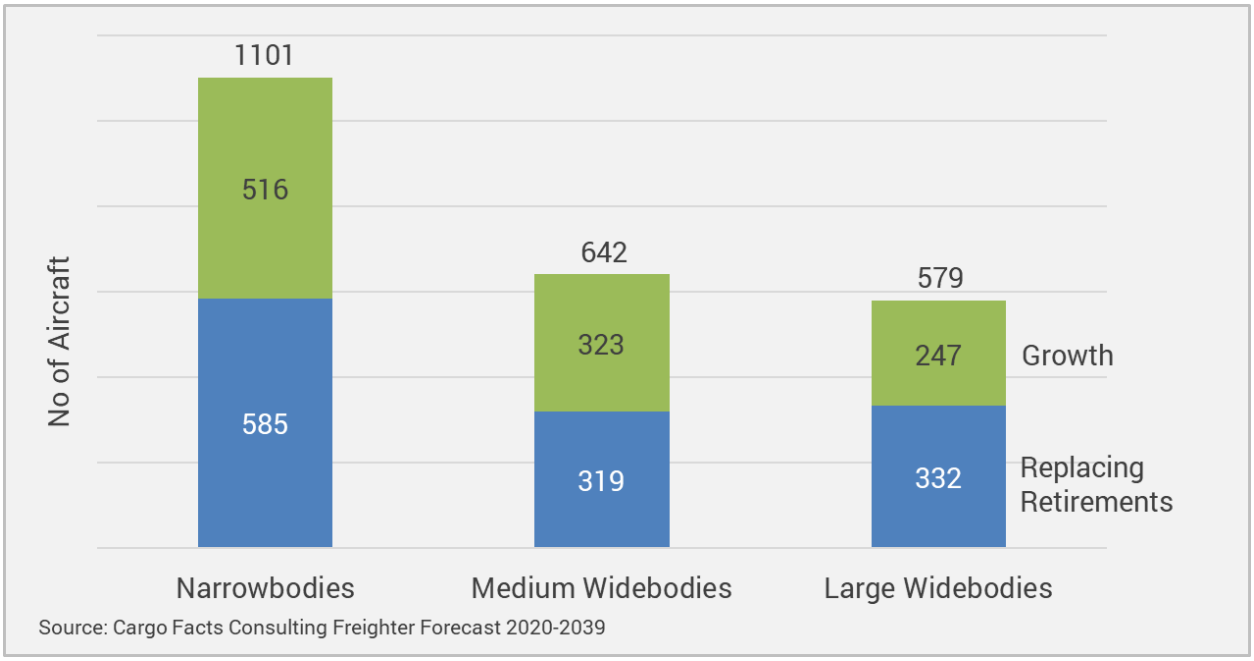
Figure 5 - Baseline Jet Freighter Fleet Forecast 2020 - 2039



The portion of freighters in the narrowbody size category is forecast to grow by nearly 3% through 2039, to about 41% of the total.

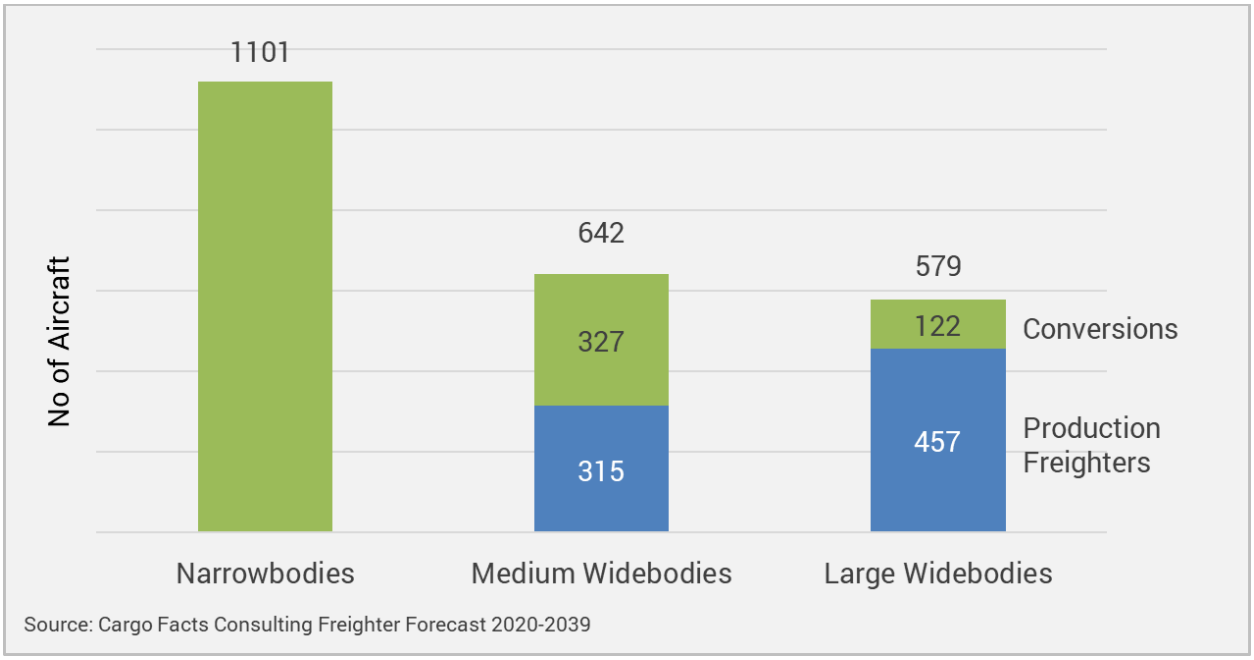
The net growth in fleet size is 1,086 (of all sizes), which when combined with 1,236 retirements, produces the overall need for 2,322 freighters through 2039. This total fleet requirement equates to an average of 116 units per year. Figure 6 shows the details of the new and replacement aircraft added for each size category through 2039.

Figure 6 - New and Replacement Jet Freighters Added 2020 - 2039



The added freighters will consist of 762 production freighters (33% of the total) and 1,560 P-to-F conversions, or 67% of the total fleet (Figure 7).

Figure 7 - New and Converted Jet Freighters Added 2020- 2039



Nearly 60% of the production freighters will be large widebody types, and the share of production freighters added in the large widebody segment will be close to 80% compared to conversions. The operator mix, cargo densities, utilization and unit cost requirements in this segment favor production freighters. Given the lack of active production programs, an abundance of P-to-F feedstock and low aircraft utilization, we do not foresee any production freighter deliveries in the narrowbody segment.

Table 5 provides details of our estimated composition of the baseline fleet on a model-by-model basis twenty years (2039) in the future.

Table 5 - 2039 Baseline Jet Freighter Fleet

Narrowbody *< 40 tonnes*	Medium Widebody *40 - 80 tonnes*	Large Widebody *> 80 tonnes*
1225 Total Units	**892 Total Units**	**854 Total Units**
27 MD-80	27 A300-600	599 777
17 737-300/400	453 A330	21 747-400
528 737-700/800	347 767-300	107 747-8
482 320/321	65 787/ 767XF	127 A350
171 757-200		

Source: Cargo Facts Consulting Freighter Forecast 2020-2039

Note the dominance of the following types: 737NGs and A320s/321s in the narrowbody segment; A330s and 767-300s in the medium widebody segment; and 777s plus significant roles for 747-8s and potentially A350s in the large widebody segment. Based on our prediction, there will be less nose door capable aircraft operating in the large widebody fleet in 2039 than today – 128 vs 245. This will have fundamental implications for the outsized cargo market.

4.3 Jet Freighter Fleet Forecast Assumptions

The forecast reflects our assessment of manufacturers' future product strategies to determine which specific aircraft types will be offered as jet freighters over the next twenty years. Some models shown in our forecast may not become available in freighter configuration, while some that we do not show may be introduced. To the extent that such circumstances develop, it is important for readers of this report to recognize that the availability or non-availability of any particular model is unlikely to affect the overall

demand for freighter aircraft. Overall demand is a zero-sum game, meaning that other models will fill the gap. Table 6 provides and overview of the current and future freighter aircraft supply situation which drives our future fleet composition estimates.

Table 6 - Aircraft Available to Operators During the Forecast Period

	Narrowbodies	Medium Widebodies	Large Widebodies
Facing near-term extinction	DC-9, 727, Bae 146, 737-200	DC/MD10-10, A300B4, A310	747F Classic, DC-10-30F/40F
At peak use, or with little future growth potential	MD-80, 737-300/400, 757-200	767-200, A300-600, A330-200F	747-400F/ERF, 747-400SF/BCF, MD-11F
Expanding role going forward	737-700/800, A321	767-300F/BDSF/BCF, A330-200/300P2F)	777F, 747-8F
Future aircraft	A320, 737-900	787-9F, 767XF, A330-900F	777-300ERSF, A350 F/P2F, 777XF

In the *narrowbody segment*, the individual aircraft mix is based on:

- Feedstock availability limiting further conversions of 737 classics and 757s.
- 737NG and A320/321 conversions available throughout the whole period with enough feedstock to support this.
- We assume a first redelivery of the A321-200P2F in 2020 and A320-200P2F in 2021 following certification of the aircraft.
- A320 conversions are likely to be available starting 2021 as conversion companies receive their supplemental type certificates.
- No manufacturer developing or offering a production freighter program in this segment.

In the *medium widebody* segment the individual aircraft mix is based on:

- An end of the 767-300F production freighter program within the next 10 years and the 767-300 P2F programs within the next 15 years. Although we understand there has been some discussion of a stretched and reengined 767 as an alternative to a 787 freighter, we did not consider this

aircraft, but note that depending on acquisition cost and specifications, this could affect some demand in the large widebody segment. We note that in 2020, Boeing has increased the production rate of the 767 from two and a half (2.5) to three (3) units per month.

- Feedstock supporting A330-200 and -300 freighter conversions are available throughout the whole forecast period.
- An A330-900F becoming available within the next five years. Given that the freighter has similar capabilities to an A330-300 such a program would require a launch of the program would require a substantial order from a customer such as Amazon, FedEx, UPS, DHL, or SF Express.
- A 787-9F becoming available after 2028. The launch and viability of such a program would depend on the availability of a stretched and upgraded 767. We feel that a stretched an upgraded 767 would be more attractive to operators than a higher capital cost 787 freighter.
- Due to uncertainty surrounding timing and positioning of Boeing's NMA program we have not factored such an aircraft into our forecast at this point in time.

By comparison, in the *large widebody* segment the individual aircraft mix is based on:

- No further deliveries of the 747-8F beyond the current backlog of 17 aircraft and last production. Unless Boeing were to secure a large order from the US military for this aircraft, we would expect the program would become inactive after 2022.
- A transition from a 777-200F to a 777XF after 2025. At this stage we think a 777-8F would be more likely than a 777-9F as the aircraft represents a natural extension of the 777-200F. By comparison a 777-8F is expected to have 29 main-deck positions compared to 27 on the 777-200F. A potential 777-9F would have 35 main-deck positions and consequently compares more to a 777-300ERSF with 33 pallet positions.
- An A350-900/1000F becoming available within the next 5 years. At time of writing we understand that Airbus has aggressively been pursuing a launch customer for the program.
- A 777-300ER conversion available from 2022, following the official launch of the Israel Aerospace Industries (IAI) - GECAS program in late 2019.
- We did not assume any 777-200ER becoming available as the declining feedstock situation as of 2022 would affect the long-term viability of the program. In contrast the feedstock for the 777-300ER will increase over the next 15 years.

Regarding retirements, we recognize that freighter aircraft types typically have useful economic lives in excess of thirty years, with small freighters applied in low-utilization regional express networks often remaining in service over forty years. On average, we predict the retirement of approximately 62 jet freighters per year. Over the next twenty years more than 1,200 freighters from the current fleet (about two thirds of those now in operation) will be retired.

Weak market conditions resulted in the parking of a significant quantity of otherwise serviceable jet freighters beginning in the last half of 2012. Early in 2018 we noted that roughly fifty 747-400 freighters and fifty MD-11 freighters are parked. Fueled by strong cargo demand in 2017, about 21 previously parked MD-11F, 747-400 ERF, 747-400BCF/BDSF and even A300B4 were returned to service in 2018. As of late 2019, the in-storage fleet is at historical lows of approximately 6%.

4.4 Jet Freighter Sensitivity Analyses

Our analysis technique allows us to determine the impact on freighter requirements given various assumed levels of demand growth, changes in freighter productivity, and shifts in the ratio of freighter-to-belly use. Small changes in assumptions can have large impacts in terms of fleet requirements.

Figure 8 shows the significance of underlying growth as a determinant of jet freighter flee size. A demand shift of half a percentage point results in roughly a 10% change – 275-300 planes – in the size of the freighter fleet in 2039.

Figure 9 shows the significance of assumed shifts in freighter productivity. A 0.5 percentage point change in productivity results in roughly a 10% change – about 280 planes – in the size of the freighter fleet in 2039.

Figure 10 shows the significance of changes in the freighter-belly ratio. Here the middle bar depicts the baseline case, which assumes a decline in the freighter share from 50% today to 42.5% in 2039. If the ratio remains unchanged then this will lead to the requirement for an additional 286 widebody freighters.

