BofA SECURITIES

Commercial Aerospace

Comm'l Aero Primer Part 2 – understanding the OEMs and their suppliers

Primer

Part 2- The major players: OEMs and suppliers

In Part 2 of our Commercial Aerospace primer we delve into the major players in the industry, including the OEMs (Original Equipment Manufacturers) and their suppliers. We highlight that while the OEM market is highly consolidated (with only two major manufacturers), the supply base is largely fractured with a range of actors including large multi-industrial conglomerates and small mom-and-pop shops.

Commercial aerospace today is a duopoly

There are two major suppliers of large civil aircraft – Airbus and Boeing. These firms design, develop, and assemble large civil aircraft. They both machine and fabricate metal parts used to build the aircraft. These firms also support large civil aircraft through a variety of aftermarket services, including spares, modification, flight training, and technical support.

Fragmented commercial aero supply chain

Many industrial and multi-industry firms provide engineered products and systems to commercial aerospace. Although there has been increased concentration among these suppliers, the industry is very fragmented. Suppliers range from large conglomerates that have consolidated many aero players to small mom and pop shops. Typically, there are two or three dominant suppliers of each subsystem. Companies tend to specialize in businesses related to a core skill (such as communications), though recent merger activity has resulted in suppliers that are more diversified across different aerospace segments.

Niche markets offer opportunities to compete

Finally, we break down the broad categories of commercial aircraft: single-aisle, twin-aisle, and regional. Within each major segment, aircraft are differentiated by several factors including: 1) range, 2) seats, 3) cargo capacity, and 4) number of engines. We believe it is critical for investors to understand these differences to more fully comprehend which aircraft compete against each other as well as identify possible areas of opportunity within the market for new aircraft.

07 February 2024

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Prior Chapters:

Part 1: The Basics of Aviation and Flight

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Timestamp: 07 February 2024 03:00AM EST

Understanding the OEMs and their suppliers

A little bit of history

The two largest Western commercial airline manufacturers, Airbus and Boeing, can trace their roots back almost 100 years. The two major regional jet manufacturers, Bombardier and Embraer, are more recent ventures.

The evolution of the industry has followed a classic pattern, showing an emerging market, shake-out, and consolidation. Bill Gunston's *World Encyclopedia of Aircraft Manufacturers*, published in 1993, identified 3,272 companies worldwide that had built aircraft since the dawn of flight. He noted that 1,251 of these were based in the United States, but clearly, only a fraction of these survive today.

It is helpful for investors to understand the history of the sector because companies have cultures shaped by experience, and because history can suggest what might change in the future.

The Boeing Company and other US primes

Boeing was founded in 1916 as Pacific Aero Products

The predecessor of Boeing, Pacific Aero Products, was founded in 1916, and renamed Boeing Airplane Company in 1917. It began manufacturing seaplanes. In the aftermath of World War I, the company built boats and furniture, as military business dried up. The company tended to focus on larger aircraft types, but in the 1920s and 1930s it produced several different successful fighters (which were then called pursuit aircraft) for the U.S. Navy.

In 1927, the company formed a subsidiary, Boeing Air Transport, after it won a contract to haul mail for the U.S. government. This airline used Boeing Model 40A aircraft. Two years later, Boeing merged with several other major suppliers, including Pratt & Whitney, Hamilton Standard, and Stearman to become United Aircraft and Transport. However, in 1934, the U.S. government ordered the company to be broken up into what we know as Boeing, United Technologies (now RTX) and United Airlines. Boeing retained Stearman, which was based in Wichita, Kansas. Today that operation is known as Spirit AeroSystems.

Boeing remained more or less a niche player in civil aircraft in the 1930s. Its best-selling product was the Boeing 247, followed by the Boeing 307, which offered a pressurized cabin. At the time, civilian air travel was very expensive compared to travel by boat or train. Long-range service was provided mainly by flying boats (seaplanes), with Martin the leader in this area. The exhibit below shows the 1938 sales of aircraft firms in the U.S., and includes both commercial and military aircraft, as well as aircraft engines.

Exhibit 1: US aircraft industry sales rankings in 1938
Boeing remained more or less a niche player in civil aircraft in the 1930s

Company	Aircraft Sales ($ millions)
Douglas	$28.30
United Aircraft	13.3
Martin	12.4
Consolidated	12.2
Lockheed	10.3
North American	10.1
Curtiss-Wright	9.7
Grumman	4.9
Seversky	3.6
Boeing	2
Brewster	1.5
Bell	1.2

Source: BofA Global Research, company data
Note: Values in 1938 U.S. dollars

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Boeing was a minor player in civil aviation in the 50s

However, military markets continued to provide Boeing the greatest opportunities. It developed the B-17 bomber in the late 1930s, followed by the B-29. These two aircraft were the leading heavy bombers produced by the United States during World War II.

Boeing continued as a niche player in civil aviation markets in the early 1950s. In the immediate post-war period, Douglas, Lockheed, and Vickers of the U.K dominated the civil airliner market. Boeing sold a military transport, the Stratocruiser, which was developed at the end of World War II for six airlines in late 1949/1950. That was the extent of its participation in the market for piston aircraft.

Boeing began researching swept wings in the late 1930s. The development of a supersonic wind tunnel, along with German research on swept wing design captured in 1945, enabled Boeing to develop swept wing aircraft designs. Boeing's first major success came in 1946 when its design for a new Air Force bomber, called the B-47, was selected for production.

Boeing believed that jet-propelled aircraft would prove far superior to propeller-driven aircraft for civil aviation, and in 1952, the company's board authorized development of a new jet aircraft seating approximately 100 passengers. The plane emerging from this decision was ultimately called the 707, and the prototype first flew in 1954. PanAm ordered the aircraft in 1955.

Boeing was not the only company designing jet aircraft in the U.S., Douglas also developed a design it dubbed the DC-8, but it was not as advanced as the 707 when marketed. Boeing's dominance in civil aviation was established by the 707, which was followed by a steady stream of new aircraft designs.

Exhibit 2: The 707 was a major Boeing success
Boeing's dominance in civil aviation was established by the 707 || Turkish Airlines Boeing 707 – April 1976

Source: Wiki Commons

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Exhibit 3: Boeing aircraft
Product launch and entry into service

	Launch	Entry into Service	Last Civil Delivery
707	1954	1958	1978
717	1995	1999	2006
727	1960	1963	1984
737-100/200	1965	1967	1969/1988
737-300	1981	1984	1999
737-400	1986	1988	2000
737-500	1987	1990	1999
737-600	1995	1998	2006
737-700	1993	1997	2018
737-900	1997	2001	2005
737-900ER	2005	2007	2019
737-800	1994	1998	2020
757-200	1979	1982	2005
757-300	1996	1999	2004
747-100/200/300	1965/1970/1980	1969/1971/1983	1986/1991/1990
747-400	1985	1989	2009
767-200	1978	1982	1994
767-200ER	1982	1984	2003
767-300	1983	1986	2001
767-300ER	1987	1988	2014
767-300F	1993	1995	2020
767-400ER	1997	2000	2009
777-200	1990	1995	2007
777-200ER	1991	1997	2013
777-300	1995	1998	2006
777-300ER	2000	2004	
777-200LR	2000	2006	2021
777F	2008	2009	
747-8F	2005	2011	2023
747-8I	2005	2012	2021
787-8	2003	2011	
787-9	2003	2014	
787-10	2013	2018	
737MAX 7	2011	2024E	
737MAX 8	2011	2017	
737MAX 9	2011	2018	
777X	2013	2025E	
737MAX 10	2017	2025E	

Source: BofA Global Research, Boeing

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Douglas and McDonnell Douglas

Boeing's success in civil airliners was not pre-ordained. In the 1960s, it faced stiff competition from Douglas. After some initial development problems, Douglas established the DC-8 as a competitor to the 707. The DC-8 was first delivered in 1960. In 1962, Douglas moved forward with the DC-9. By 1966, Douglas had a backlog of more than 500 orders for the DC-9, but it had severe problems managing production increases. The company lost control of costs, resulting in major financial shortfalls. In 1966, Douglas merged with McDonnell to form McDonnell Douglas.

Exhibit 4: Douglas and McDonnell Douglas aircraft
Product launch and entry into service

	Launch	Entry into service	Last civil delivery
DC-8	1955	1960	1972
DC-9	1963	1965	1982
MD-80	1979	1980	1999
MD-90	1989	1993	1999
MD-95 (Boeing 717)	1995	1999	2006
DC-10	1970	1971	1989
MD-11	1986	1990	2000

Source: Boeing

Exhibit 4: Douglas and McDonnell Douglas aircraft
Product launch and entry into service

	Launch	Entry into service	Last civil delivery

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McDonnell Douglas opted for a strategy mainly to develop derivatives of its different family members. The DC-9 was stretched with more powerful engines and improved avionics, and this became the MD-80 (introduced in 1980), which in turn became the MD-90 (introduced in 1993). The DC-10 was modified with new engines, a longer fuselage and other features and was introduced as the MD-11 in 1990. The MD-95 was a re-shortened version of the MD-80 and was based off the DC-9. The MD-95 was renamed the 717 after Boeing took over McDonnell Douglas in 1997.

McDonnell Douglas merges with Boeing in 1997

After a corporate near-death experience on the C-17 military transport aircraft program that coincided with a sharp downturn in civil aviation in the early 1990s, McDonnell Douglas explored a series of strategic options to claw back the market share it had lost to Boeing and Airbus. It considered building a larger version of the MD-11 in Taiwan, merging with Airbus partners, and finally, in mid-1996, committing to a $15bn development program that aimed to revamp its product line. None of these came to be, and in 1997 following a loss on the Joint Strike Fighter development program, the company merged with Boeing.

Exhibit 5: DC-8's maiden flight in 1985
Douglas established the DC-8 as a competitor to the 707

Source: Boeing

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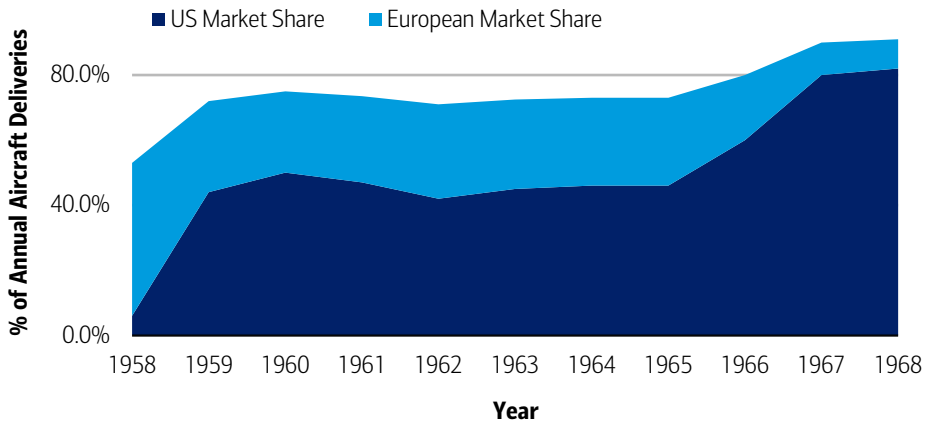
Europe: Airbus and its predecessors

Europe's civil aircraft industry traces its roots back to the beginning of aviation. However, the Second World War disrupted the continent's industry. France's aircraft industry was nationalized in 1936-1937 in a move to disperse manufacturing, which was highly concentrated around Paris. Germany's aerospace industry was dismantled after World War I and again destroyed in World War II. The U.K.'s industry was fragmented, although several dominant firms began to emerge in the 1950s. Interestingly, the deHavilland Comet pioneered commercial jet flight upon its introduction in 1952, but a series of accidents (eventually attributed to metal fatigue) severely curtailed its development.

US jet airliners dominated the market in the 1960s

The introduction of jet airliners resulted in U.S. dominance of the market in the 1960s. Exhibit 6 shows that from 1958-1968, the total share of U.S. manufactured jet (Boeing, Douglas, and Convair) deliveries rose from 50% to 80%.

Exhibit 6: Catalyst for the formation of Airbus
From 1958-1968, the total share of U.S. manufactured jet deliveries rose from 50% to 80%



Source: Airbus

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During this period, European-built aircraft either saw delivery declines of aircraft introduced in the 1950s or made relatively little headway against American competitors with new aircraft launched in the 1960s. Europe lost significant market share against the U.S. in the 1960s.

- Sud Aviation's 104-seat Caravelle, which was introduced in 1959, saw deliveries decline through the 1960s.
- In the U.K., British Aircraft Corp. was offering the VC-10 (a 150-185-seat jet) and the 1-11, a 90-seat jet. Hawker Siddeley was offering the 103-seat Trident.
- Deliveries of the deHavilland Comet were essentially completed in 1962.
- Germany, which had a distinguished legacy of aerospace accomplishments, was not building large civil aircraft, but it had an industry that was capable of participating on such programs.

Britain, France and Germany began to explore joint project

In the mid-1960s, Britain and France began to explore joint development of a high capacity, low-cost, subsonic airliner that would be well-suited for transport service between major European cities (the two countries had launched collaboration on the supersonic Concorde jet in 1962). In May 1965, the British Minister of Aviation announced a joint Anglo-French working group to examine the project, and in June, the German government was invited to participate in the project.

In July 1966, the three governments chose prime contractors for the Airbus project:

- France selected Sud Aviation, based in Toulouse.
- U.K. selected Hawker Siddeley Aviation.
- Germany chose a consortium of companies formed for Airbus.

Sud Aviation merged with Nord Aviation and SEREB in 1970 to form Aerospatiale. Hawker Siddeley merged with British Aircraft Corp. in 1978 to form British Aerospace.

The German consortium was comprised of Dornier, Messerschmitt Bolkow Blohm (MBB), Siebel, Hamberger Flugeugbau, and VFW. With the initial exception of Dornier, these firms were merged to form Deutsche Aerospace, which, in turn, was eventually merged into DaimlerChrysler.

Exhibit 7: Concorde
British Airways Concorde in 1986

Source: Wiki Commons

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Airbus is created

In September 1967, the three governments signed a Memorandum of Understanding for the development of the Airbus A300, with an in-service date of 1973. Germany was to contribute 25% of the development costs, while Britain and France were each to provide 37.5%. Rolls-Royce was to provide engines for the aircraft and Sud Aviation led the design of the airframe.