Figure 8 - Demand Growth Impact on 2039 Jet Freighter Fleet Forecast

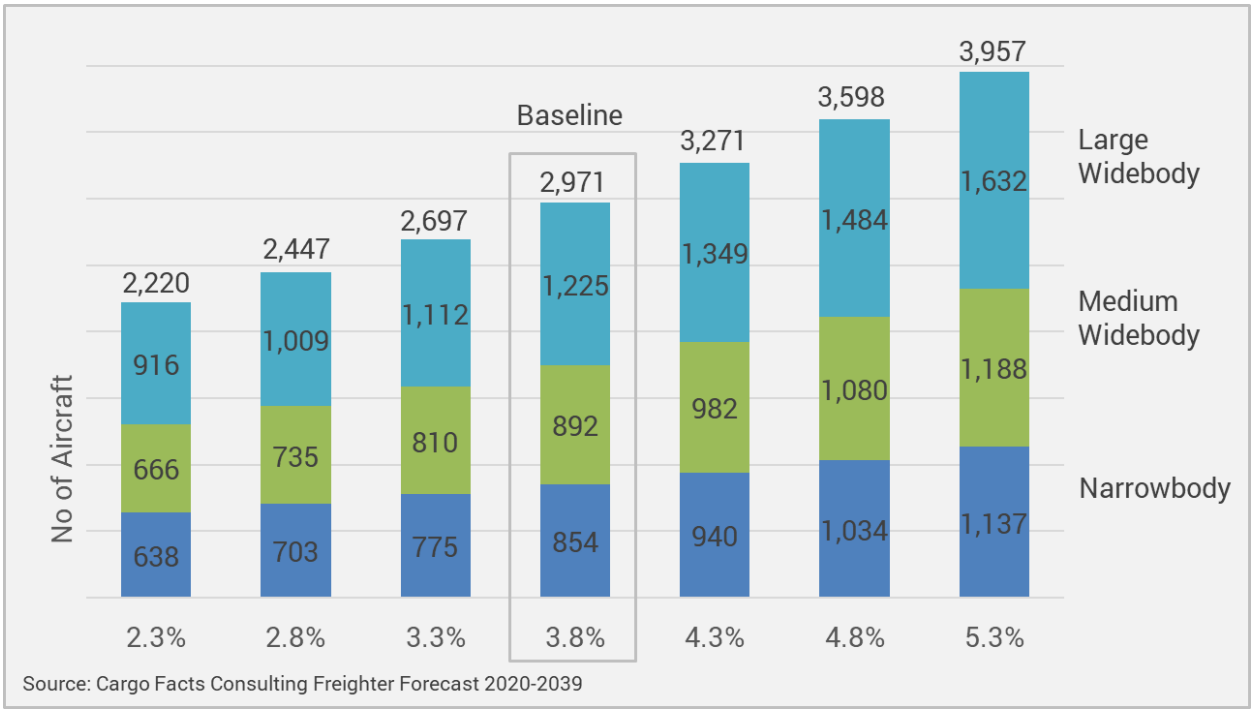


Figure 9 - Productivity Growth Impact on 2039 Jet Freighter Fleet Forecast

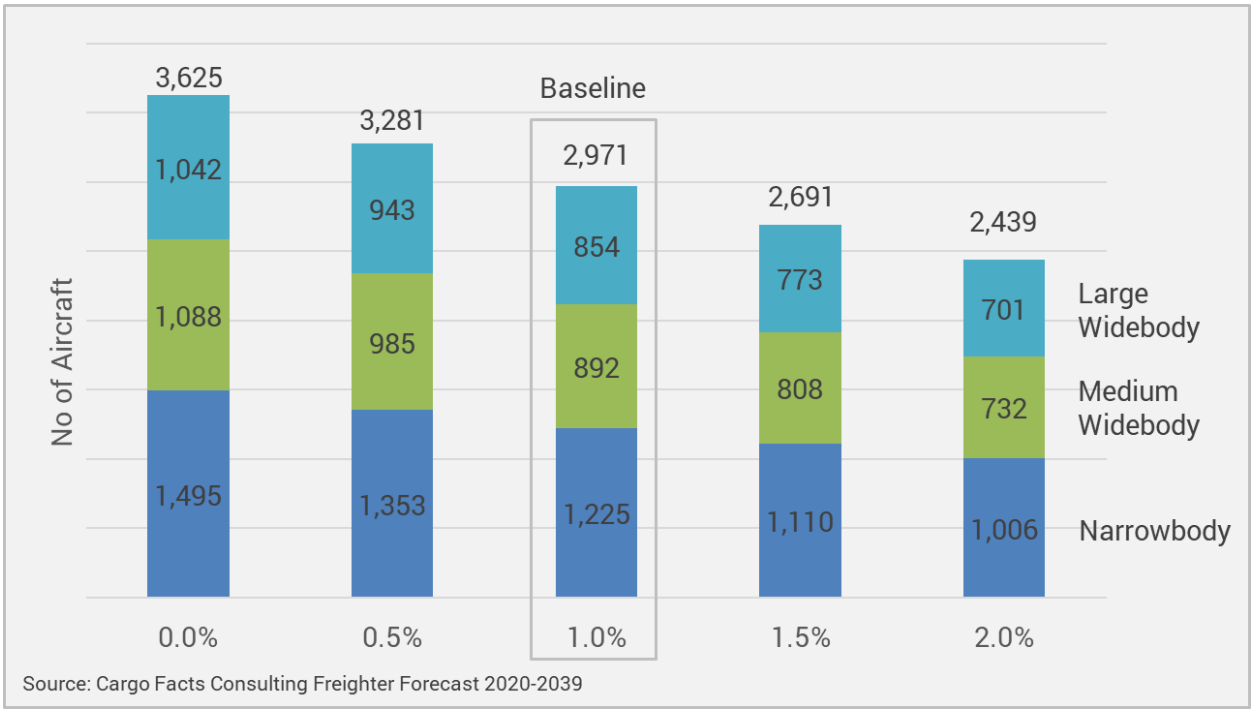
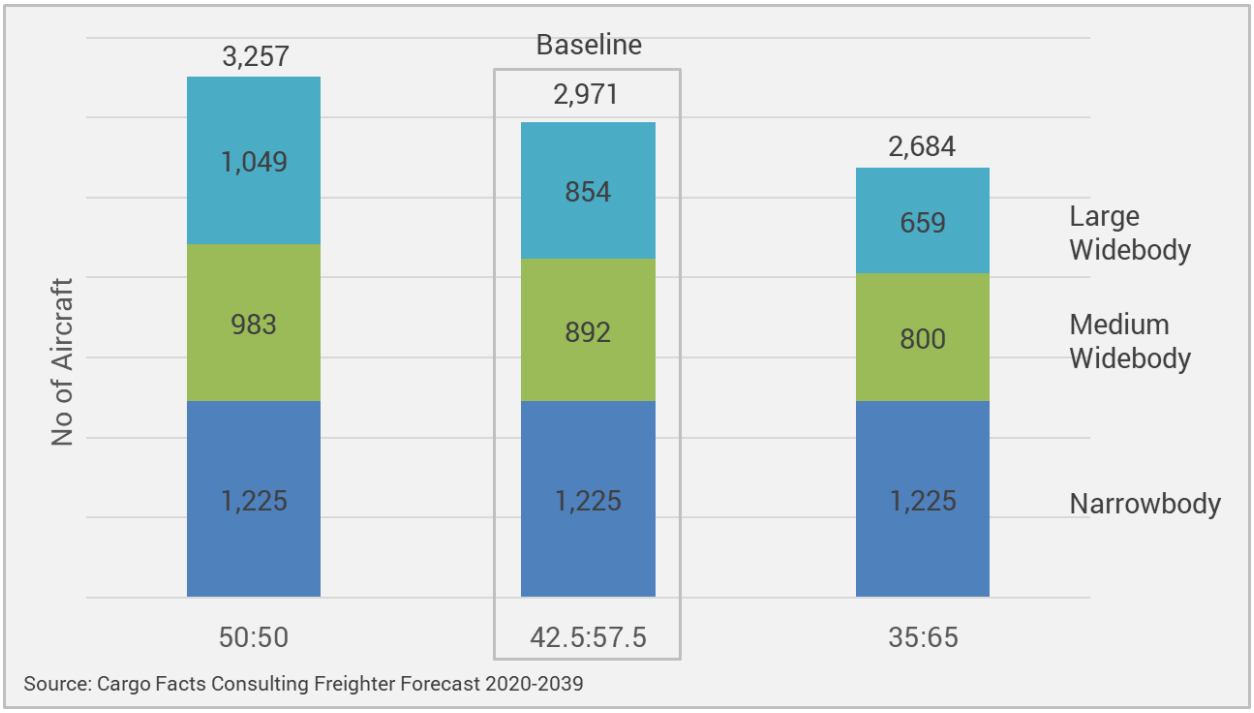


Figure 10 - Freighter Belly Ratio Changes Impact on 2039 Freighter Fleet Forecast



Source: Cargo Facts Consulting Freighter Forecast 2020-2039

4.5 Re-shoring, Belly Capacity, and B2C E-commerce: Fundamental Shifts?

Our long-term baseline forecast assumes the continuation of key trends relating to worldwide economic activity and integration. Our sensitivity analysis considers the effect of changes to traffic growth, belly freighter shift and productivity. However, it is worth further discussing the potential effects and likelihood of different scenarios relating to re-shoring, bell capacity dynamics, and more business to consumer e-commerce traffic. These result in both upsides and downsides for freighter demand and are likely to have different effects on individual freighter segments. Our Cargo Facts Consulting Insights platform regularly publishes analysis on topics such as these and their impact on the air logistics business.

Re-Shoring

Following the 2008/2009 crisis, world trade never resumed its previous trend and has followed a flatter growth rate. Prior to this it was customary to see air cargo forecasts predicting long term growth rates of in excess of 6% per year. In recent years, large export driven economies such as China have focused more on domestic led consumption rather than export led growth, and trade tensions have had an impact on trade flows and sourcing patterns.

Re-shoring would likely hit the demand for large freighter capacity more than other segments, given that most medium widebodies and all narrowbodies and feeders are operated in regional and domestic networks. A growth rate decline by half a percent on intercontinental routes would likely reduce large freighter demand by about 100 aircraft over a 20 year period.

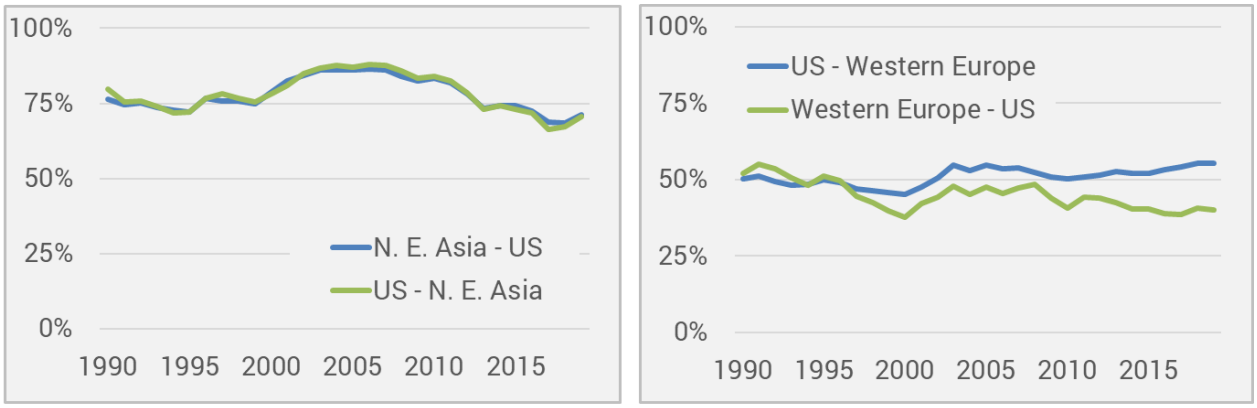
It is unclear whether reshoring would lead to greater demand for regionally operating aircraft, but we feel that additional regional demand is likely to be picked up by trucks. For example, although US air freight import volumes declined by 6% in 2020, truck import tonnage from Mexico increased by 3.1%.

Belly Capacity

The current pandemic induced crisis has the potential to reset the mix of passenger lower hold capacity available in the market. On average, just over half of air cargo traffic is transported in the bellies of passenger aircraft, this figure has been trending downwards since the mid-2000s where it peaked at about 60% of total freight tonne kilometres carried. The share varies substantially by market.

Figure 11 provides an overview of the development on the two main US East-West markets. While the freighter share on the transpacific is close to 75%, on the transatlantic it varies between 40% on Westbound and 55% on Eastbound lanes.

Figure 11 - Freighter Share on Major US East-West Markets 1990-2019



Source: Cargo Facts Consulting Analysis of t100 segment data for US and international carriers

Our long-term forecast assumes that the freighter share will decrease as more freight capable passenger aircraft are deployed on international markets – 787s, A350s and the 777-8 and particularly the 777-9. The latter has up to 230m³ of cargo space in the belly – as much as the total space of a 757-200 freighter. The current crisis may accelerate this process: roughly one third of the passenger widebody fleet consist

of A380s, A340s, 777-200ERs and older 747-400s. The retirement of these aircraft is likely to be accelerated during the current crisis. This will drive up average industry belly capacity per seat.

Increased cabin densification may counter this trend and reduce the amount of belly capacity per seat. As it would a decision by passenger airlines that the 777-9 is too big and too risky to operate in a post COVID-19 world. These dynamics have a fundamental impact on the demand for large widebody capacity.

B2C E-Commerce

Dedicated e-commerce aircraft networks have hitherto been limited primarily to Amazon, which operates a fleet of 50 aircraft in the US and which is expected to grow to at least 64 in the US. In Europe, the dedicated fleet is currently smaller and consists of slightly less than 10 aircraft, most of which are operated by ASL. In late 2019, our Global E-Commerce Outlook took a detailed look at the air capacity procurement strategies of major e-commerce platforms and found that while many rely on air capacity. With few exceptions, e-tailers see own controlled logistics as a key source of competitive advantage. However, these platforms primarily tend to buy air capacity indirectly through commercial relationships with express carriers or postal companies that utilise air to move shipments in domestic and regional networks. We found that approximately half of shipments moving through express networks are business to consumer traffic and that this segment is the main source of growth. However, while this traffic has been good for volumes, it has affected yields. International and domestic express yields dropped in both domestic and international markets as the share of e-commerce increased.

Online retrial has done exceptionally well during the current crisis. While physical retail outlets were shut down, e-commerce platforms provided a near monopoly on most goods other than food and household items. If stay-at-home ordering were to drive permanent change in customer behaviour to the detriment of brick-and-mortar retail, this would improve capacity utilisation and scale economies of express networks and it would be good for margins despite lower yield levels. However, it could also make it more economic for Amazon and others to operate their own air and ground delivery networks in less densely populated areas. In both cases, the effect would be an upside for the demand for narrowbody and medium widebody freighter capacity.

5. Feeder Freighter Fleet Analysis and Forecast

5.1 Background

While there are a wide range of both turboprop and regional jet freighter aircraft, we have placed a lower limit of approximately 8500 lbs. (3.8 tonnes) and an upper limit at roughly 20,000 lbs. (9 tonnes). In volume terms, this means between 1000 ft^3 (or 30m^3) and 3000 ft^3 (80m^3). In seat terms, between 40 and 100 seats. Further criteria include:

- Aircraft with a large cargo door
- Aircraft available in containerized or palletized configuration, or
- Likely to be replaced by one of the above following retirement

However, we find that aircraft in this weight band operate in outside this segment competing with smaller aircraft such as EMB 110s/120s or larger aircraft such as the Bae146, DC-9s or even 737s. The below 3.8 tonne category is home of a more than 150 general cargo, feeder operators, and on demand charter operators which between operate around 1000 aircraft. These range from Cessna Caravans, Learjets, Falcons, Metros and EMB 110/120s. Most of these are operated in North America and a very large share of these aircraft are well beyond retirement age. While we believe there is a great deal of potential for ATR, Dash 8s and CRJs to replace capacity in this segment, we have excluded these aircraft from our feeder fleet tally and forecast. Please contact us if you have further interest in this segment including an assessment of opportunities in this segment.

Specifically, we have focused on ATR 42/72 variants, CRJ 200s, Dash-8 variants, ATPs and HS 748s, F27s and F50s, CV 580s, as well as AN-26/32, AN-74 and Saab 340s. In our fleet counts we have included both bulk loaded and containerized versions of these aircraft.

5.2 Current Fleet and Recent Developments

Table 7 shows the composition of the turboprop/RJ freighter fleet at the start of 2020. This fleet, which forms the point of departure for our twenty-year turboprop/RJ freighter forecast, contains a mix of older technology models nearing retirement and newer, modern aircraft.

Compared to last year, most of the fleet quantities remains largely unchanged but there are five additional CRJ 200s in 2020. When determining whether an aircraft is active or not, we analyze radar and other data

to determine whether an aircraft has flown in the last 365 days. Only if it has, we include it in the current fleet. We count approximately forty parked ATPs, F27/50s and some ATRs (mainly -42s).

Table 7 - Current Feeder Freighter Fleet

Feeders (Turboprops and Regional Jets) *8,500 – 20,000 lbs (3.8 – 9 tonnes)*
243 Total Units
43 ATR 42
65 ATR 72
5 Dash 8-100/Q300
5 Dash 8-Q400
16 CRJ 200
12 ATP, 10 HS 748
21 CV 580/5800, 12 F27/50
31 Saab 340
20 AN 26/32, 3 AN 74

Source: Cargo Facts, Cargo Facts Consulting analysis of fleet, transaction and utilisation data

The modest change in fleet size in the last year hides some of the changes taking place in this segment, specifically:

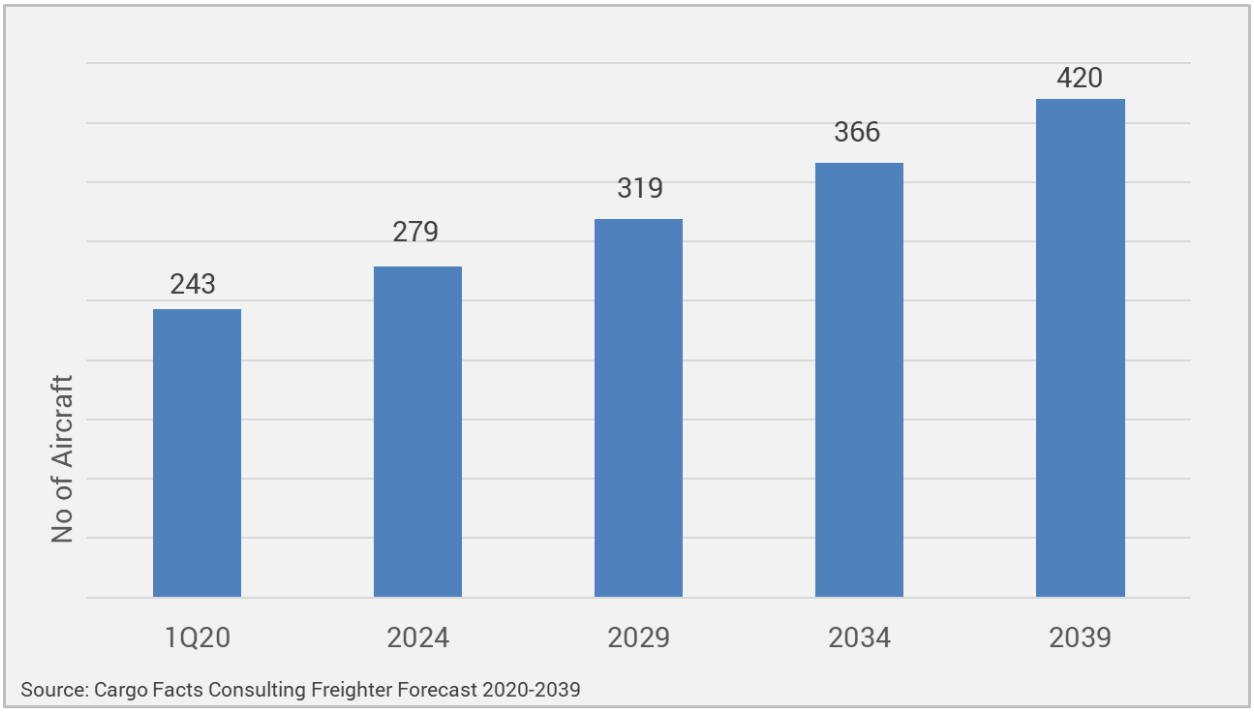
- IPR Conversions and Aeroconseil have been carrying out a number of ATR-72 conversions in the recent months. Aeronconseil redelivered an ATR 72 freighter to Poland-based SprintAir and another one to Pelita Air in Indonesia while IPR Conversions redelivered the first ATR 72 freighter to Cebu Pacific and the third ATR 72 to Hawaiian Airlines (for its subsidiary 'Ohana). ACIA Aero Capital acquired an additional 33.3% stake in IPS conversions, becoming the sole owner of IPR's conversions and the leader in the ATR conversion business. IPR remains the sole holder of a large cargo door STC for both ATR 72s and 42s which enables the operators to load containers and larger items while other conversions only allow ATR freighters to carry cargo in bulk.
- Going forward, the delivery of the first ATR 72-600 production freighters to launch customer FedEx starting 2021 will see the introduction of the first new aircraft into a segment that consists wholly of converted aircraft.

- The Bombardier turbo-prop fleet remains unchanged but could pick up momentum with the new large Q300 cargo door conversion program developed by Collins Aerospace and Air Inuit. Although Collins secured the STC for the passenger to freighter conversion in 2017, the large cargo door STC certification is expected in late 2020. This would allow the loading of palletized cargo and large items. Air Inuit has plans to retrofit two additional Q300s with the large cargo door modification.
- Although the active CRJ200 fleet increased by six aircraft, this included four reactivated aircraft. While operating economics favor turboprop aircraft in this segment, the higher cruising speed and operating altitude of the CRJ has made it attractive with both feeder operators on long thin routes and on demand charter operators with a focus on the US, Mexico and Europe.

5.3 Twenty Year Feeder Freighter Forecast

The expected evolution of the turboprop/RJ freighter fleet over the next twenty years is depicted in Figure 12. The fleet is shown to increase from 243 units in Q1 of 2020, to 420 units at the end of 2039.

Figure 12 - Baseline Feeder Freighter Fleet Forecast 2020 - 2039



Overall, the total number of turboprop/RJ freighters in 2039 is forecast to be about 1.7 the baseline quantity of 243 units. The net growth in the turboprop/RJ fleet size is 177, which when combined with

224 retirements, produces the overall need for 401 freighters through 2039. This total fleet requirement equates to an average of 20 turboprop/RJ units per year. All of the added feeder freighters in the forecast, with the exception of 90 ATR 72-600s (about 21% of all additions), will be freighter conversions (see Figure 13).

Figure 13 - Feeder Freighter Forecast Fleet Development 2020-2039

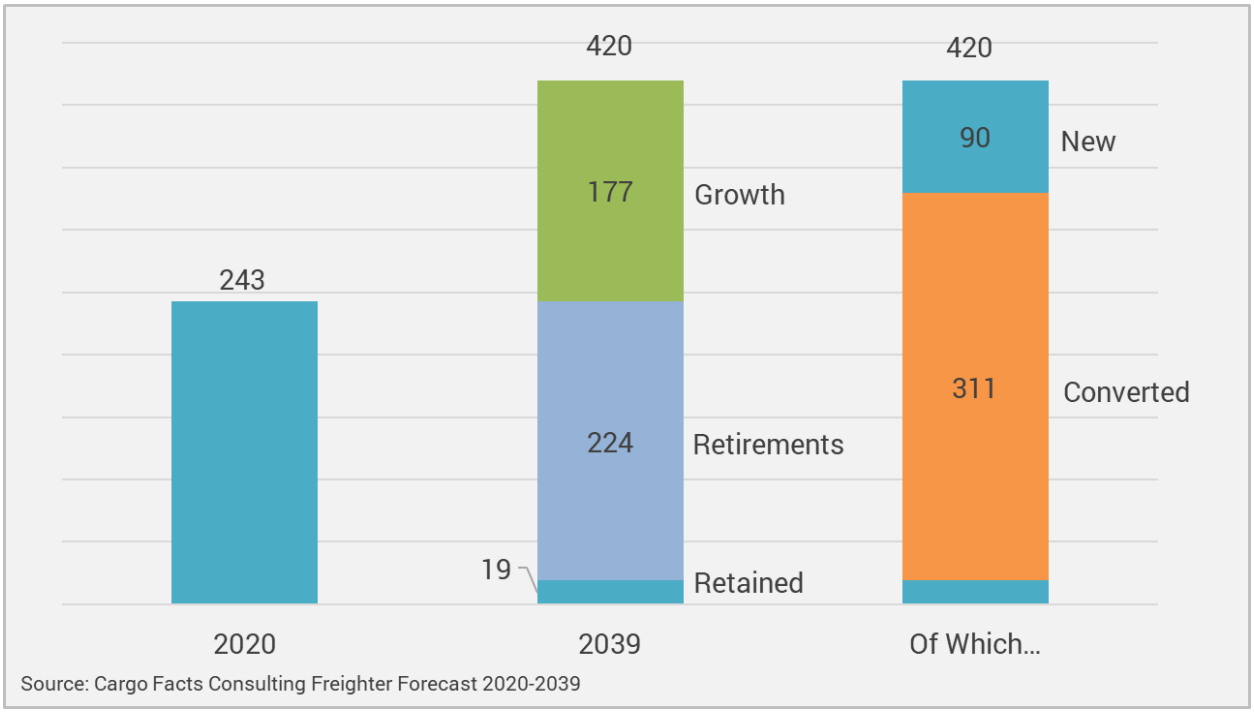


Table 8 shows the detailed composition of the turboprop/RJ freighter fleet on a model-by-model basis at the end of forecast period in 2039 under our baseline scenario. Based on our assessment, we see the ATR 72 being the single dominant type in the feeder segment, followed by the Dash 8 series, with upside for both if the CRJ 700/900 program does not materialize.

Table 8 - Future Feeder Freighter Fleet 2039

Feeders (Turboprops and Regional Jets) *8,500 – 20,000 lbs (3.8 – 9 tonnes)*
420 Total Units
6 ATR 42s 212 ATR 72s 26 Dash 8-Q300s 81 Dash 8-Q400s 44 CRJ 200s 50 CRJ 700/900s

Source: Cargo Facts Consulting Freighter Forecast 2020-2039

5.4 Feeder Freighter Forecast Assumptions

As with the Jet Freighter forecast (Chapter 4), the turboprop and regional jet ("feeder") freighter forecast reflects our assessment of future product strategies and aircraft availability over the next twenty years. Some models shown in our forecast may not become available in freighter configuration, while some that we do not show may be introduced. This is unlikely to affect overall demand within the segment but most certainly will affect the relative market shares of different types.

The main types of aircraft that will be involved in the future evolution of the turboprop/RJ freighter fleet over the next twenty years can be broken down into four sub-groups. As shown in Table 9, three of these groups contain aircraft currently in service, while the fourth group contains aircraft under development for later entry into service. The aircraft types are all passenger-to-freighter (P-to-F) conversions, except the ATR 72-600 which is a new production model. There are currently active large cargo door conversion programs for the CRJ 200 (AEI), ATR 72/42 (IPR) and Dash 8 Q300 (Air Inuit/ Collins, although the STC is not expected until the end of the year). There is no large cargo door program available for the Dash 8-Q400, but we expect one to become available over the forecast period.

Table 9 - Feeder Freighter Fleet Available to Operators

	Turboprops/ Regional Jets
Facing near-term extinction	Saab 340, CV 580, HS 748, Fokker F27/50, Bae ATP, AN26/32/74
At peak use, or with little future growth potential	ATR 42
Expanding role going forward	ATR 72, Dash 8-Q300, Dash 8-Q400, CRJ 200
Future aircraft	ATR 72-600, CRJ 700/900, E190/195

Note that there are no active nor launched programs for the CRJ700/900 or the Embraer 190/195 program, although there has been some discussion about launching programs for these aircraft. We have not considered an E170/175 program as we feel the aircraft would be too small to effectively compete with turboprops.

5.5 Feeder Freighter Sensitivity Analyses

As with our analysis of the jet freighter fleet segments, we have also examined the impact of changes to the assumptions used in the baseline forecast for the turboprop/RJ market segment. The results of that sensitivity analysis are summarized below.

A demand shift of 1 percentage point per year results in roughly a 20% change – about 80 planes – in the size of the turboprop/RJ freighter fleet in 2039 (See Figure 14). For example, if demand grows by 4.8% per annum, the required fleet would grow to about 508 (compared to the baseline forecast of 420). A 0.5 percentage point change in productivity results in roughly a 10% change – 40+ aircraft – in the size of the turboprop/RJ freighter fleet in 2039. For example, a 0.5% improvement in productivity would reduce the 2039 turboprop/RJ fleet to roughly 380 units (compared to the baseline forecast level of 420, See Figure 15). Change to the freighter-belly ratio will not impact the demand for turboprop/RJ freighters as they rarely compete against passenger belly capacity.

Figure 14 - Demand Growth Impact on 2039 Feeder Fleet Forecast

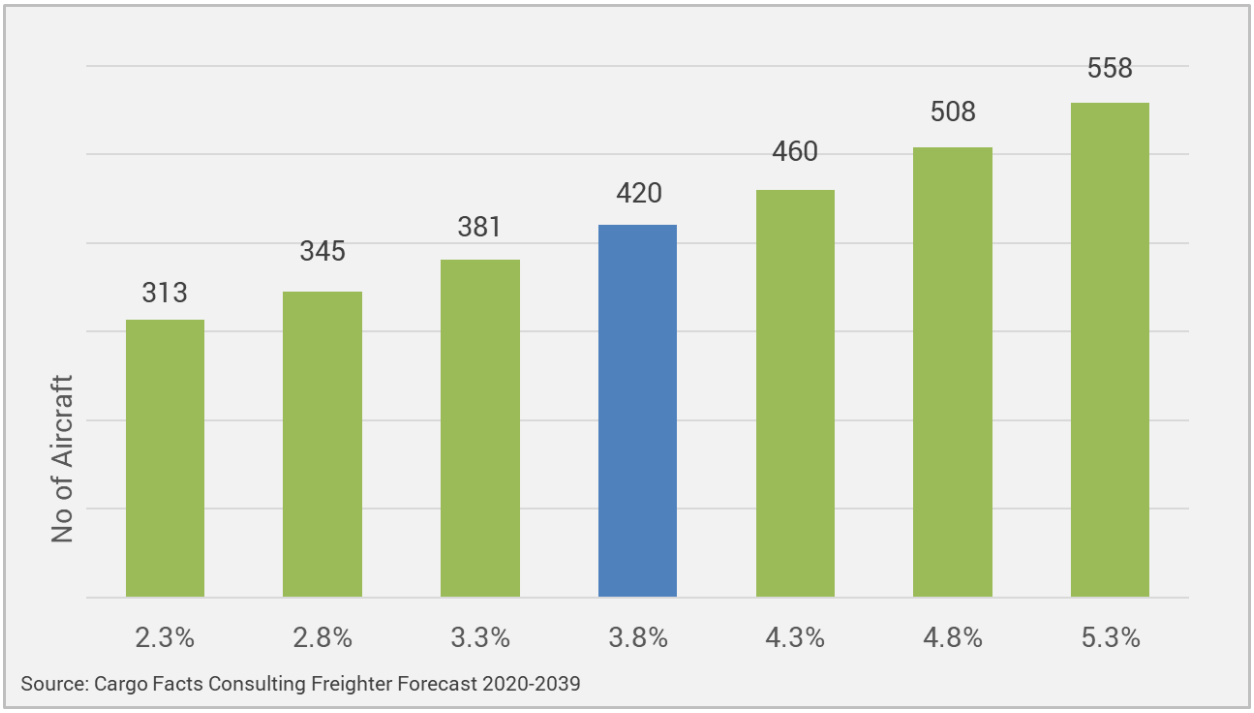
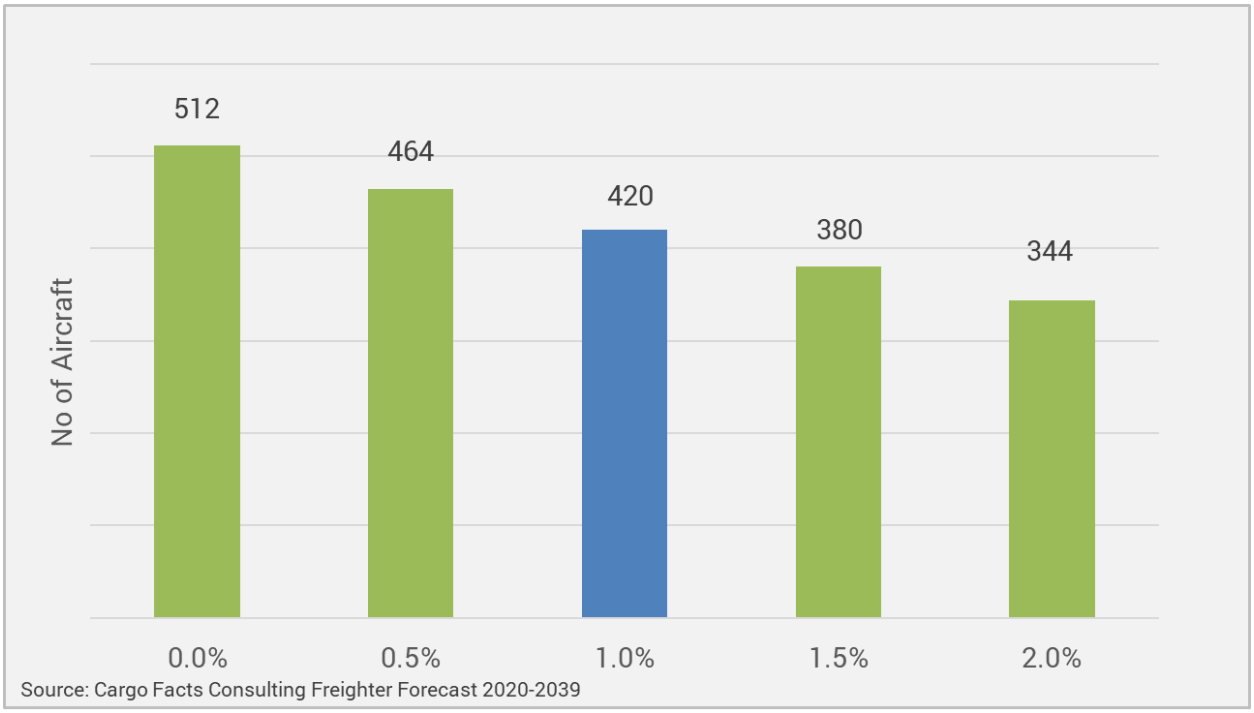