In 1968, however, Sud Aviation announced a reorientation of the program, including a provision that future versions of the A300 could be offered with engines other than the Rolls-Royce RB211. Accompanied by British disdain of another Concorde-like aviation development project and questions about its commercial and technical merits, British government opposition to the program grew and in 1969, France and Germany agreed to launch the A300 without British government participation.

Airbus was formed in 1970

In 1970, Airbus was formed as a "Groupement d'Interet Economique," or GIE. A GIE partnership, under French corporate law, is a partnership that does not pay taxes. It dividends its profits to its partners, so at the level of Airbus Industrie, at the end of any given year, there are no retained earnings held by the partnership.

Spain's CASA joined Airbus in 1972 by taking a 4.2% share and Iberia, the national airline of Spain, agreed to purchase four A300s. British participation continued on the A300 because it would have been too costly to drop Hawker Siddeley and bring on another company to develop and build the wing for the aircraft. Interestingly, the German government provided Hawker Siddeley with DM$250mn for the project.

The central roles and responsibilities of each of the partners on the A300 were not all that different from specialties each partner subsequently focused upon. Aerospatiale built the nose section and lower center fuselage section. Hawker Siddeley designed and

built the wings and Deutsche Airbus built fuselage sections and the vertical tail surfaces. CASA provided the horizontal tail surfaces. Approximately 40% of the production costs were incurred in France and 28% in Germany.

Britain rejoined Airbus in 1979

The British rejoined Airbus in 1979, but it was only after a protracted flirtation with Boeing on the 7N7 program, which became the 757. In 1976, Aerospatiale announced that it had signed a letter of intent with Boeing to participate on the 7N7 program, in exchange for participation on the A310 program – obviously, nothing ever came of this. British Aerospace concluded that its role in Airbus would be stronger than being a subcontractor to Boeing and there were broader government policies (European obligations) at play as well. Britain, under a Labor government, agreed to a 20% stake in Airbus, and this helped pave the way for launch of the A310, a smaller version of the A300.

Since 1979, the relative positions of the Airbus partners have not changed much. Until the formation of EADS (announced in October 1999), Aerospatiale Matra and DaimlerChrysler Aerospace each owned 37.9%, BAE SYSTEMS 20% and CASA 4.2%. In the 1980s, Airbus agreed to establish a second single-aisle final assembly line in Hamburg and the A321 and A319 are now completed at this facility, but otherwise the principal roles of each of the partners follow the pattern set with the A300.

Entering the business later than Boeing, Airbus was prepared to adopt new technologies, including digital flight controls and greater use of composites in its aircraft. This helped Airbus to emerge as a peer competitor to Boeing in the late 1980s.

In the 1990s, the view developed that if Airbus were to compete against Boeing, it would have to create a corporate form similar to Boeing's. In 1996-98, the members of the Airbus GIE agreed to exchange their Airbus assets for a stake in a new "Single Corporate Entity" comprising Airbus.

Airbus was a business unit of EADS

Differences in valuation gave way to a series of bilateral moves. DASA agreed to buy CASA in June 1999. In October 1999, DASA and Aerospatiale Matra agreed to merge to form EADS (European Aeronautics, Defense and Space), with CASA and Daimler Chrysler subsequently introduced to this company as well. As a result, EADS was an 80% shareholder of Airbus, with BAE SYSTEMS owning the remainder. In 2001, an agreement was reached between BAE SYSTEMS and EADS to form an Airbus Integrated Company (AIC). Each partner injected most of their Airbus-related manufacturing activities into the AIC in return for a direct equity stake. However in 2006, BAE exercised its put option regarding its 20% stake in Airbus.

It is interesting to note that Airbus' gains in market share were broadly at the expense of Douglas and Lockheed Martin, rather than Boeing; although, in 2003 Airbus exceeded Boeing deliveries for the first time.

EADS reorganized as Airbus Group

In September 2012, a merger between BAE SYSTEMS and EADS was publicly announced. A month later it was terminated because the interests of "government stakeholders cannot be adequately reconciled" (BAE SYSTEMS press release). A year later EADS announced a corporate restructuring and a rebranding as Airbus. In January 2014, EADS was reorganized as Airbus Group, with three divisions (Airbus, Airbus Defense and Space, and Airbus Helicopters).

After failed merger with BAE SYSTEMS, the French, German and Spanish governments agreed to a new shareholder structure that potentially reduces political influence of these governments in Airbus (the target is an aggregated ownership of as much as 12%).

Large civil jet OEMs that faded into history

The history of the introduction of Airbus and Boeing products suggests that these companies survived to dominate the large civil airliner market because they effectively managed their development and production programs and because they offer a full range of products that meet airlines' needs. Several airline manufacturers are no longer in the business.

Convair: formed in 1943, exited civil market in the 1960s

Convair no longer exists and most of the jets it made in the 1950s and 1960s are long retired. It was formed in 1943 by the merger of Consolidated Aircraft and Vultee; General Dynamics purchased it in 1954. Convair's main focus was military aircraft and space, but it also built piston engine civil transports in the late 1940s and 1950s. In the mid-1950s, Convair developed a four-engine jet transport, called the 880. It sold 65 of these aircraft and 36 of an improved version called the 990. Convair exited the civil aircraft market in the 1960s. General Dynamics sold off parts of the former Convair in the early 1990s to Lockheed (the Fort Worth division that makes the F-16).

Fokker: stopped producing civil jets in 1997

Fokker no longer makes civil aircraft. This Dutch company can trace its origins back to the beginning of the aviation industry. The more recent version of Fokker was formed in 1947 when the Dutch government combined Fokker, De Scheldt and Aviolanda in a single company called Fokker.

Like many civil aircraft companies in the late 1940s and 1950s, Fokker concentrated on developing a replacement for the DC-3 transport aircraft (and its military version, called the C-47). Fokker entered the jet market in the early 1960s with a design for a 50-65-seat passenger jet. The company introduced a larger version of this aircraft in 1986 (the Fokker 100).

For an 11-year period beginning in 1969, Fokker was merged with the German firm, VFW. However, in 1980, VFW was folded into MBB and de-merged with Fokker. DASA (Daimler's aerospace operations) took a 51% stake in Fokker in 1991, which later increased to 78%. DASA, however, in 1996, withdrew its investment in Fokker, forcing the company into bankruptcy. Fokker ceased producing aircraft in 1997.

Lockheed: delivered commercial jets from 1957 to 1983

Lockheed had been a leader in the piston engine airliner market. It designed and built the Constellation, which was initially used as military transport, and in 1957 it began deliveries of the Electra – a state-of-the-art turboprop – just at the dawn of the commercial jet transport market.

In the early 1960s, Lockheed did not immediately follow Boeing, Douglas, and Convair into the civil jet market, but instead concentrated on military transports. It built the C-141 and C-5. However, in the mid-1960s, the company began examining ways to re-enter the civil market and focused on needs for medium haul, high volume routes. It won a launch order from TWA for the L-1011 in 1968, and deliveries began in 1972. Lockheed built 250 L-1011s, and the last one was delivered in 1983, marking Lockheed's exit from the commercial aerospace business.

Commercial aerospace today is a duopoly

There are two major suppliers of large civil aircraft – Airbus and Boeing. These firms design, develop, and assemble large civil aircraft. They both machine and fabricate metal parts used to build the aircraft. These firms also support large civil aircraft through a variety of aftermarket services, including spares, modification, flight training, and technical support.

Boeing Commercial Airplanes group

How it is organized

Boeing Commercial Airplanes, or BCA, is responsible for commercial aircraft design and production. BCA is headquartered in the Puget Sound region (Seattle, Washington) and employs more than 60,000 people across its US and international operations.

BCA comprises five aircraft programs 737, 747, 767, 777, and 787. Global customer support, which was previously provided by Commercial Aviation Services (CAS), is now managed by Boeing Global Services (BGS), a separate business segment. The unit is responsible for all support activities such as spare parts sales, training, and aircraft modifications.

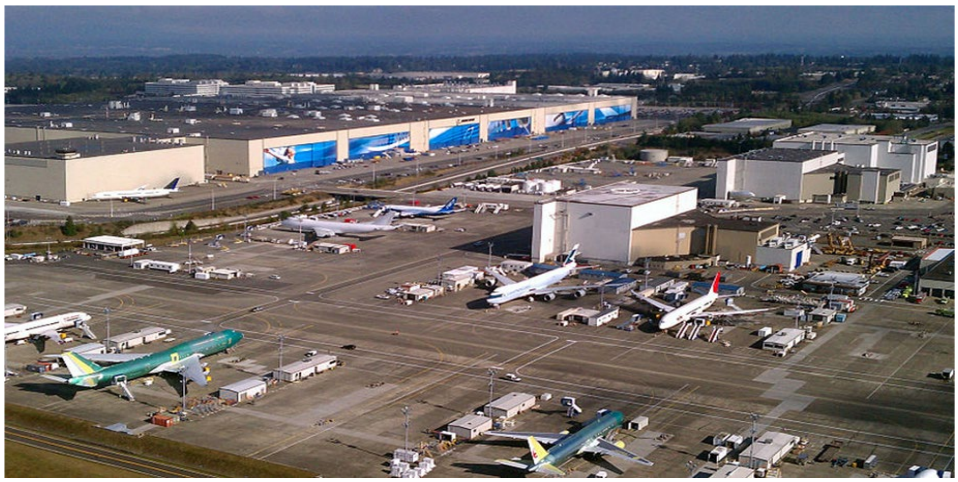
Major Boeing facilities

Boeing Commercial Airplanes has operations in more than a dozen US cities and countries. BCA major manufacturing facilities include:

Everett, Washington

Everett, Washington is 34 miles from BCA's headquarters in Seattle. At the Everett site, Boeing builds wings, assembles interiors, and does final assembly for twin-aisle aircraft (767, 747, 777, and 787).

Exhibit 8: Boeing's Everett facility
At the Everett site, Boeing builds wings, assembles interiors, and does final assembly for twin-aisle aircraft



Source: Wiki Commons

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Renton, Washington

Renton is responsible for final assembly of single-aisle aircraft, namely the 737NG and 737 MAX, as well as the Boeing Business Jet (BBJ). Fuselage sections for the 737-600/700/800 are sent by rail to Renton from Spirit AeroSystems (Wichita, Kansas). Wire harnesses and wings for the 737 are also built at Renton. More than 14,500 aircraft (~30% of global fleet) were built at the Renton site. On the military side, the P-8 and 737-800 military derivative are both built at this facility, as well.

North Charleston, South Carolina

Boeing's North Charleston facility is located about 10 miles north of Charleston, South Carolina. It is home to the second 787 final assembly and delivery facility. Here Boeing also fabricates, assembles, and installs systems for aft fuselage sections of the 787 and joins and integrates mid-body fuselage sections.

The Fabrication Division: Auburn, Washington & other sites

The Fabrication Division is located in Auburn, Washington, 19 miles south of Seattle. It provides parts, tools and assemblies for BCA. Products range from small sheet metal brackets to 747 wing skins. The Fabrication Division also has sites at:

Portland, Oregon: precision machined parts; wing chords for the 787

Frederickson, Washington: composite manufacturing center; skin and spar; 777 empennage; 787 vertical tail

Winnipeg and Manitoba, Canada: machined parts; composite secondary structures

Sydney and Melbourne, Australia: aerostructures; composite and metal components

St. Louis, Missouri: 777X composite wings

Long Beach and Seal Beach, California

The Long Beach and Seal Beach division is located in southern California. At the Long Beach facility, Boeing performed final assembly of 717s, MD80s, and MD11s. After these aircraft went out of production, Boeing then used the Long Beach facility for engineering and support for all in-production and out-of-production aircraft. Since Boeing no longer uses this facility for final assembly, Boeing Realty Corporation is developing the unused area into a mixed-use development property called Douglas Park. Boeing uses the south west section of the facility for the production of military aircraft. It was most recently used for the final assembly of the C-17. However, in September 2013 Boeing announced the termination of the C-17 program, and C-17 production at the Long Beach plant ended in November 2015. Nevertheless, Boeing remains in the area with its Long Beach design center, which provides customer support operations, advanced concept engineering, and MRO services for the C-17 and other aircraft that are currently out of production.

Airbus

How it is organized

Airbus was formed in 1970 as a consortium of France's Aerospatiale and Deutsche Airbus, a grouping of leading German aircraft manufacturing firms. Together, the companies had decided to build the A300, the first twin-engine twin-aisle airliner, to fill a gap in the market and to challenge American supremacy in the aviation industry. Shortly afterward, Spain's CASA joined the consortium, and in 1974 Airbus Industrie GIE moved its headquarters from Paris to Toulouse.

British Aerospace joined Airbus Industries in 1979. Each of the four partners, known as Airbus France, Airbus Deutschland, Airbus U.K. and Airbus España, operated as national companies with individual responsibilities to produce parts of the aircraft, to be transported to Toulouse for final assembly. The GIE provided a single face for sales, marketing and customer support.

In 2001, Airbus became a single, fully integrated company. The European Aeronautic Defence and Space Company (EADS), a merger of the French, German and Spanish interests, acquired 80% of the shares and BAE SYSTEMS, the successor to British Aerospace, acquired 20%. BAE sold its stake in Airbus to EADS in 2006.

From EADS to Airbus

In September 2012, a merger between BAE SYSTEMS and EADS was announced. A month later it was terminated because the interests of "government stakeholders cannot be adequately reconciled" (BAE SYSTEMS press release). A year later, EADS announced a corporate restructuring and rebranding as Airbus. In January 2014, EADS was reorganized as Airbus Group NV, combining the divisions for development and marketing of civil and military aircraft, as well as communications systems, missiles, space rockets, helicopters, satellites, and related systems. The newly formed Airbus Group has three divisions (Airbus, Airbus Defense and Space, and Airbus Helicopters).