Figure 15 - Productivity Growth Impact on 2039 Feeder Fleet Forecast



6. Airline User Analysis

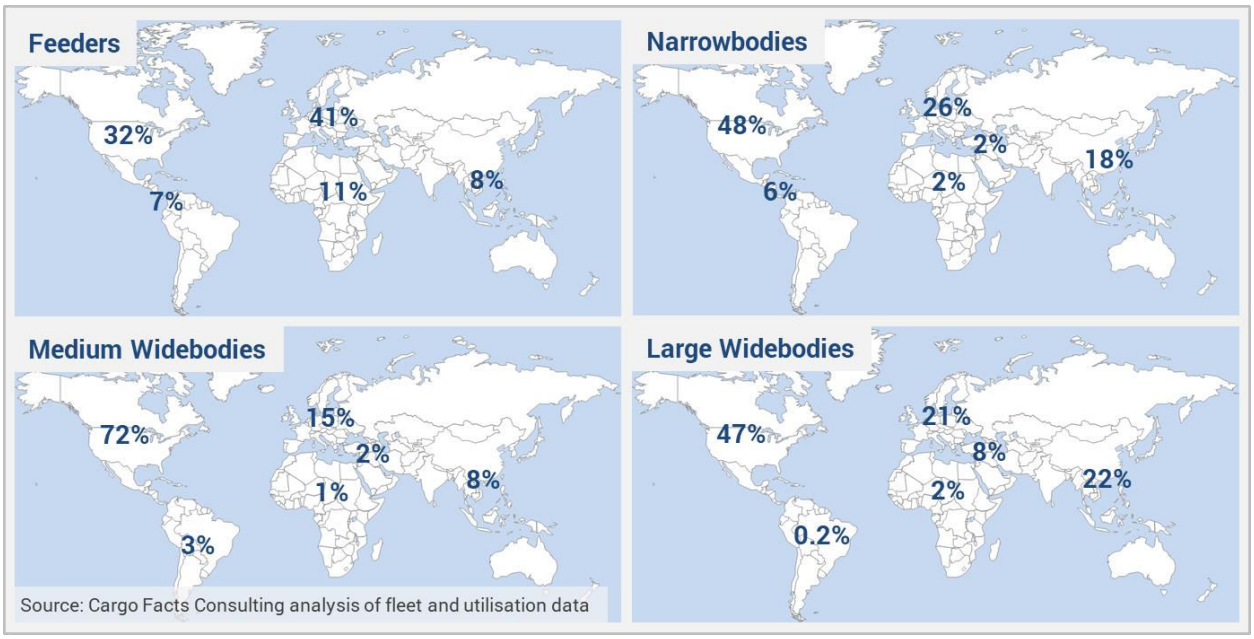
6.1 Operator Diversity

There are over 200 airlines worldwide that operate across one or more of the four freighter aircraft categories covered in this report (feeders, narrowbody, medium and large widebody freighters). While a number of airlines operate aircraft across all segments (such as ASL Aviation Group or DHL, for example), or at least across three segments (FedEx, UPS, SF Express or Atlas Air), most are focused on a single freighter size segment. For example, only 15 airlines operate both narrowbody and widebody freighters, and among the widebody freighter operators, only 11 operate both medium and large capacity types. Overall, the number of freighter operators has declined in recent years. For example, six years ago there were 111 operators of narrowbody freighters and 90 operators of widebody freighters compared to 99 and 78 today.

6.2 Fleet Use by Geography

On a worldwide basis about half of all freighters are still currently operated in North America, although there are distinct differences between size categories. Figure 16 shows the distribution of the complete jet freighter fleet by domicile region.

Figure 16 - Freighter Fleet Distribution by Geography Q1 2020

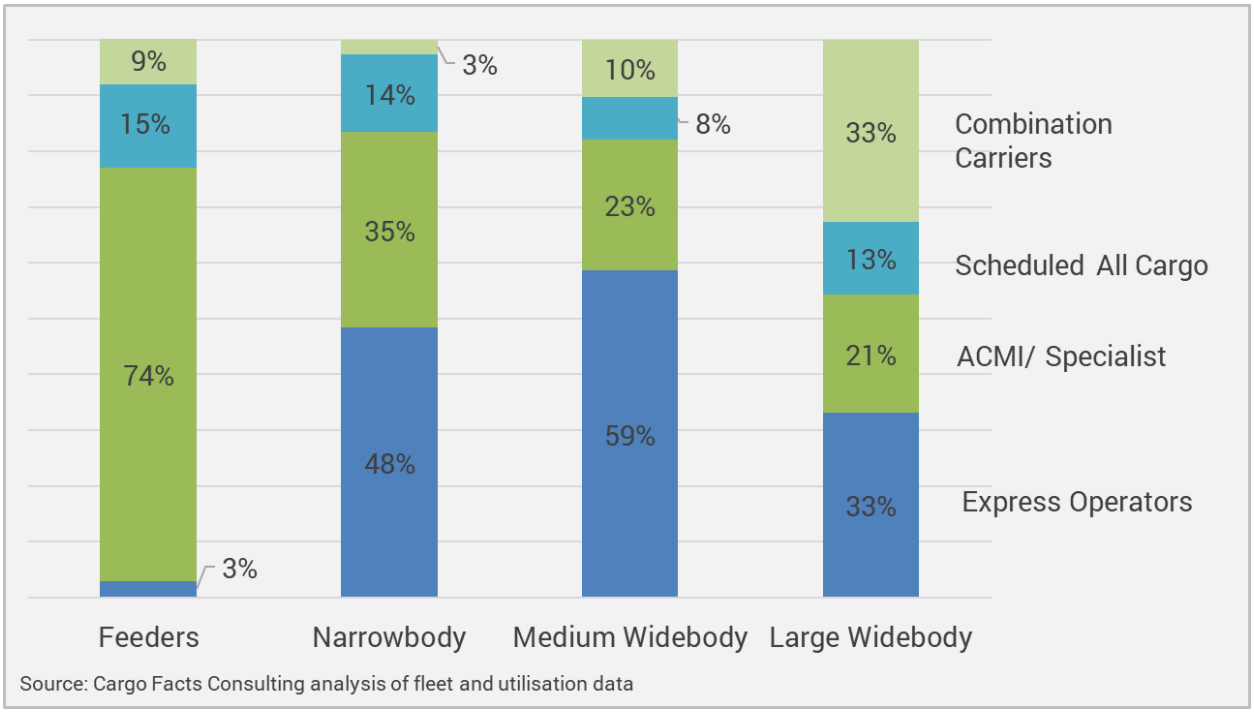


Most feeder aircraft are operated in Europe, North America and Africa. The largest share of aircraft in all three jet freighter categories are operated in North America, followed by Europe and Asia. Asia has been increasing its share of both narrowbody and large widebody capacity but dropped down in its share of overall medium widebody capacity as Amazon has added to its dedicated 767 fleet over the last three years.

6.3 Fleet Use by Business Model

Most freighters are operated by or for the express, postal and increasingly also the E-commerce business. Figure 17 shows the distribution of the freighter fleet by business model.

Figure 17 - Current Fleet Share by Operator Business Model Q1 2020



Source: Cargo Facts Consulting analysis of fleet and utilisation data

Most large widebody capacity is operated by combination carriers (which have both freighters and passenger aircraft), all cargo carriers, and some specialist charter or ACMI carriers, who either operate for express carriers, directly for freight forwarders, charter customers or other all cargo and combination airlines. In this segment, only a third of capacity is operated directly by FedEx, UPS, DHL and SF Express.

The picture in the other jet segments is different. Most narrowbody and medium widebody freighter are either operated directly by or indirectly for express carriers FedEx, UPS, DHL, SF Express or for e-commerce provider Amazon. The main third-party capacity providers include Atlas Air Worldwide Holdings (including

Atlas Air, Polar Air Cargo and Southern Air), Air Transport Services Group (ATSG, including ABX Air and ATI Air Transport International), ASL Aviation Group and Swiftair/ West Atlantic Group. Particularly DHL Express makes wide use of third party contracted lift, while FedEx and UPS are limited by scope clauses in their pilot contracts.

In the feeder segment, where scope clauses do not apply, most capacity is operated by third party carriers such as ASL, Swiftair, Empire Airlines or Mountain Air Cargo for express carriers FedEx, UPS and DHL. Within this segment there are a limited number of combination carriers or all cargo carriers that operate aircraft on inter island services or on thinner routes to remote locations or secondary markets.

7. Freighter Aircraft Supply – P-to-F Feedstock Analysis

7.1 Conversion Market Drivers

Passenger-to-Freighter (P-to-F) conversion is an essential element in the development of the global fleet of freighter aircraft. Historically, the option of acquiring production freighters has been available in the widebody, but not in narrowbody or feeder market. But even in the widebody segment about half of the freighters have been converted from passenger configuration.

Three primary factors are essential to support P-to-F conversion:

- The availability of used passenger aircraft "feedstock" of suitable age, hours and cycles,
- Suitable feedstock prices, and
- The existence of certified freighter conversion programs.

In assessing the likelihood of P-to-F conversions, we take into account the number of aircraft of a particular type that were produced in passenger configuration and the period of time over which production took place. That explains, for example, why the 767-300ER (with over 500 built, mostly over sixteen years from 1988 through 2004) is popular for future P-to-F conversion, while the A300-600 (with fewer than 200 built, mostly over twelve years from 1984 through 1996) will see no further conversion activity.

Also important in assessing P-to-F opportunities is understanding that most conversions are done on aircraft between 16 and 25 years, although there are cases of both younger as well as older aircraft being converted.

7.2 Average Age at Conversion

The average age at conversion has been trending upwards. Part of this is due to the continued popularity of older generation types such as the 737 classics, 757 and 767. This may change as feedstock for these types begins to dwindle and 737NG, A320/321 and A330-200/300 conversion activity takes over.

Currently, narrowbody freighters (such as the 737, 757 and MD-80) are being converted at ages of between 21 and 22 years and medium widebody freighters (767 or A330) at between 20 and 23 years. During the first decade of this century, the customary age for narrow-bodies was between 17 and 19 years, and 15 to 20 years for medium wide-body freighters. Figure 18 and Figure 19 provide an overview

of the number of narrowbody and medium widebody conversions, respectively, between 2000 and 2019, as well as scheduled completions in 2020.

Figure 18 - Narrowbody Conversions and Average Age at Conversion 2000 - 2020

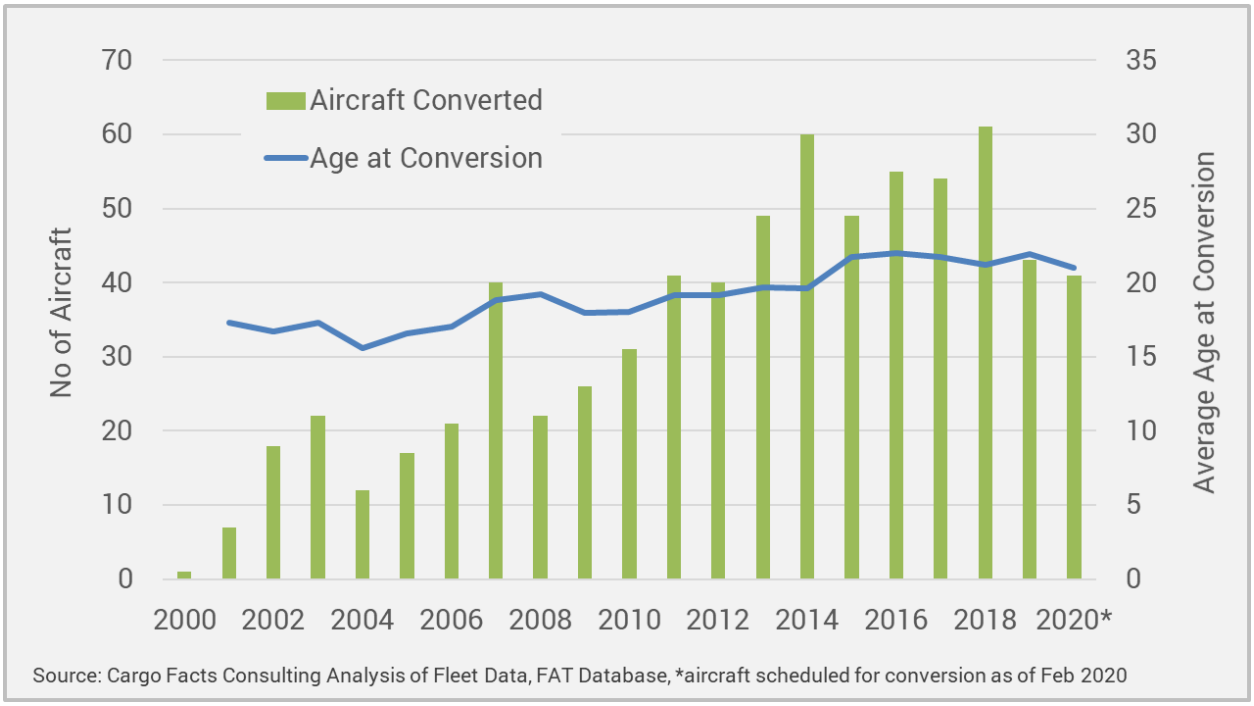
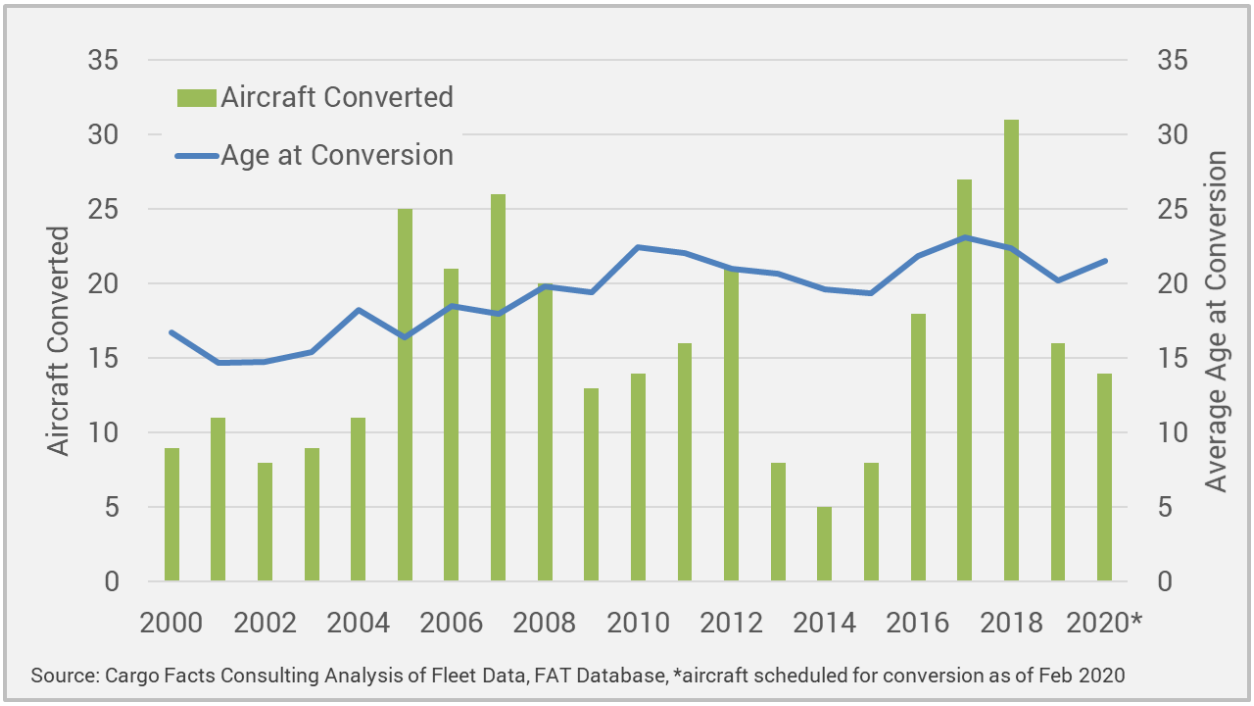


Figure 19 - Medium Widebody Conversions and Average Age at Conversion 2000 - 2020



The average age at conversion of narrowbody aircraft has been following a moderate upward trend since the early 2000s but has been flat since about 2015. Within the segment, the picture has been somewhat mixed. Due to the continued popularity of 737 classics and 757s the average age of these types has naturally been trending upwards as feedstock becomes older and harder to come by. Most aircraft seem to be in the 23-25 year age range. For the MD-83 conversions that have taken place the age has been older. On the other hand, most 737NG conversions have been in the 17-18 year age range.

For medium widebody aircraft such as the 767-200, 767-300, A310, A300-600 and A330-200 and A330-300, the average age at conversion has been on the rise since the early 2000s, but has remained relatively flat since then at between 20 and 23 years, although the last four years have seen conversion of about 25 units over the age of 25. As the 767 feedstock ages but the aircraft continues to remain popular, it is very likely that we will see the conversion of older units. This average may start to come down as A330-200 and A330-300 values drop and on ramp costs for these aircraft types become more attractive to customers.

We have not included a chart for large widebody equipment as there has been no activity in this segment since the last two 747-400 were converted by Israel Aerospace Industries (IAI) and redelivered to Asiana in 2017.

The following section examines the quantities in the feedstock pool for various freighter conversion candidates – not all of which currently have active conversion programs. In reviewing the material that follows it is important to keep in mind the production periods and the quantities that have been produced for each model under discussion. As part of our analysis here we focus on feedstock supply only and not prices, although we have included a section on the impact of the COVID-19 crisis on the feedstock market.

Table 10, Table 11, and Table 12, provide an overview of production periods, production quantities, and feedstock totals in the 16-25 year age bracket now and into the future for narrowbody, widebody and feeder aircraft. Note that for the older types that are out of production feedstock declines going forward, while for the newer types of feedstock will increase in the future.

Please note that all aircraft quantities below include aircraft in storage, maintenance or under repair in addition to all the active units at the time of this analysis (April 2020). The *Feedstock Analysis Tool* provided as a supplement to this forecast and hosted on the Cargo Facts Consulting Insights site (www.cfcinsights.com) provides additional detail by aircraft type and split in 16-20 and 21-25 year age brackets for 21 different aircraft types, ranging from turboprops to large widebody jets.

7.3 Narrowbody Freighter Feedstock

The narrowbody freighter market is in transition from older to new generation aircraft types. The suitable feedstock pool for 737-300, 737-400 and 757-200 aircraft is declining, while the stock of ripe 737 NGs and A320 family aircraft are increasing (see Table 10).

Table 10 - Narrowbody Feedstock Summary

Model	Production Years	Passenger Deliveries	Feedstock Quantities for 16-25 years old aircraft		
			2020	2023	2026
737-300	1984 – 1999	1,113	161	51	0
737-400	1988 – 2000	486	22	7	2
737-700	1997 – 2019	1,285	514	806	780
737-800	1998 – 2019	5,135	765	1,247	1,532
737-900	2001 – 2019	564	51	76	130
757-200	1982 – 2005	995	222	156	87
757-300	1998 – 2004	55	55	55	48
A320-200	1998 – present	4,690	781	1,152	1,425
A321-200	1996 – present	1,660	224	312	421
MD-82/-83/-88	1981 – 1999	330	70	33	0

Source: Cargo Facts Consulting Feedstock Analysis Tool

To be more specific, the pool reduces in future years as aircraft that become 26 years old in each succeeding year are removed from the pool. Such reductions in theory would be offset by aircraft 14 years of age that would be added to the pool in each succeeding year. But in the case of 737-300, as shown in Table 10, there are no such young units. The pool declines by 68% to 51 in 2023 and by then, all of the 51 available 737-300 aircraft are in the 21-25 year age bracket. Similarly, the conversion for the 737-400 (with only 486 deliveries from 1988 to 2000) will be coming to an end since there are currently around twenty units in the 21-25 year age bracket. By 2026, there will be no 737 Classics in the prime conversion range.

Moving forward to other aircraft in narrowbody segment, the feedstock for the newer generation 737 and A320/A321 family will increase in the future. As shown in Table 10, Boeing stopped production of the 737 NGs in 2019 while Airbus still produces a mix of NEOs and CEOs in 2020. The current production totals

are 1,285 for 737-700, 1,660 for the A321-200, and around 5,000 each for the 737-800 and A320-200. These high quantities result in a favorable feedstock situation today for these models, with improving conditions going forward. Somewhat of an exception is the A321, for which low production totals in the late 1990s constrain age-appropriate feedstock today and through 2024. It is important to note that the individual quantities for the 737-800 and A320-200 are roughly double the quantities of the 737-300, 737-400 and 757-200 combined.

As for the most popular aircraft in the narrowbody segment, feedstock is declining for the 757-200 and 757-300 passenger aircraft. The overall feedstock amount for 757-200 is larger than -300 due to the larger production amount. We also note that there has so far been no program announced for the 757-300 since it would be hard to justify with only 55 aircraft in service. However, Precision Aircraft Solutions has been mulling launching one. We believe that conversions of 757s will be feasible from a feedstock perspective until 2025, several years longer than the case for the 737-300 or 737-400 models. Although it is important to note that the two 737 Classic types and the 757-200 will still dominate the worldwide freighter composition in the short term.

7.4 Widebody Freighter Feedstock

In the medium widebody aircraft segment, 767-300 feedstock availability declines over the period from 2020 to 2034, during which the feedstock in the older age bracket is larger than the younger ones because of the production years. Nearly one-third of the total produced are now over 25 years old. In contrast, the total feedstock quantities for A330-200/-300 in the age bracket of 16-25 years old are growing over the time period from 2020 to 2034. Note that the feedstock in the older year age bracket for A330-200 is also growing over the time, while the feedstock in the younger age bracket are growing over the time for A330-300. Table 11 summarizes the feedstock quantities in the 16-25 year age bracket but for more details, please consult the Feedstock Analysis Tool available on the Cargo Facts Consulting Insights site.

In the large widebody aircraft segment, the feedstock situation for the 777-200ER and 777-300ER are developing in opposite directions opposite trends. The feedstock in the conversion zone for 777-200 grows from 2020 to 2023, then steadily declines over the period from 2023 to 2033. This can be explained by the production years of this type, from 1997 to 2013. Its feedstock in the younger year age bracket is declining while the older year age has a growth at the beginning before the number drops. The feedstock availability for 777-300 shows an opposite trend: both the feedstock in the older year age bracket and the younger year age bracket are growing over the time period from 2020 to 2034.

Table 11 - Widebody Feedstock Summary

Model	Production Years	Passenger Deliveries	Feedstock Quantities for 16-25 years old aircraft		
			2020	2023	2026
767-300ER	1988 – 2014	666	199	163	118
A330-200	1988 – present	588	156	261	295
A330-300	1993 – present	755	116	158	209
777-200ER	1997 – 2013	422	320	335	242
777-300ER	2004 – present	807	10	122	220

Source: Cargo Facts Consulting Feedstock Analysis Tool

7.5 Turboprop/ Regional Jet (Feeder) Freighter Feedstock

Regarding feedstock in the turboprop/ regional jet segment, our analysis is focused on the ATR 42/72, Dash 8-Q300 and -Q400, the Bombardier CRJ 200 and CRJ 700 and the Embraer E-190 and E-195 (Table 12).

We see feedstock for ATR 42 and Dash 8-Q300 declining and feedstock for all other segments increasing. This will limit the potential for additional ATR 42 and Dash 8 Q300 conversions in favour of higher volume 19,000 lbs (8.5 tonne) aircraft, which will become the reference in this segment, replacing both existing 8,500 – 1,4000 lbs (3.8 – 5 tonne) aircraft currently in operation. It is likely the regional freighter fleet will continue to see plenty of new ATR 72 conversions going forward since demand for this model is especially strong for large-door conversions, thanks to the flexibility it gives to easily move containerized cargo without returning cargo to warehouses for sorting. An exception is the CRJ 200 which shows steady feedstock but declining in 2026 and losing about 100 units available per year. We have excluded the Saab 340 from our feedstock analysis as we foresee very little development for this aircraft. However, we have included the Embraer E-190 and E-195 as there has been some interest in pursuing the development of a conversion program for this aircraft.

Table 12 - Turboprop/ RJ Feedstock Summary

Model	Production Years	Passenger Deliveries	Feedstock Quantities for 16-25 years old aircraft		
			2020	2023	2026
ATR 42-300/-500	1984 – present	414	86	59	44
ATR 72-200/-500/-600	1988 – present	551	104	130	190
Bombardier Dash 8-Q300	1998 – 2007	267	69	94	78
Bombardier Dash 8-Q400	2000 – present	594	69	151	250
Bombardier CRJ 200	1991 – 2006	939	710	710	633
Bombardier CRJ 700	2001 – present	346	150	215	237
Embraer E-190	2005 – present	564	1	115	250
Embraer E-195	2006 – present	172	0	12	46

Source: Cargo Facts Consulting Feedstock Analysis Tool

7.6 Crisis effect on the feedstock market

Last year the largest constraint on new generation narrowbody feedstock was the knock-on effect of the grounding of the 737 Max in March 2019. At the beginning of 2020 the idle 737 Max fleet stood at more than 740 units, including approximately 380 units that had been delivered at the time of grounding in March 2019. This has restricted the flow of both suitably priced 737-800 as well as A321 feedstock into the passenger to freighter conversion market.

A secondary constraint has been the lack of available conversion programs. Since 2020 there are now three certified conversion programs for the 737-800 (Boeing, AEI and IAI) and one program for the A321. Further A320 and A321 programs are nearing certification and by 2021 there should be a full suite of programs available in this segment. Table 13 shows an overview of currently active, in development, launched and planned jet freighter conversion programs.

Table 13 - Current and Future Jet Freighter Conversion Programs as of April 2020

	AEI	IAI	Boeing	EFW	PEMCO	321/ Precision	ST Aerosp.	Sine Draco	C3
MD-80	X								
737-300	X				X				
737-400	X				X				
737-700		X			1H '20				
737-800	X	Apr '20	X						
A320				Launched					4Q '20
A321				Feb '20		Mid '20		Planned	3Q '21
757-200						X	X		
767-200		X							
767-300		X	X						
A330-200				X					
A330-300				X					
777-300		2022							

Source: Cargo Facts Consulting Feedstock Analysis Tool

The medium widebody segment is also nearing the point of transition from older to newer generation capacity. However, the continued availability of reasonably priced feedstock for the popular 767-300 passenger to freighter conversion has slowed down the transition of this market to the A330-200P2F and A330-300P2F. Currently each of the programs have only a single customer – EgyptAir (for the A330-200) and DHL (for the A330-300).

As a consequence of the implosion of passenger airline traffic as a consequence of the COVID-19 pandemic, as of mid-April approximately 40% of the world's passenger airliner fleet is in storage. While governments around the world have pledged aid to the airline business, it is expected that a large number of airlines will fail. This will potentially increase the size and reducing the cost of available feedstock of 737s, A321s and A330s. Whether this feedstock will become available to the freighter market depends on how fast passenger demand recovers.

However, it is worth noting that while new generation feedstock will come down in price, old generation feedstock will also see drops in value. In the current low fuel price environment, there is little incentive to accelerate retirements of older freighter aircraft in favor of newer, more efficient capacity.

8. About Cargo Facts Consulting

Cargo Facts Consulting is a specialized air logistics advisory and research firm. Formerly also known as Air Cargo Management Group, we have been in business since 1978. Since 2019, we are based in Luxembourg, with offices in New York and Seattle.

Our clients turn to us for deep advice, data and insights on key aspects that effect product development, marketing, fleet planning and strategy in air logistics. These clients come from across the whole air cargo and express business and include financial institutions and investment firms, leasing companies, government, aircraft manufacturers and conversion companies, airlines, express companies, airports and other service providers.

Our consulting experience spans projects that encompass airline network planning, fleet planning, due diligence, route development, investment assessment, air cargo and express market analysis, and aircraft technology. Our data and forecasts populate financial models related to many facets of the business, and our analysis is used in product development by a wide range of company. We also provide deep analytics for the type of data- and mission-related marketing in the aviation sector.

We strive to be the most knowledgeable and highly valued provider of strategic advice to the global air freight transportation and logistics industry. We provide actionable solutions, not just data and research based on critical needs and business objectives. We facilitate business evolution that yields greater profits and efficiency. And we do so often through long-term relationships that create a deep and more-meaningful dialogue with our customers.

Through Cargo Facts and Air Cargo World, our sister media organizations, we have a unique and high-visibility insight into industry trends and market developments as they happen.

Appendix 1 – Freighter Forecast Assumptions

In developing our predictions, we adopt a top-down forecasting method. We begin by establishing a baseline level of freight-tonne-kilometres (FTKs) for the total group of freighters within each size category in the base year. We then determine the number of FTKs required at the end of each five-year period based on three important input variables:

- future growth in air freight demand
- assumed shifts in freighter productivity
- changes in the ratio of freighter-to-belly use

This approach allows us to determine the required jet freighter fleet quantity in each of the three size groups at the end of each five-year period.

We then take into account the specific freighter models that will be available during the forecast period and make a detailed prediction of the make-up of the fleet by aircraft type. As noted previously, we account for additions to the freighter fleet (new production deliveries and added P-to-F conversions), along with reductions in the fleet (from retirements), to meet the needed FTK growth for the period.

The target growth can be met by a variety of combinations of additions and retirements of specific jet freighter types, so the final results reflect our best judgment about the relative popularity of the competing models. More narrative on this can be found in Chapters 4.3 (Jets) and 5.4 (feeders).

Our baseline assumptions are as follows:

- 3.8% annual growth in air freight demand. See 3.2 for more information.
- 1.0% annual increase in freighter productivity.
- A 7.5 percentage point shift (to a higher belly share) over 20 years in the fleet-wide freighter-to-belly use ratio. This is driven primarily by the availability of more freight capable passenger aircraft.

Our forecast models and presents the effect of changes to baseline assumptions (see chapters 4.4 and 5.5).

Appendix 2 – Freighter Aircraft Characteristics

In this appendix we provide an overview of the indicative weights for both existing and future aircraft types in all four segments (feeders, narrowbody, medium widebody and large widebody). The data reflects manufacturers' or converters' information as interpreted by Cargo Facts Consulting.

For some aircraft types with unknown freighter capability, we have made our own indicative estimates of weights, volume and basic performance data. This includes aircraft such as a 757-300, 737-900, 787-9F, A330-900F, 777-8/9F, A350-900/100F, and 777-200ER and 777-300ER conversions.