Major Airbus facilities

Airbus has multiples plants disseminated mainly in Europe reflecting its foundation as a consortium. The main final assembly lines for commercial aircrafts are:

Toulouse, France (A320, A330 family, A350 family and A380)

Hamburg, Germany (A318, A319, A320 and A321)

Seville, Spain (A400M)

Tianjin, China (A319 and A320)

Mobile, Alabama, USA (A319, A320 and A321)

Mirabel, Canada (A220)

European Footprint

Final assembly lines

Toulouse, France: Toulouse is Airbus' headquarters and one of four final assembly centres for the company. Final assembly of all Airbus twin-aisle aircraft, and the A320, is completed at Toulouse. Toulouse also does final assembly for the A330, the A380, and the A350 family (-900/1000). Other Airbus facilities in Toulouse handle hard metals machining, wire harness assembly, and assembly of aircraft engine pylons. Test and design activities are also centred in Toulouse.

Hamburg, Germany: Airbus assembles A318, A319, and A321 aircraft at a facility in Hamburg. This facility can fabricate fuselage sections for single aisle aircraft. As part of the negotiations for the A380, it was agreed upon that the production directorate for the single-aisle family would be moved to Hamburg.

Fabrication facilities in France

Airbus has several fabrication facilities in France. In addition to those mentioned, the company now controls several facilities that were owned by Aerospatiale Matra that supplied parts to Airbus. In 2008, the French sites Meaulte and St. Nazaire Ville were merged into Aerolia.

At St Nazaire, Airbus does metal forming and stretching, tubing and assembly of fully equipped forward and center sections for twin-aisle aircraft.

At Nantes, Airbus does chemical milling, large parts machining, some composites work and assembly of central wing boxes.

At Meaulte, Airbus does alloy parts machining and assembly of cockpit and nose sections for all Airbus aircraft.

U.K. facilities: Broughton & Filton

There are two major Airbus facilities located in the U.K. A facility at Broughton provides wings for all Airbus aircraft. At Filton (near Bristol), there is a cargo conversion operation and fuselage sections of the A321 are fabricated. Core activities at Filton include the design, engineering and support for Airbus wings, fuel systems, and landing gear integration. GKN bought Airbus' Filton factory in 2008, and develops composite wing structures for the A350.

Fabrication facilities in Germany and Spain

Facilities in Spain are mainly engaged in fabrication of composite aircraft parts, including tail sections. Airbus has facilities in Madrid, Toledo, and Seville.

There are several facilities in Germany that do machining and fabrication of metal parts. Some of the larger ones include Bremen and Stade. Major investments have been made at several German facility areas for the production of the A380. These facilities include Stade, Bremen, and Hamburg.

The duopoly reaffirmed: no successful challengers, yet

Previously, we wrote that the duopoly in the narrowbody market was being challenged as Airbus and Boeing face competition from new entrants. Bombardier was a key contender with its development of the C Series and China is currently developing the Comac C-919. However, Bombardier sold its C Series platform to Airbus (now renamed the A220) and Comac's C-919 has only taken a handful of commercial flights.

Embraer has chosen to re-engine its current E-175, E-190, and E-195 regional jets rather than compete directly with Boeing and Airbus in the 130-160 seat segment, thus giving birth to the E2 jet family. While the E190-E2 and E195-E2 are currently in service, first delivery of the E175-E2 has been pushed to 2027/2028 due largely to scope clause concerns.

Regional jets: dominated by Embraer, Bombardier exited

Embraer is similar to Airbus and Boeing to the extent that it offers families of products and its designs, develops, assembles, and supports regional aircraft. Bombardier officially exited the regional jet business with the sale of the CRJ series to Airbus. ATR (owned by Airbus and Leonardo) and BAE SYSTEMS are niche players in the regional aircraft market. ATR builds turboprops seating 42-50 and 64-72 passengers. New players in the regional jet market include China with the ARJ-21 and Russia with the UAC (Sukhoi) Superjet 100 (SSJ100).

Fragmented commercial aero supply chain

Many industrial and multi-industry firms provide engineered products and systems for commercial aerospace. Although there has been increased concentration among these suppliers, the industry is very fragmented. Suppliers range from large conglomerates that have consolidated many aero players to small mom and pop shops. Typically, there are two or three dominant suppliers of each subsystem. Companies tend to specialize in businesses related to a core skill (such as communications), though recent merger activity has resulted in suppliers that are more diversified across different aerospace segments.

With a few exceptions, the major suppliers deal with all the major primes, though U.S. firms typically have more work with Boeing, while European firms have more work with Airbus. However, with both major primes seeking a more global supply chain, this is changing.

Boeing categorizes its suppliers as "Tier 1, Tier 2 or Tier 3."

- **Tier 1 suppliers** provide major subassemblies and systems, such as engines, landing gear and major aerostructure sections.
- **Tier 2 suppliers** provide systems and equipment, such as avionics, flight control actuators and wheels and brakes.
- **Tier 3 suppliers** tend to be smaller, specialized shops that provide machined parts, castings, and plastic parts, also known as POPs (purchased outside parts).

Boeing currently deals with ~20,000 suppliers from over 50 countries. Boeing tracks supplier performance through an enterprise-wide rating system with five color-coded threshold standards: Gold (best), Silver, Bronze, Yellow, and Red. Suppliers are graded on Delivery, Quality, and General Performance Assessment. Boeing then distributes an annual Boeing Performance Excellence Award (BPEA) to Silver and Gold-rated suppliers, as well as a Supplier of the Year award.

Boeing's subcontractor base has become more international, and the current cycle has entailed that the company is looking for more capacity outside the U.S. Some of this is driven by international offsets and some by the simple fact that these suppliers can meet Boeing's needs.

Aircraft engine primes

For the major aircraft engine suppliers, the roster of major suppliers has not changed significantly.

General Electric (GE)

General Electric (GE) conducted some of the earliest development work on military jet engines for the U.S. It entered the commercial market with the CV-880, which was a turbojet engine for the Convair 880. It expanded further, with the CF-6 engine, which powered DC-10s and other twin-aisle aircraft. GE Aerospace, currently a subsidiary of GE, is set to become its own publicly traded entity in 2024 following the spinoff of GE's energy business.

Pratt & Whitney (P&W)

Pratt & Whitney is now a part of RTX (previously United Technologies Corp). It was formed in 1925 by Frederick Brant Rentschler, an engineer who left Wright, then the largest engine supplier in the U.S. Pratt J57 engines powered the Boeing 707 and played a leading role in civil aircraft engines. Pratt & Whitney's next generation commercial jet engine, the PurePower PW1000G geared turbofan (GTF) engine, entered service in early 2016 and competes with CFM's LEAP. For more information on the GTF see Part 1 of our primer.

Rolls-Royce

Rolls-Royce began manufacturing automobiles in 1906. It entered the aircraft engine market in 1914 and has since been a leading player. Rolls-Royce took over the development of the jet engine from Rover during WWII. The U.K. supplied designs and engines to the U.S. (both to GE and Pratt & Whitney), kick starting the U.S. jet age.

Financial difficulties in developing the innovative three-shaft RB211 engine for the Lockheed L-1011 aircraft forced the company into bankruptcy and ownership by the U.K. Government ensued in 1971. The motor car operations floated off to the public later that year, and the company was privatized as an aero engine maker in 1987.

Alliances, consortiums, and joint ventures are prevalent in engine market

Rolls-Royce, General Electric, and Pratt & Whitney are the major aircraft engine suppliers. The three major firms design, develop, manufacture, and support aircraft engines. However, there are several inter-relationships and joint ventures, and, in most cases, there is now only one (sole) or two engines offered on airliners. Given the high cost of developing an engine, the major suppliers have sought to form inter-relationships and joint ventures.

CFM International

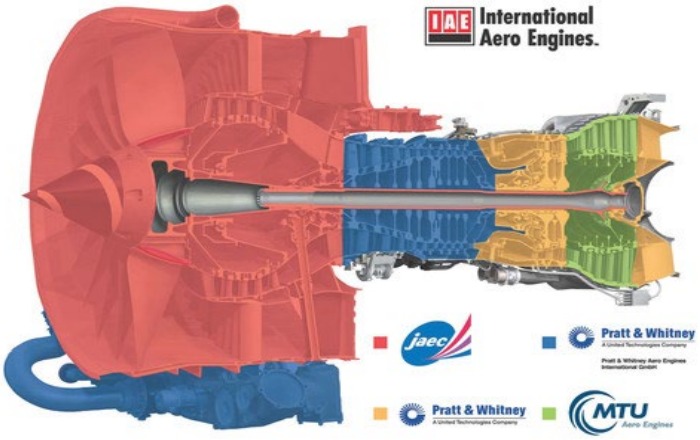
CFM International is a joint venture between GE Aviation and Snecma, a division of Safran of France. The joint venture was formed to build and support the CFM56 series of turbofan engine. In 1971, Snecma and GE embarked on a joint venture to build a smaller turbo fan engine for civil aircraft. From this venture, the CFM-56 family of engines was created. CFM is now producing its latest generation of jet engines: the LEAP.

International Aero Engines AG (IAE)

International Aero Engines AG (IAE) was founded in 1983, and its partners include Pratt & Whitney, Rolls-Royce, the Japanese Aero Engines Corporation (JAEC), and MTU Aero Engines. Each contributed an individual module to the V2500. The V2500 powers the Airbus A320 family (A319, A320, A321, and the Airbus Corporate Jetliner (ACJ)), the Boeing MD-90, and the Embraer C-390.

In October 2011, Rolls-Royce agreed to sell its share in IAE to Pratt & Whitney, but under the agreement would continue to supply high pressure compressors, as well as engineering support and final assembly of 50% of V2500 engines. As part of the agreement, P&W and Rolls-Royce also agreed to form a new partnership for mid-size commercial aircraft. However, in September 2013, the parties announced the cancellation of their plan to form a new joint venture.

Exhibit 9: V2500 engine
Module contributions of each company are highlighted



Source: Company reports

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The Engine Alliance (EA)

The Engine Alliance is a 50/50 joint venture between General Electric and Pratt & Whitney, formed in August 1996 to develop a family of engines for new high-capacity, long-range aircraft. The GP7000 powers the A380 and competes with the Trent 900.

Aerostructures and nacelles

One of the largest independent aerostructures suppliers is Spirit AeroSystems. Other large players include the Japanese heavies (Kawasaki Heavy Industries, Mitsubishi Heavy Industries and Fuji Heavy Industries). Alenia (now Leonardo) also supplies aerostructures to Airbus, as does Latécoère of France. Triumph Group entered the Aerostructures business in 2010 by acquiring Vaught Aircraft Industries. However, Triumph completed its portfolio shaping with the sale of its aerostructures busies to Daher Aerospace in July, 2022. Independent nacelle suppliers include Collins Aerospace (now part of RTX), Aircelle (a Safran subsidiary), GKN, Spirit, and Latécoère.

Exhibit 10: Aerostructure and nacelle players
Triumph (not listed below) completed its portfolio reshaping with the sale of its aerostructures business

Company	Forward fuselage	Other fuselage	Nacelles / Thrust reversers	Struts / pylons
Spirit	■	■	■	■
Safran Nacelles			■	
Leonardo		■	■	
GKN	■	■	■	■
Collins (RTX)			■	■
Airbus (Stelia, Premium Aerotec)	■	■		■
Japanese Heavies		■		
Latécoère	■	■		■
Sonaca Group	■	■		
Aernnova	■	■	■	

Source: BofA Global Research, company reports

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Flight controls and avionics

Flight controls have increasingly become fully integrated systems that encompass sensors, communications and the controls and displays. Honeywell, Collins Aerospace (now RTX), Garmin, Thales, and Smiths Industries (part of GE Aviation Systems) are key suppliers in this segment. While Garmin's avionics division currently supplies glass flight decks to business jet OEMs, the G5000 (which is used on several Textron models) could be Garmin's gateway to avionics suites in larger aircraft, which have traditionally been dominated by Honeywell, Thales, and Collins Aerospace.

Wheels and brakes, landing gear

In landing gear, the two major suppliers are closely aligned with either Airbus or Boeing. Boeing designs its own landing gear but does not manufacture these very large structures. Precision Castparts (owned by Berkshire Hathaway) provides titanium forgings for the larger gear, which are then finished by Collins Aerospace. Collins Aerospace currently supplies all landing gear for Boeing aircraft. Safran landing systems (previously Messier Bugatti Dowty), supplies Airbus with landing gear (although lost out to Collins Aerospace for the main landing gear of the A380). For the 777X, Herous-Deutek will provide the landing gear (UTC Aerospace Systems previously lost this program).

RTX's legacy UTC Aerospace Systems (previously Goodrich), Honeywell and K&F Industries (owned by Meggitt) are leading suppliers of wheels and brakes. Others include Dunlop Aerospace (also owned by Meggitt), Triumph Group, and Esterline Control Systems.

Exhibit 11: Boeing 777-300 chassis
Herous-Deutek manufactures the 777's landing gear

Source: Wiki Commons

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Interiors

The cabin interior market saw considerable consolidation in the 1990s, led mainly by B/E Aerospace (acquired by Rockwell Collins in 2017, now Collins Aerospace of RTX), which is a leading supplier of aircraft seats. Other interior parts suppliers include Zodiac (owned by Safran), Recaro, AIM Altitude (formerly AIM Aviation), and Triumph Interiors (set to be one of the remaining elements of the Structures business).

In-flight entertainment (IFE) systems have been an area of intense interest

In-flight entertainment (IFE) systems have been an area of intense interest by airlines, however, the technical challenge of getting a multi-media, multiple-channel system to work in such a demanding environment has been greater than many would have expected due to the complexity of the systems. Major in-flight entertainment suppliers include Collins Aerospace (RTX), Thales Avionics in-Flight Systems (formerly Sextant), and Panasonic (formerly Matsushita).

Metals

We noted earlier that aluminum is the most widely used material on large civil aircraft (for more information see Part 1 of our primer).

- Leading aluminum suppliers to the civil aerospace industry include Arconic and Rio Tinto Alcan. Additionally, there are a number of specialty suppliers of heat-treated aluminum.

- Titanium suppliers include the Russian VSMPO-Avisma and U.S.-based suppliers Allegheny Technologies, RTI International Metals (owned by Arconic), and Titanium Metals (owned by Precision Castparts).