We have included information on maximum takeoff weight (MTOW), Operating Empty Weight (OEW), Structural Payload and Volumes. We have not included indicative tare weights as these will depend on whether aircraft are being operated in palletized configuration. To get to revenue payload, readers will need to subtract tare weight. Cargo Design Density equals max structural load divided by total cargo volume. This figure represents the design loaded density including the tare weight of containers. A “+” symbol in main deck positions for narrowbodies signifies a "half-sized" pallet.

Note that Operating Empty Weight (OEW) often includes tare weight. In our assessment OEW would include cargo loading systems but not the tare weight of containers and pallets. The same applies to

Weights and volumes are provided both in lbs. and kgs, and ft^3 and m^3.

We welcome feedback on any of these characteristics, particularly for aircraft types that have not yet been launched.

Table 14 - Narrowbody Freighter Characteristics (Imperial)

Model	Maximum Takeoff Weight (lbs)	Operating Empty Weight (lbs)	Main Deck Pallet Positions	Main Deck	Belly Holds (Contain-erized)	Bulk	Total Cargo Volume (ft^3)	Max Structural Payload (lbs)	Range with Max Payload (naut mi)	Volume Limited Payload at 7.0 lbs/ft^3 (lbs)	Design Cargo Density (lbs/ft^3)
BAe 146-300QT	97,500	55,850	7.5	2,475	none	810	3,285	23,150	960	22,995	7.0
737-200F	124,500		7	2,800	none	875	3,675	38,200	1,175	25,725	10.4
MD-83SF	160,000	76,900	12	4,400	none		5,027	45,100	1,200	35,200	9.0
737-300F	139,500	67,100	8+	3,680	none	1,065	4,745	42,500	1,600	33,215	9.0
737-400F (LGW)	143,500	69,900	10+	4,560	none	1,375	5,935	43,100	1,250	41,545	7.3
737-400F (HGW)	150,000	70,900	10+	4,560	none	1,375	5,935	47,100	1,725	41,545	7.9
737-700BDSF	154,500	76,700	8+	3,680	none		4,645	45,000	2,100	32,515	9.7
737-800SF	174,200	85,600	11+	5,000	none	1,555	6,555	52,700	2,000	45,885	8.0
737-800BDSF	174,200	85,300	11+	5,000	none	1,555	6,555	53,000	2,000	45,885	8.1
737-900F (est)	187,700	87,524	12+	5,500	none	1,555	7,055	61,976	2,000	45,885	9.5
A320-200F (est)	169,800	91,492	10+	4,693	910	208	5,811	48,280	2,000	40,677	8.3
A321-200F (est)	196,300	103,176	14	6,048	1,300	208	7,556	61,500	1,850	52,892	8.1
727-200F	203,100	98,600	12	5,280	none	1,525	6,805	56,400	1,650	47,635	8.3
757-200SF	240,000	116,000	15	6,600	none	1,790	8,270	70,000	2,400	57,890	8.5
757-300SF (est)	271,000	130,000	18	7,920	none	2,382	10,302	80,000	2,400	72,114	7.8

Table 15 - Narrowbody Freighter Characteristics (Metric)

Model	Maximum Takeoff Weight (kg)	Operating Empty Weight (kg)	Main Deck Pallet Positions	Main Deck	Belly Holds (Contain-erized)	Bulk	Total Cargo Volume (m^3)	Max Structural Payload (kg)	Range with Max Payload (naut mi)	Volume Limited Payload (kg) at 110 kg/m^3	Design Cargo Density (kg/m^3)
BAe 146-300QT	44,225	25,333	8	70	none	23	93	10,501	960	10,226	113
737-200F	56,472	0	7	79	none	25	104	17,327	1,175	11,440	167
MD-83SF	72,575	34,881	12	125	none	0	142	20,457	1,200	15,649	144
737-300F	63,276	30,436	8+	104	none	30	134	19,278	1,600	14,771	144
737-400F (LGW)	65,091	31,706	10+	129	none	39	168	19,550	1,250	18,476	116
737-400F (HGW)	68,039	32,160	10+	129	none	39	168	21,364	1,725	18,476	127
737-700BDSF	70,080	34,791	8+	104	none	0	131	20,412	2,100	14,460	155
737-800SF	79,016	38,828	11+	142	none	44	186	23,904	2,000	20,406	129
737-800BDSF	79,016	38,691	11+	142	none	44	186	24,040	2,000	20,406	130
737-900F (est)	85,139	39,700	12+	156	none	44	210	28,112	2,000	20,406	152
A320-200F (est)	77,020	41,500	10+	133	26	6	164	21,899	2,000	18,090	133
A321-200F (est)	89,040	46,800	14	171	37	6	214	27,896	1,850	23,522	130
727-200F	92,125	44,724	12	149	none	43	193	25,583	1,650	21,184	133
757-200SF	108,862	52,617	15	187	none	51	234	31,752	2,400	25,745	136
757-300SF (est)	122,924	58,967	18	224	none	67	292	36,287	2,400	32,070	124

Table 16 - Medium Widebody Freighter Characteristics (Imperial)

Model	Maximum Takeoff Weight (lbs)	Operating Empty Weight (lbs)	Main Deck Pallet Positions	Main Deck	Belly Holds (Contain-erized)	Bulk	Total Cargo Volume (ft^3)	Max Structural Payload (lbs)	Range with Max Payload (naut mi)	Volume Limited Payload at 7.0 lbs/ft^3 (lbs)	Design Cargo Density (lbs/ft^3)
A310-200F	313,000	165,920	16	7,960	2,169	610	10,129	89,000	2,200	70,903	8.8
A310-300F	346,100	169,920	16	7,960	2,169	610	10,129	86,700	3,350	70,903	8.6
767-200ERF	351,000	165,000	20	9,896	2,485	430	12,381	101,400	2,840	86,667	8.2
A300B4-200F	363,760	172,100	20	9,950	2,894	565	12,844	97,900	2,100	89,908	7.6
A300-600RF	375,900	179,230	21	10,450	3,708	610	14,158	107,400	2,650	99,106	7.7
A300-600F (production)	375,900	175,420	21	10,450	3,708	610	14,158	111,180	2,750	99,106	7.7
767-300BCF	412,000	181,520	24	11,884	3,396	430	15,280	127,480	3,100	106,960	8.1
767-300BCF (winglets)	412,000	185,720	24	11,884	3,396	430	15,280	124,580	3,150	106,960	8.2
767-300SF	412,000	180,800	24	11,884	3,396	430	15,280	128,200	3,100	106,960	8.1
767-300SF (winglets)	412,000	183,800	24	11,884	3,396	430	15,280	125,200	3,150	106,960	8.2
767-300F (production)	412,000	181,000	24	11,884	3,153	430	15,037	127,000	3,250	105,259	8.4
787-9F (est)	560,000	235,000	26	14,040	5,688	402	20,130	165,000	n.a.	140,910	8.2
A330-200F production	513,700	238,100	22	11,880	3,572	610	15,452	143,300	4,000	108,164	9.3
A330-200P2F	513,700	242,508	22	11,880	3,572	695	15,452	132,300	3,900	108,164	8.6
A330-300P2F	513,700	251,327	26	14,040	5,098	695	19,138	134,500	3,600	133,966	7.0
A330-900F (est)	553,000	260,366	26	14,040	5,098	695	19,138	138,634	n.a.	133,966	7.2

Table 17 - Medium Widebody Freighter Characteristics (Metric)

Model	Maximum Takeoff Weight (kg)	Operating Empty Weight (kg)	Main Deck Pallet Positions	Main Deck	Belly Holds (Contain-erized)	Bulk	Total Cargo Volume (m^3)	Max Structural Payload (kg)	Range with Max Payload (naut mi)	Volume Limited Payload (kg) at 110 kg/m^3	Design Cargo Density (kg/m^3)
A310-200F	141,975	75,260	16	225	61	17	287	40,370	2,200	31,532	141
A310-300F	156,989	77,075	16	225	61	17	287	39,327	3,350	31,532	137
767-200ERF	159,211	74,843	20	280	70	12	350	45,994	2,840	38,542	131
A300B4-200F	164,999	78,063	20	282	82	16	363	44,407	2,100	39,983	122
A300-600RF	170,506	81,297	21	296	105	17	401	48,716	2,650	44,074	122
A300-600F (production)	170,506	79,569	21	296	105	17	401	50,430	2,750	44,074	126
767-300BCF	186,880	82,336	24	336	96	12	432	57,824	3,100	47,567	134
767-300BCF (winglets)	186,880	84,241	24	336	96	12	432	56,509	3,150	47,567	131
767-300SF	186,880	82,010	24	336	96	12	432	58,151	3,100	47,567	134
767-300SF (winglets)	186,880	83,370	24	336	96	12	432	56,790	3,150	47,567	131
767-300F (production)	186,880	82,100	24	336	89	12	426	57,606	3,250	46,810	135
787-9F (est)	254,012	106,594	26	397	161	11	570	74,843	n.a.	62,665	131
A330-200F production	233,011	108,000	22	336	101	17	437	65,000	4,000	48,102	149
A330-200P2F	233,011	110,000	22	336	101	20	437	60,010	3,900	48,102	137
A330-300P2F	233,011	114,000	26	397	144	20	542	61,008	3,600	59,577	113
A330-900F (est)	250,837	118,100	26	397	144	20	542	62,884	n.a.	59,577	116

Table 18 - Large Widebody Freighter Characteristics (Imperial)

Model	Maximum Takeoff Weight (lbs)	Operating Empty Weight (lbs)	Main Deck Pallet Positions	Main Deck	Belly Holds (Contain-erized)	Bulk	Total Cargo Volume (ft^3)	Max Structural Payload (lbs)	Range with Max Payload (naut mi)	Volume Limited Payload at 7.0 lbs/ft^3 (lbs)	Design Cargo Density (lbs/ft^3)
MD-11F	630,500	241,395	26	15,718	4,702	510	20,420	208,705	3,650	142,940	10.2
MD-11SF	630,500	246,200	26	15,718	4,702	510	20,420	203,900	3,550	142,940	10.0
A350-900F (est)	617,295	n.a.	27	18,385	4,465	403	22,850	187,393	n.a.	159,950	8.2
A350-1000F (est)	696,661	n.a.	33	22,440	6,496	403	28,936	209,439	n.a.	202,552	7.2
777F production	766,000	299,500	27	18,385	4,465	600	22,850	236,200	4,965	159,950	10.3
777-8F (est)	775,000	n.a.	29	19,720	5,295	547	25,015	n.a.	n.a.	175,105	n.a.
777-9F (est)	775,000	n.a.	35	23,832	8,131	547	31,963	n.a.	n.a.	223,744	n.a.
777-200ERSF (est)	650,000	305,000	27	18,385	4,465	600	22,850	190,000	4,000	159,500	8.3
777-300ERSF (est)	775,000	336,000	33	22,440	6,496	600	28,936	222,000	4,800	202,552	7.7
747-400SF	870,000	357,000	30	20,674	3,735	520	24,409	253,000	4,100	170,863	10.4
747-400BCF	870,000	360,640	30	20,674	3,735	520	24,409	250,500	4,100	170,863	10.3
747-400F	875,000	349,700	30	21,462	4,085	520	25,547	260,300	4,450	178,829	10.2
747-400ERF	910,000	350,400	30	21,462	4,085	520	25,547	260,600	4,970	178,829	10.2
747-8F	987,000	420,400	34	24,462	5,330	520	29,792	306,600	4,390	208,544	10.3

Table 19 - Large Widebody Freighter Characteristics (Metric)

Model	Maximum Takeoff Weight (kg)	Operating Empty Weight (kg)	Main Deck Pallet Positions	Main Deck	Belly Holds (Contain-erized)	Bulk	Total Cargo Volume (m^3)	Max Structural Payload (kg)	Range with Max Payload (naut mi)	Volume Limited Payload (kg) at 110 kg/m^3	Design Cargo Density (kg/m^3)
MD-11F	285,990	109,495	26	445	133	14	578	94,667	3,650	63,567	164
MD-11SF	285,990	111,675	26	445	133	14	578	92,488	3,550	63,567	160
A350-900F (est)	280,001	n.a.	27	520	126	11	647	85,000	n.a.	71,132	131
A350-1000F (est)	316,000	n.a.	33	635	184	11	819	95,000	n.a.	90,078	116
777F production	347,452	135,851	27	520	126	17	647	107,139	4,965	71,132	166
777-8F (est)	351,535	n.a.	29	558	150	15	708	n.a.	n.a.	77,872	n.a.
777-9F (est)	351,535	n.a.	35	674	230	15	905	n.a.	n.a.	99,502	n.a.
777-200ERSF (est)	294,835	138,346	27	520	126	17	647	86,183	4,000	71,132	133
777-300ERSF (est)	351,534	152,407	33	635	184	17	819	100,698	4,800	90,090	123
747-400SF	394,626	161,933	30	585	106	15	691	114,759	4,100	75,985	166
747-400BCF	394,626	163,584	30	585	106	15	691	113,625	4,100	75,985	164
747-400F	396,894	158,621	30	607	116	15	723	118,070	4,450	79,528	163
747-400ERF	412,770	158,939	30	607	116	15	723	118,206	4,970	79,528	163
747-8F	447,696	190,690	34	692	151	15	843	139,072	4,390	92,742	165

Table 20 - Feeder Freighter Characteristics (Imperial)

Model	Maximum Takeoff Weight (lbs)	Operating Empty Weight (lbs)	Total Cargo Volume (ft^3)	Max Structural Payload (lbs)	Range with Max Payload (naut mi)	Volume Limited Payload at 7.0 lbs/ft^3 (lbs)	Design Cargo Density (lbs/ft^3)
Saab 340	28,000	17,200	1,470	8,500	335	10,290	5.8
CRJ 200SF ER	51,250	29,426	1,356	14,574	700	9,492	10.7
CRJ 200SF LR	53,250	29,426	1,356	14,574	1,100	9,492	10.7
CRJ700 (est)	75,000	43,142	2,525	19,158	900	17,675	7.6
ATR-42-300	37,300	22,812	2,000	14,000	460	14,000	7.0
ATR-72-500	48,500	26,933	2,700	19,000	520	18,900	7.0
Dash 8-Q300	43,000	26,000	1,865	13,500	750	13,055	7.2
Dash 8-Q400	65,200	35,200	2,730	19,800	1,100	19,110	7.3

Table 21 - Feeder Freighter Characteristics (Metric)

Model	Maximum Takeoff Weight (kg)	Operating Empty Weight (kg)	Total Cargo Volume (m^3)	Max Structural Payload (kg)	Range with Max Payload (naut mi)	Volume Limited Payload (kg) at 110 kg/m^3	Design Cargo Density (kg/m^3)
Saab 340	12,701	7,802	42	3,856	335	4,576	93
CRJ 200SF ER	23,247	13,347	38	6,611	700	4,221	172
CRJ 200SF LR	24,154	13,347	38	6,611	1,100	4,221	172
CRJ 700 (est)	34,019	19,569	72	8,690	900	7,865	122
ATR-42-300	16,919	10,347	57	6,350	460	6,226	112
ATR-72-500	21,999	12,217	76	8,618	520	8,405	113
Dash 8-Q300	19,504	11,793	53	6,124	750	5,806	116
Dash 8-Q400	29,574	15,966	77	8,981	1,100	8,498	116

Appendix 3 – Aircraft Program Summaries

This section contains descriptive profiles of the most popular aircraft in narrowbody, medium widebody, large widebody and feeder segments.