- The nickel alloys used in aircraft engines are provided by Haynes International, Carpenter, Allegheny, and SMC (owned by Precision Castparts).

Actuators

There are multiple suppliers of flight control actuators, including Collins Aerospace (previously UTC Aerospace Systems), Moog, Parker Hannifin, Curtiss-Wright, Safran, Nabtesco (formerly Teijin Seiki), and Eaton.

Composites

Hexcel is the leading supplier of composite prepreg to the civil aircraft market. It also produces carbon fiber, honeycomb sandwich panels, and finished composite structures. Hexcel is the primary and secondary composite supplier to the A350.

Other carbon fiber producers include Cytec (Solvay), Toray, and Toho Tenax (the latter two are Japanese firms). Hexcel's main competitor in prepreg materials is Cytec. Toray is a key supplier of composite materials for the Boeing 787.

Other components

- Woodward (formerly Woodward Governor) supplies fuel and engine control systems and control system components (e.g., fuel pumps, engine controls, actuators, air valves, fuel nozzles, and electronics).

- Ducommun provides fuselage skins, aerostructures, and machining.

- Triumph Group provides engine and airframe components, machining, and aftermarket services.

- ATI (formerly Ladish) and Doncasters provide small forgings and castings.

- Precision Castparts (owned by Berkshire Hathaway) provides large forgings and castings.

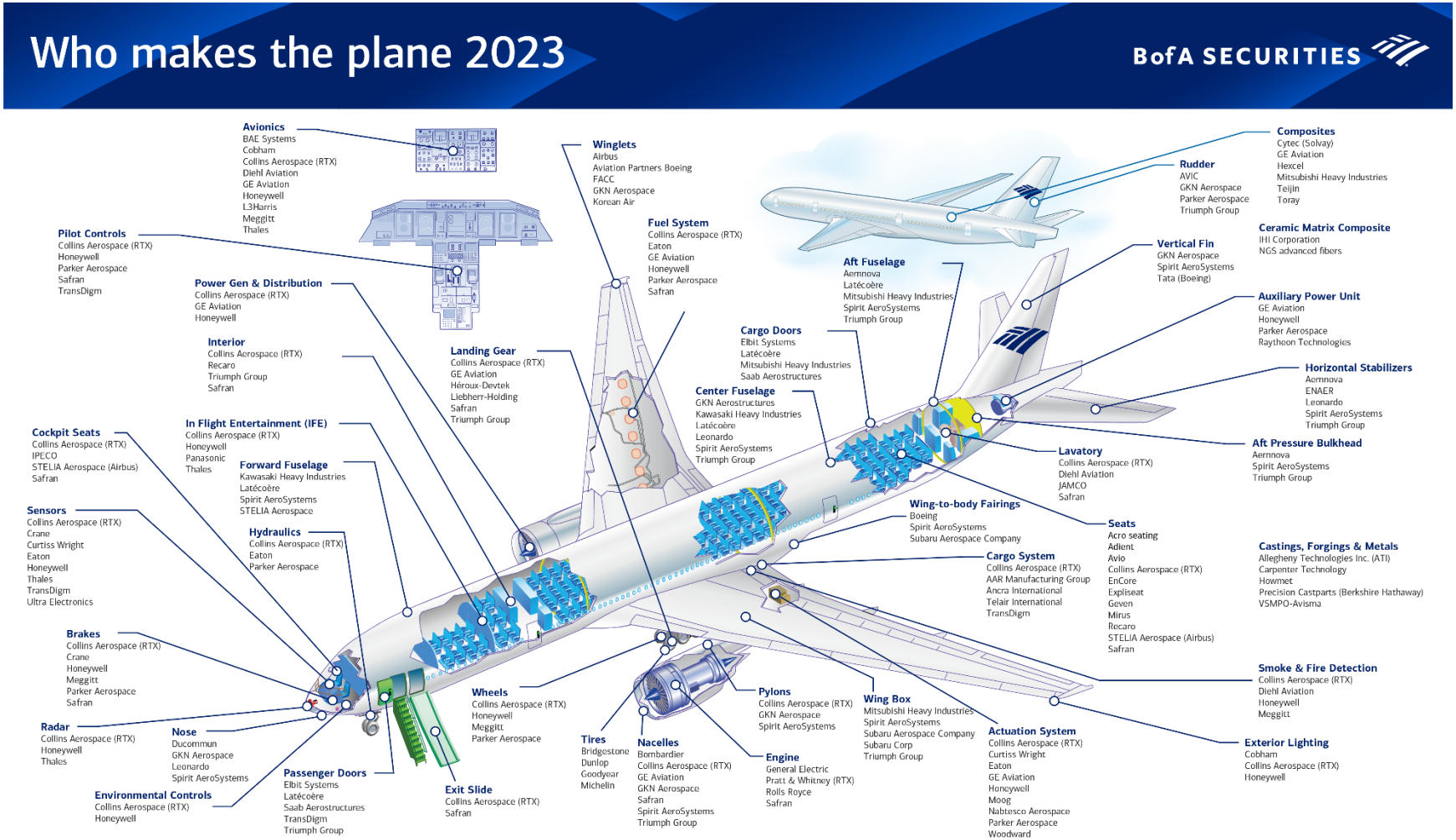
Fasteners

Major fastener suppliers include KLX (purchased by Boeing in 2018), Howmet (formerly Arconic/Alcoa, includes Huck, Fairchild), Grating Fasteners Inc. (GFI), Hi-Shear, and Precision Castparts (including Air Industries Company, Cherry Aerospace, Fatigue Technology, PB Fasteners, SPS Technologies, Shur-Lok Company, and T.J. Brooks).

Machined parts

There are thousands of smaller firms that provide machined parts to the aerospace industry.

Exhibit 12: Who makes the plane?
The aerospace supply chain is highly fractured



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Source: BofA Global Research

Major commercial aerospace suppliers

The figure above contains a smaller version of the BofA Global Research Who Makes the Plane poster, in which we highlight key suppliers of civil aero parts and systems. The following are brief profiles of these companies, including an overview of which parts/systems each one supplies. Many of these suppliers are in the BofA Global Research coverage universe at the time of publication.

Crane (CR)

Crane Company, based in Stamford, CT, is a diversified manufacturer of engineered industrial products. The Aerospace & Electronics segment offers an integrated source for sensing, power, braking, electronics, and other products that are used not only in aircraft engines and landing gear but also space satellites and medical implants. Engineered Materials is made up primarily of Crane Composites, the world leader in fiberglass reinforced plastic (FRP) composite materials. Process Flow Technologies unit provides highly engineered products and systems, including valves, pumps, lined pipe, instrumentation, and controls.

Curtiss-Wright Corporation (CW)

Curtiss-Wright Corporation designs, manufactures, and overhauls precision components and systems and provides highly engineered products and services to the aerospace, defense, automotive, shipbuilding, processing, oil, petrochemical, agricultural equipment, railroad, power generation, security, and metalworking industries. The company is headquartered in Davidson, NC.