Narrowbodies

MD-80 Family

The MD-80 was produced in significant quantities from 1980 through 1999. More than 1,100 of several sub-variants were built, all in passenger configuration. Somewhat surprisingly, no P-to-F conversion program was launched for the MD-80 until early in 2010, when Aeronautical Engineers, Inc. announced plans to convert the aircraft. AEI succeeded in gaining FAA certification for its MD-80 P-to-F program in the first quarter of 2013. Four MD-80 variants, the -81, -82, -83, and -88 versions, have the same external dimensions, but have differences in engine variants, take-off weights and cockpit configurations. A shorter-fuselage MD-87 was also produced but is not considered a candidate for freighter application. The fuselage of the MD-80 is narrower than the fuselage of other commonly used narrowbody aircraft such as 727s, 737s, 757s and DC-8s. As a result, to maximize space utilization MD-80s carry pallets/containers with 88-inch x 108-inch base dimensions. The use of such non-standard pallets/containers for many years discouraged the development of an MD-80 P-to-F program. MD-80s, which are powered by two Pratt & Whitney JT8D-200 series engines, have relatively high fuel consumption and noise compared to other two-engine narrow-body models of the same vintage, which are equipped with newer-technology higher bypass engines (e.g., the 737-300 equipped with CFM-56 engines). However, there are a lot of positive at-tributes of the MD-80, including high production quantities, and the Douglas aircraft heritage that carries a reputation for structural integrity and low maintenance cost. In addition, the value of used MD-80s has fallen significantly in recent years, which means that a freighter-converted MD-80 has a lower price than 737-300F/-400F models which offer similar capability. Despite such attributes, demand for MD 80 freighter conversions has been slow to develop, indicating the MD-80 will play a niche role. Aeronautical Engineers, Inc. has converted a total of 18 MD-80s (all MD-82 and MD-83 types) since 2013 and has plans to convert another seven units in 2020. Aeronaves TSM is the largest MD-83F operator with twelve freighters and plans to convert at least two more.

737-300/-400: Classic Family

737-300 and 737-400 model aircraft (also referred to as 737 Classic models) were built during 1984-1999. Approximately 1,100 of the -300 type and approximately 500 of the -400 were constructed, all in passenger configuration. The -300 and -400 are similar, although the -400 type has a stretched fuselage. PEMCO has had a 737-300 conversion program since the early 1990s, developed using Boeing engineering data, and it certified a 737-400 P-to-F program in 2006. PEMCO also offers a 737-400 passenger-to-combi conversion program (certified in 2007). Israel Aerospace Industries (IAI) certified a P-to-F program for the 737-300 in 2004, and for the 737-400 early in 2009. Aeronautical Engineers, Inc. certified a 737-300 P-to-F program in 2005, and a 737-400 P-to-F program in 2007. The 737-300/-400 types, along with the 757-200 are newer alternatives to the outgoing three-engine 727-100/200 freighter models. The relatively small size of freighter-converted 737 Classics (8-10 pallets) results in attractive cost-per-trip but places them at a disadvantage on a cost-per-ton-mile basis against the larger 757-200. AEI offers a 737-400 conversion that can accommodate 10 full-size pallets/containers (plus an 11th smaller-sized pallet). Our expectation was that the diminishing feedstock of the right age could put an end to the P-to-F conversion of 737 Classics in large quantities by 2020 but we have seen some ACMI operators adding 737 Classics to their fleets in the past twelve months while feedstock for 737 NG conversions remains in short supply. The COVID-19 crisis will certainly change the outlook of 737 Classics.

737-700/-800/-900/-900ER: Next Generation Family

The Next Generation 737 700/ 800 models succeeded the 737 300/ 400 models after 2000, with over 6,700 units of both types delivered by the end of 2019 and with production continuing while the shift to the newest 737 passenger type – the 737MAX family – began in 2017 (Boeing has now over 4,600 orders on the books for this family type). The Next Generation models have entered the prime period for P to F conversion and will be popular for conversion beyond 2035. The 737-700 has the same fuselage dimensions as the 737-300, while the fuselage of the 737-800 is about ten feet longer than that of the 400. The greater capacity of the longer 800 (11 full-size pallets/containers) will likely make it the preferred model for freighter conversion. Boeing offers a production 737-700C (Military C-40) as a convertible aircraft with a large main-deck door, but deliveries thus far mostly have been to government and private (non-airline) customers. In April 2014, AEI announced it was moving forward with development of a 737-800 P to F program and received FAA STC for the converted 737-800 in February 2019. AEI has converted two 737-800s so far and has plans to convert ten more units in 2020. Israel Aerospace Industries (IAI) disclosed in mid-2015 that it was also entering 737-700/-800 freighter conversion market, starting with the -700 variant. The first IAI-converted 737-700BDSF was delivered

to launch customer Alaska Airlines in September 2017, Alaska Airlines now operates three 737-700BDSF. IAI received its 737-800 STC from the FAA in April 2020. Boeing indicated some time ago that it was also interested in this market, so it formally launched a 737-800 P to F program in February 2016 and delivered the first converted 737-800BCF to GECAS / West Atlantic on April 2018. So far, they have converted 17 aircraft and its conversion backlog is over 100 units. More recently, PEMCO announced it was moving forward with a 737NG conversion program, starting with the -700 model and flight testing for its 737-700 FlexCombi was completed in late 2019. In combination, these various programs have orders well in excess of 100 units, mostly of the -800 type. Also, of potential interest for P-to-F conversion are two variants of the 737-900: the basic -900 & the higher weight -900ER. The -900 retains the MTOW and fuel capacity of the -800, trading range for payload. Since this variant was not very successful (only 52 units were delivered), Boeing decided to introduce the -900ER in 2007, a variant that meets the range and capacity of the 757-200 and competes with the A321. A total of 505 units of the 900ER and have been delivered to date but no programs for this type have been announced yet.

A320/A321 Family

The A320 family has proven to be extremely popular in the 100-185 seat category of narrowbody passenger aircraft. The two most popular variants are the A320 introduced in 1988, and the A321 introduced in 1994. Both current-engine-option (CEO) models remain in serial production, but they have been joined by the so-called NEO (new-engine-option) versions that incorporate the new PW1000 geared turbofan engine or the new CFM LEAP-1A engine. Delivery of A320 NEOs began in 2016. Nearly 4,700 A320s and 1,700 A321s (CEO types alone) were delivered through March 2020. No production freighter exists for any A320 family model. Airbus, EADS-EFW and two Russia-based partners formed a joint venture partnership in 2008 called Airbus Freighter Conversion GmbH to design, certify and manufacture a freighter conversion program for A320 and A321 aircraft. That program was unexpectedly suspended in mid-2011, at which time Airbus stated that the popularity and value of A320/A321 passenger aircraft remained too high to support a viable P to F program. There also was speculation that technical issues played a role in the decision to cancel the program. More recently, in September 2014 little-known US-based PACAVI Group, Inc. announced it was "spearheading a new program for conversions of Airbus A320 and Airbus A321 aircraft from passenger to freighter con-figuration." Certification for the PACAVI A320 freighter was planned for 2017. As it turned out, PACAVI ran into financial problems, and by October 2016 had ceased operations before it had certified any P-to-F program. Separately, Airbus, this time in conjunction with EFW and ST Aero, launched a new A320 family P to F program in mid-2015. The A320 (with 10+ pallet positions) and

A321 (with 14 pallet positions) have more capacity than the 737-700 and -800 models, which carry only 8 and 11 pallets, respectively. The Airbus models also are equipped to handle containers in the lower-deck compartments while the 737NGs are not. This P to F effort is headed by Dresden-based EFW, which is now a 45:55 joint venture between Airbus (with the minority share) and ST Aero. During 2017 a new entity, 321 Precision, joined the A321 freighter conversion race. The company is a joint venture between Precision Aircraft Solutions (well known for its successful 757 P-to-F program), and ATSG (known primarily for the leasing and operation of 767 freighters, but also the new parent company of PEMCO). Other parties are also interested in converting A320s/321s into freighters. 321 Precision expects to receive its STC by mid-2020. C3 Aero (C-cubed Aero) announced in September 2017 it was moving forward with a program to convert both the A320 and A321 and in September 2019, C3 acquired an A320 airframe and inducted the aircraft for conversion to freighter configuration at FMS in Kansas City. C Cubed Aerospace should receive its FAA STC for the A320 conversion program as early as 3Q or 4Q of 2020. Elsewhere, Sine Draco has disclosed plans to develop an A321 conversion program, and there are rumors that IAI and one or two other parties are also interested in the A320/321 conversion market. Luxembourg-based Vallair signed on to become the launch customer for both, Precision and EFW's A321 P-to-F A321 program and it is set to begin placing freighter-converted A321s with Qantas Freight and other carriers this year. Vallair has placed one order with 321 Precision and 10 orders with EFW. EFW obtained SFAA STC for its A321 P2F program in early 2020 and will start converting the A321s at a second site in Guangzhou, China in addition to the ST Engineering facility in Singapore. EFW has indicated that they also have an A320 program in works but demand for the A321P2F has delayed the induction of the first A320.

757- 200

Production of the 757-200 and 757-300 extended from 1982-through-2005, during which 914 passenger units and 80 freighters were built. The freighters were built from 1987-1999, mostly for UPS. The factory-built freighters can accommodate 15 main-deck pallets. Boeing developed a freighter conversion program for DHL and modified 34 aircraft in 2001-2003. The Boeing program found no additional customers due in part to its high price for conversion ($7.5 million). Precision Aircraft Solutions certified a 757-200 P-to-F program in 2005, and Alcoa-SIE completed certification of a competing program in 2006. The Precision and Alcoa-SIE conversion programs were priced more favorably in the range of $4-$5 million. Late in 2009 PEMCO World Air Services acquired the Alcoa-SIE 757 P-to-F STC but had no success in the market with this program, and no longer offers 757 conversions. Singapore-based ST Aero, and its Mobile Aerospace unit in the US, developed another 757-200 P-to-F program using data licensed from Boeing. The ST Aero program was certified in mid-

2008, and ST was selected by FedEx to convert approximately ninety (later raised to 119) 757s to freighter configuration through 2016. The total quantity of in-service 757-200 freighters stands at 273, including more than 200 converted units. The in-service quantity takes into account retirement of a significant number of the units converted for DHL over fifteen years ago. The companies involved in P-to-F conversion of 757s also developed programs to convert 757-200s into combi aircraft that accommodate a mix of passengers and freight on the main deck. A small number of combi conversions have been completed, mainly for use in military and government support. The 757 is the largest of the competing narrowbody freighter candidates. It offers two-crew, two-engine economics with cargo volume about 25% more than the 727-200F. The 20+ year production period is an advantage for future freighter conversions. Converted 757s been used mainly as 727-200F replacement aircraft, but the relatively high cost of acquisition and conversion, plus the high cost of engine maintenance, places the higher-performance 757 at a disadvantage compared to the lower priced 737-300/-400 of similar age for applications outside the networks of major express companies. Thus, the main use of 757-200Fs to date has been in express network operations. In a similar manner to the 737 Classic models, the feedstock pool of 757s for freighter conversion is shrinking. Precision has converted a total of 126 units and has twelve outstanding orders in 2020. We believe the period for conversion of 757s will come to a close around 2023. There has been some discussion about the potential launch of a 757-300 conversion program. While there is not a large amount of available feedstock, there could be interest from existing 757-200 customers in a larger, stretched aircraft comparable in size to a DC-8-73 freighter.

Medium Widebody

767-200 and -200ER

Production of the twin-engine 767 began in 1982 with the 767-200 model; the higher-weight -200ER was introduced in 1984. Approximately 120 of each of the -200 and -200ER types were built. All the 767 200/ 200ERs built for the commercial market were passenger aircraft, none were freighters. Most of the -200s were built from 1982 through 1985, and most -200ERs were built from 1984 to 1993 (although twenty-five commercial -200ERs were built from 1994 through 2008). Beginning in 1998 ABX Air converted 24 767 200s to "package-freighter" configuration, without installing a large main deck cargo door, for use in the Airborne Express/DHL US express network. Israel Aerospace Industries later (in 2004) certified a large-door conversion program for the 767-200/-200ER model. Approximately 60 767 200/ 200ERs have undergone P-to-F conversion by IAI, including the 24 ABX Air "small-door" units in which large cargo doors have now been installed. Boeing in partnership with Aeronavali developed a competing 767 200SF conversion program; however, the Boeing/Aeronavali program encountered delays, and only one such conversion of this type was ever completed. Freighter-converted 767 200/ 200ERs offer similar cargo capacity to the Airbus A300 freighter family but provide somewhat greater range capability. All 767 models are limited to pallets/containers with 88-inch x 125-inch base dimensions for loading in a side-by-side arrangement (they cannot accommodate side-by-side 96-inch x 125-inch ULDs). Note: the lower decks of all 767Fs are not as cargo-friendly as other widebodies due to their narrower width. Given the low production quantities of the -200 and -200ER models, along with the effective end of their production period in 1993, no further freighter conversion of the-200 or -200ER models should take place after 2020. Attention has turned to the larger, more capable 767-300 model (profiled below) even though IAI is currently converting two 767-200s for Canada-based Cargojet.

767-300 and -300ER

The Boeing 767-300 is a widebody twin engine aircraft. The 767 family was Boeing's first two-crew glass cockpit jetliner. Boeing has produced three different series of the 767, the -200, -300 and -400. The 767-300ER entered service in 1988 as an updated extended range version of the 767-300. The MTOW of the 767-300ER was originally 407,000lbs but later increased to 412,000lbs in 1993. The 767-300ER can be outfitted (and freighter converted) with or without winglets. Freighter conversion of the 767-300ER got off to a slow start due to 787 delivery delays preventing some airlines from releasing their aging 767-300ER passenger aircraft as planned. In 1995 Boeing introduced the 767-300F, the production freighter version of the 767-300ER. The 300F has a main deck capable of holding up to 24

88x125-inch pallets and up to 30 LD2s (a container unique to the 767 fuselage and belly contour) on the lower deck. The 767-300F is still in production, with a backlog of 54 orders as of April 2020 for FedEx and UPS. Boeing certified a 767-300BCF (Boeing Converted Freighter) program in June 2008, with conversions done at ST Aero (Singapore). Israel Aerospace Industries completed development and certification late in 2009 of a competing P-to-F program (the 767-300BDSF), marketed on a joint venture basis with Mitsui under the M&B Conversions name. Conversion activity on the 767-300ER model was weak at first but has picked up significantly over the past five years. We expect that conversion activity will remain strong for several years, but feedstock limits will become more problematic around 2025. Orders by FedEx for more than 100 units since 2011 will keep 767-300F production going for several years, as will orders by the US Air Force for an aerial tanker based on the 767-200. Boeing decided to increase its production rate of 2.5 to 3 aircraft per month in early 2020. To help improve efficiency as rate increases, Boeing transferred the assembly of 767's forward fuselage to AeroSystems in Wichita, KS. Production 767-300ER freighters were the largest, most capable of the twin-engine medium-capacity widebody freighters available in the market until the A330-200F entered service in mid-2010. The 767-300F has greater payload-range capability than the A300-600F, but less than the A330-200F. A major benefit of the 767 300ER as a conversion candidate is its high production totals over an extended period (nearly 600 units built over more than 20 years). P-to-F conversion of 767 300ERs is expected to extend beyond 2025.

A300-600 and -600R

Airbus freighters (A300B4, A300-600 and A310-200/-300) long dominated the medium-widebody segment of the freighter aircraft market. The A300-600 is the largest of these Airbus models, and it has proven popular mainly in regional express networks. The A300-600 was developed as a follow-on type to the A300B2/B4 that had been the first Airbus models. Airbus produced 293 A300-600 and higher-weight -600R units from 1984 through 2007, of which 106 were production freighters. The A300-600 (similar to other Airbus freighters) can accommodate 96-inch x 125-inch pallets/containers in a side-by-side arrangement on the main deck. The lower deck can handle 96-inch x 125-inch pallets and industry-standard LD-3 containers. The A300-600 is restricted to regional operations based on its relatively limited range capability with a full load. Approximately 60 A300-600s have been converted to freighter configuration in a P to F program developed by EADS EFW (Dresden). US-based Flight Structures, Inc. achieved certification of a competing A300-600 P-to-F program in December 2008, but just five FSI A300-600 conversions have been completed. Production of passenger-configured A300-600s totaled fewer than 200 units, and less than 20 such aircraft were delivered after 1995, so the

supply of suitable feedstock has dropped to near zero, and as a result P-to-F conversion of A300-600s has ended.

A330-200/-300 and A340

Airbus introduced the two-engine A330 and the four-engine A340 as companion models in 1993. Both were originally offered with two fuselage lengths, carrying the -200 and -300 model designations. The A330 proved to be more popular than the A340 because of its two-engine operating economics. More than 1,500 passenger-configured A330s have been built (split about 45:55 between the -200 and -300 types). A total of 377 A340s were built (including about 220 A340-300s) in the period from 1993 through 2010; A340 production ended in 2010. (Note that this A330/340 overview excludes the stretched A340-500 and -600 types, which are not expected to become freighter conversion candidates.) EADS/Airbus announced the launch of a production A330 200F program in January 2007. This type, an all-cargo derivative of the A330-200 capable of carrying 65 tonnes over 4,000 Nm or 70 tonnes up to 3,200 Nm. To overcome the standard A330's nose-down body angle on the ground, the A330-200F uses a revised nose undercarriage layout to provide a level deck during cargo loading and unloading. The normal A330-200 undercarriage is used, but its attachment points are lower in the fuselage. The A330-200F is easily identifiable by the distinctive “bulge” surrounding the nose gear. The freighter has not been a commercial success. As of April 2020, 38 A330-200Fs had been delivered, with a firm order backlog of just three units. Furthermore, a number of the delivered units have been taken out of service by their owners. The lack of orders for the A330-200F calls into question whether Airbus will choose to terminate the program. In addition to the production A330-200 freighter, in mid-2012 Airbus, EADS-EFW and ST Aerospace formed a joint venture to develop a P-to-F program for the A330 type. In conjunction with this endeavor, ST Aero took a 35% stake in EFW (later increased to 55%). First up for the venture was development of a P-to-F program for the A330 300 model, followed closely by a conversion program for the A330-200. Late in 2014 EgyptAir became the launch customer for the program, signing an agreement for conversion of two A330-200 aircraft from its own passenger fleet. Egypt Air operates now three A330-200Fs. DHL became the launch customer for the -300 in 2016, and it took re-delivery of the first newly certified A330-300P2F late in 2017. DHL placed orders for eight -300 conversions (plus ten options) while three of those have been redelivered as of April 2020. The converted A330-300 is aimed at express operators, which have low density cargo, and want to take advantage of the stretched fuselage of the -300 model. The production A330-200F has not gained market acceptance, despite the significant gains in both payload and range capability it offers compared to the competing 767-300F. The A330/340 have the same fuselage cross-section as the A300/310. They have wider fuselages than the 767, but narrower fuselages than the MD-11, 777 and

747 models. A330 models can carry side-by-side 96-inch x 125-inch pallets/containers (22 total for the A330 200F). The A330 models are also smaller and have lower takeoff weights than competing 777 models. Thus converted 777 freighters (none of which exist today), are expected to offer greater payload-range capability than the A330 freighters. After 2022, we expect to see a noticeable decrease in the price of feedstock in combination with an increased number of airframes available, creating more favorable conditions for A330P2F conversions. In 2014, Airbus announced the A330NEO (New Engine Option) family, featuring the A330-800 and the larger A330-900. The -900 entered service in late 2018 with TAP Portugal. There have been rumors that Airbus is considering an A330 neo production freighter, perhaps based on a -900 platform. At the time of writing it remains unclear whether Airbus will invest in the design of a new medium widebody freighter.

Large Widebody

MD-11F

The MD-11 never achieved widespread popularity as a passenger model but has proven popular as a freighter. Two-hundred MD-11s were produced from 1989-through-2001. Of these, 64 were delivered as freighters or combis. McDonnell Douglas developed a freighter conversion program that Boeing continued after the McDonnell Douglas/Boeing merger in 1997, and about 120 units underwent conversion. Touch labor on most of the conversions was done by Aeronavali or Singapore Technologies (SASCO). Boeing stopped offering the MD-11 freighter conversion program, due to lack of demand and lack of feedstock. The MD 11F remains popular in express network applications, but its use in the general cargo market declined significantly after the 2008/09 recession.

777F (including 777X and 777 P-to-F conversions)

Boeing launched a production 777 freighter program in 2005 based on the 777-200LR passenger model. To date Boeing has received 217 orders for the freighter from twenty-four customers). Certification of the 777F was achieved in February 2009, and Boeing had delivered 170 777Fs through the end of 2019, leaving a backlog of 46 units. The 777F offers enhanced capability compared to the MD-11 freighter. The 777F has a wider fuselage than the A330, and it can accommodate 10-foot-high pallets on the main deck. The 777F is the only large capacity, twin-engine freighter. Boeing's interest in a 777 P-to-F program appears to have declined over the past few years based on a lack of enthusiasm in the concept by potential customers. However, GECAS and IAI partnered in late 2019 to announce the launch of a 777-300ER P2F program. With a portfolio of more than thirty-five 777-300ERs, GECAS is also providing the conformity aircraft as part of its launch order for up to thirty 777-300ERSF conversions, including 15 firm and 15 options. Due to enter service in 2022, this aircraft can carry 25% more volume than the 777F, retaining the engine, pallets and containers commonality. With a total cargo volume of 29,000 cubic feet and its range capability, this aircraft is well positioned to replace aging 747-400 and MD-11 freighters. IAI expects this STC for 2022. Boeing is moving forward with the enhanced 777X version of the passenger model for introduction by 2020. We presume that a follow-on 777XF production freighter will be developed as well, but with service introduction after 2025. Boeing has not disclosed details about the transition of production from the current 777 model to the new 777X, nor for how long after 777X production begins that it will continue to build the existing 777F model.

747-400 and -400ER

Boeing produced the 747-400 model from 1989 through 2009, during which time it delivered 508 passenger and combi units, and 165 freighters (these totals include the extended range, ER, versions). Approximately 245 747-400 freighters were built (including the production -400F and -400ERF units, plus P-to-F conversions), although about 175 were in active service in April 2020. Boeing certified a 747-400BCF passenger-to-freighter conversion program in December 2005 and a combi-to-freighter conversion program in 2007. Israel Aerospace Industries (IAI) certified a competing program for both passenger- and combi-configured 747-400s in 2006. Boeing's conversions have been performed by TAECO (China), although Boeing sold kits to Korean Airlines and Singapore Airlines, through which the engineering units of these carriers completed some installation/conversion work. No 747-400 P-to-F conversions were completed from 2010 through 2016, and Boeing announced in 2016 that it had officially suspended its -400BCF program. Surprisingly, IAI announced about the same time that it had received an order (from EVA Air) for conversion of two combi-configured 747-400s, which were re-delivered in 2017. In theory the 747-400 remains a candidate for P-to-F conversion through 2021 based on the production period for the passenger version, although we doubt that any more -400 P-to-F conversions will be completed. The roughly 80 conversions that have been done is a much smaller quantity than originally anticipated before the 2008/09 recession and subsequent period of weakness in global air cargo demand. Until the 747-8F went into service late in 2011, the 747-400 and -400ER freighters were the largest, most capable commercial freighter aircraft. Compared to the earlier-generation 747-200/-300 models, the -400/-400ER feature a two-person flight crew, enhanced payload-range performance, lower fuel consumption and reduced noise. Production 747 freighters are equipped with side cargo doors and top-hinged nose cargo doors; converted passenger aircraft have side cargo doors only. The newer model freighters – the 747-8F and 777F – offer bigger size and/or better operating economics. The 747-400F and ERF have lost their status as "top-of-the-line" freighters, but they will play a significant role in the freighter aircraft market for many years, given that these production freighter models represent about 25% of all large freighters currently in operation. The production -400F offers the nose door and sufficient performance enhancement to distinguish it from the P-to-F versions. Thus, retirements among the 747-400 freighter family mainly have been units of the converted 747-400BCF and 747-400BDSF types.

747-8

Boeing launched the 747-8 program in 2005 based solely on orders for the freighter version (ten firm orders from Cargolux and eight firm orders from Nippon Cargo). The 747-8F's first flight took place in February 2010, and FAA certification was achieved in September 2011. First deliveries of the 747-8F took place in the fourth quarter of 2011, and 90 units had been delivered by the end of March 2020.

Boeing has recorded 107 orders for the freighter version from eleven airline customers (this number includes the recent order from UPS for a total of 28), leaving a backlog of 17 units as of April 2020. The -8F incorporates 787 technology to provide enhanced performance and lower operating cost than the prior generation 747-400F/ERF models. The longer fuselage provides four extra main-deck pallet positions, plus three extra belly pallet positions versus the -400F/ERF. We believe the -8 model will be produced mainly in freighter configuration through about 2022, although limited demand for the 747-8I (only 47 units delivered) passenger version could force Boeing to end the 747 program sooner. Combined production of both models dropped to 0.5 units per month in 2016, and Boeing disclosed it might be forced to terminate the program due to a lack of sales. However, the orders from UPS for twenty-eight -8Fs in 2017, and a small order for three units from undisclosed customers, have provided a reprieve for the 747-8 program. The current backlog of 17 seems enough to allow for production through 2022. Freighter conversion of passenger-configured 747-8s is a possibility after 2025, but this is considered unlikely given the small quantity of -8I passenger units expected to be produced.

The following section contains short descriptive profiles of the most popular models in the turboprop and regional jet (feeder) segments today (with payloads of 8,000-20,000 pounds):

Feeders

Bombardier CRJ Series

The Bombardier CRJ series began as the Canadair Regional Jet program in 1989. The CRJ100 model, which entered service in 1992, was a modified Canadair Challenger business jet with twenty-foot longer fuselage. The CRJ100 had typical seating for 50 passengers. The CRJ200 is identical to the 100 model except it has more efficient engines. Production of the CRJ200 continued through 2005, by which time over 900 of the 100s/200s had been built. These 50-seaters fell out of favor as regional airlines turned attention to larger models. Following the success of the CRJ100/200 series, Bombardier produced larger variants in anticipation of increasing seat limits in US airline pilot union scope clauses in competition with Embraer's E-Jets. The CRJ700, which entered service in 2001, is a stretched 70-seat derivative of the CRJ200 that also featured a new wing, and slightly widened fuselage. The CRJ700 was followed by the higher capacity CRJ900 and 1000 models, the latter of which entered service in 2010, with up to 100 seats. Through the end of 2019 a total of nearly 900 of the CRJ700/900/1000 family had been produced, including about 330 CRJ700s and 430 CRJ900s. The CRJ700/900/1000 family directly competes with the Embraer 170/175/190 models. Until 2015 the only application of the CRJ models in a freighter role was a package freighter modification for the CRJ200 developed by Cascade Aerospace in 2007. The CRJ200PF (Package Freighter) was developed at the request of West Air Sweden to respond to a demanding request for proposal from the Norwegian Post. The CRJ200PF is not equipped with a large cargo door and as a result all cargo is bulk-loaded through the original aft baggage door. A large-door CRJ200SF freighter conversion was certified by Aeronautical Engineers, Inc. late in 2016. The first CRJ200SF was delivered to Gulf & Caribbean Cargo in December of that year and AEI has converted twelve aircraft through the end of 2019. The program was developed in conjunction with the manufacturer, Bombardier. The converted CRJ200 can carry eight 88x61.5-inch pallets.

ATR 42/72 Series

The ATR 42 is a twin-turboprop, short-haul regional airliner built in France and Italy by ATR (Avions de Transport Régional). The ATR 42 entered service in December 1985. In addition to the passenger 300 model, an ATR 42 300QC quick-change (convertible) freight/passenger version was offered. An upgraded 500, incorporating higher performance engines and other system enhancements, entered service in 1995, and the latest model, the -600, with further upgrades including a glass cockpit, was

introduced in 2012. By the end of 2018 over 479 ATR 42s had been built, along with more than 1,100 of the larger ATR 72 model. The ATR 72, a stretched variant of the ATR 42 model, entered service in 1989. Seating is available for up to 78 passengers in a single-class configuration. The ATR 72 incorporates a 15 ft. fuselage stretch, increased wingspan, and more powerful engines than the ATR 42. As with the smaller companion model, passengers are boarded using the rear door, which is unusual for a passenger aircraft, and the front door is used to load cargo. That configuration feature has helped support freighter conversion of both the ATR 42 and 72 types. The original -100 and -200 versions of the ATR 72 were augmented by upgraded -500 and -600 models from 2010. Quick change and cargo versions of the ATR models were offered but saw limited acceptance. However, several freighter conversion programs by third parties have been developed. The most successful was a program for both a bulk-load and a large door modification developed by Alenia Aermacchi. In 2015 Switzerland-based IPR Conversions acquired Alenia Aermacchi's passenger-to-freighter conversion STCs for both types of modifications. Subsequently, IPR received EASA certification to convert the newer-generation ATR 42/72-500 models, in addition to the earlier-generation ATR 42-300 and ATR 72-200 models. First delivery of a converted -500 model took place in 2017. Other bulk load ATR freighter conversions were developed by US-based M-7 (which converted ATR 42s and 72s for FedEx), and by France-based Aeroconseil. M-7 has since left the freighter conversion market, but Aeroconseil appears still to be offering ATR conversions. A major development for freighter application of the ATR 72 took place in late in 2017 when FedEx announced plans to acquire factory-built ATR 72-600s in freighter configuration. The express company placed a firm order for 30 units (plus options for 20 more) for delivery beginning in 2021. These ATR freighters will incorporate Large Cargo Door and Structural Tube Modifications from IPR (noted above).

Bombardier Dash 8 Series

The Bombardier Dash 8 (Q-Series) began as the de Havilland Canada DHC-8 or Dash 8. It comprises a family of twin-engine, medium-range, turboprop airliners first introduced in 1984. Dash 8s are now produced by Bombardier Aerospace. The aircraft has been delivered in four series: the -100 with maximum seating for 39; the -200 with the same capacity but more powerful engines, the -300 with a stretched fuselage and 50-seat capacity, and the -400 with a further stretch that can carry 78 passengers. Models delivered after 1997 have cabin noise suppression and are designated with the prefix "Q" (quiet). Production of the -100 series ceased in 2005, and the Q200 and Q300 in 2009. A total of 671 Dash 8 -100/-200/-300s were produced; production of the -400 series reached about 630 by the end of 2018.There has never been a production freighter version of the Dash 8 series, but there have been some recent freighter-related developments. In 2009 Canada-based Cascade Aerospace

developed a package-freighter conversion for the Q400 model but had sold only five conversion kits by the end of 2017. Separately, Air Inuit, a Dash 8 operator serving the northern Canada market, on its own converted two of the Dash 8-300s in its fleet into bulk-load freighters. Both the Cascade Aerospace and Air Inuit conversions load cargo through the standard aft baggage door. Bombardier is also making moves to expand the freight offerings of the Dash 8 line. In 2016 it began delivery of a production Q400 combi, and it is supporting an Air Inuit led program to develop and certify a large-door freighter conversion for the Q300. The Bombardier/Air Inuit program also includes Rockwell Collins (B/E Aerospace) as a team member. Certification by Transport Canada of a bulk-load Q300 P-to-F program was awarded in mid-2017, and work continues on a large cargo door version. The refreshed design features enhancements over the modification previously done by Air Inuit and can be sold in kit form for installation by a third party. Separately, Canada-based Voyageur Aviation early in 2017 rolled out the first freighter-converted Dash 8-100PF, with bulk loading of packages through the original aft door. DHC is considering a Dash-8 Q400 conversion program as they are seeing interest from operators to convert such model into freighters that would either retain the existing door or with large cargo doors.