Ducommun Incorporated (DCO)

Headquartered in Santa Ana, CA, Ducommun provides custom, high-reliability engineering and manufacturing services for high-cost-of-failure applications in the aerospace, defense, industrial, oil-and-gas, mining, and medical markets.

Ducommun manufactures components and assemblies for commercial aircraft, military aircraft, missile, and space programs through its two business units: Electronic Systems and Structural Systems. Electronic Systems designs, engineers, and manufactures high-reliability electronic and electromechanical systems and subsystems, including box-level assemblies, human machine interface products, printed circuit board assemblies, and lighting diversion strips and suppressors. Structural Systems designs, engineers, and manufactures contoured aerostructure components and assemblies, including rotor blade assemblies, flight control surfaces, exhaust systems, engine ducts, fuselage skins, composite winglets, ammunition handling systems, plastic extrusion products, and magnetic and mechanical seals.

Leonardo (LDO)

Leonardo, (formerly known as Finmeccanica) is an Italian-based aerospace and defense manufacturer. Leonardo is a major aerostructures supplier, making parts for both Airbus and Boeing. More recently, the company appears more aligned with Boeing, supplying 14% of the 787's structure. In 2008, management announced it would be working with Airbus to supply interface control systems and avionics for the A350.

Garmin (GRMN)

Garmin Ltd. is a worldwide provider of navigation, communications, and information devices, most of which are enabled by global positioning system (GPS) technology. Garmin designs, develops, manufactures, and markets a diverse family of hand-held, portable and fixed-mount GPS-enabled products and other navigation, communications, and information products for the automotive/mobile, outdoor, fitness, marine, and aviation markets. Garmin is incorporated in Switzerland. The Aviation segment represented 16.3% of 2022 sales and 20.7% of operating income.

HEICO Corporation (HEI)
HEICO Corporation is a technology-driven aerospace, industrial, defense, and electronics company. It operates in two segments, the Flight Support Group (FSG) and the Electronic Technologies Group (ETG). FSG designs, engineers, manufactures, repairs, distributes, and overhauls FAA-approved jet engine and aircraft component replacement parts and systems. It is not the original equipment manufacturer of the aircraft parts; it is a PMA (Parts Manufacturing Approval) producer. ETG produces electrical and electro-optical systems and components serving niche segments of the aerospace, defense, communications, and computer industries.

Hexcel (HXL)
Hexcel Corporation is an advanced structural materials company. Hexcel develops, manufactures and markets lightweight, high-performance composites, including carbon fibers, reinforcements, prepegs, honeycomb, adhesives, tooling materials and finished aircraft structures for use in commercial aerospace, space and defense and industrial applications. Hexcel is one of the largest U.S. producers of carbon fiber and the world's largest weaver of reinforcement fabrics.

Honeywell (HON)
Honeywell International is a North Carolina-based diversified global technology and manufacturing company. It was formed by the merger of Honeywell and AlliedSignal in a pooling-of-interest transaction, at the end of 1999. Honeywell's operations are organized under four business segments: Aerospace, Building Technologies, Performance Materials and Technologies, and Safety & Productivity Solutions. The company is a premier supplier of avionics, power, and control systems for the aerospace industry.

Meggitt (MEGGF)
Meggitt is a UK-based global engineering company focusing on specialist components and smart sub-systems with five main divisions: Aircraft Braking Systems, Control Systems, Equipment Group, Polymers & Composites and Sensing Systems. In civil aerospace, Meggitt covers large aircraft, BJs, RJs, helicopters, and GA. In defense, Meggitt covers military aircraft, land systems, naval platforms, training, and weapons systems. The group also has a growing presence in the energy market.

Control Systems supplies pneumatic, fluid control, thermal management and electromechanical equipment and sub-systems. Polymers & Composites specializes in fuel containment, engineered aircraft sealing solutions and technical polymers, electrothermal ice protection and complex composite structures and assemblies. Sensing Systems provides high-performance sensing and condition-monitoring solutions for high-value rotating machinery and other assets. The Equipment Group comprises safety systems, avionics, live-fire and simulation training and combat support.

Moog Inc. (MOG/A)
Moog Inc., based in Elma, NY, is a designer and manufacturer of precision motion and fluid controls and control systems for commercial & military aerospace and industrial applications. The company operates in three segments: Aircraft Controls, Space and Defense, and Industrial Controls. Servoactuators, Moog's core product, receive electrical signals from computers and then perform specific actions. Using its servoactuators, Moog builds flight and control systems for aircraft.

Precision Castparts (previously PCP; now owned by Berkshire Hathaway)
Precision Castparts, founded in 1949 is the leading manufacturer of complex metal components and products for aerospace and industrial gas turbine applications. The principal business segments of the company are Investment Cast Products, Forged Products, Airframe Products, and Metal Products. Aerospace and Power generation are the company's main source of revenue. Major customers include General Electric Company, United Technologies (now RTX), Rolls-Royce, and Boeing. In January 2016, PCP was acquired by the multinational conglomerate Berkshire Hathaway for about $37bn.

RBC Bearings (RBC)

RBC Bearings is a manufacturer of precision roller, ball, and plain bearings. RBC manufactures bearings in all major categories focusing on niche markets, primarily within the United States. The company concentrates on three segments of the bearings market: industrial, aerospace, and defense. Aerospace and defense customers represented 58% of FY21 sales. Following the company's Dodge acquisition which contributed to Industrial revenues, ~40% of FY22 revenues came from Aerospace and Defense.

The company is headquartered in Oxford, CT. Major aerospace customers include Airbus, Boeing, Embraer, General Electric, Lockheed Martin, Primus International, Snecma Group, Spirit AeroSystems, U.S. Department of Defense and various aftermarket distributors including Wesco Aircraft, Dixie Aerospace, National Precision Bearing and W.S. Wilson.

Spirit AeroSystems (SPR)

Spirit is the largest non-OEM designer and manufacturer of aerostructures in the world, with over half of revenues coming from Boeing. Spirit was formed as the result of Onex Partners purchasing Boeing Wichita (June 2005) and BAE Aerostructures (April 2006). Boeing Wichita had more than 75 years' experience in manufacturing commercial aerostructures. The company is headquartered in Wichita, Kansas.

Spirit AeroSystems is one of Boeing's largest suppliers. Spirit AeroSystems is Boeing's aerostructures subcontractor. For example, the company provides fuselage sections for the 737, the forward section of the 737, 747, 777, 767 and 787, and wing structures for the 737, 747, 767, 777 and 787.

Spirit is organized into three reporting segments: Commercial, Defense & Space, and Aftermarket.

TransDigm Group (TDG)

TDG provides a diverse array of products including ignition systems, pumps, valves, motors, actuators, controls, water faucets and systems, quick disconnects and couplings, batteries, chargers and power conditioning, cockpit security systems, composites and elastomers, audio systems, and lighting and displays. Their parts are designed into and sold as original aircraft equipment. In fiscal year 2022, 29.9% of net revenues came from commercial, regional, business jet, and general aviation aftermarket, 24.5% of sales were derived from the commercial OEM market, 42.6% came from defense, and 3.0% were non-aerospace related.

- **Esterline Corporation (ESL):** Esterline was bought by TDG in 2019 and is a specialized manufacturing company principally serving aerospace and defense markets. Approximately 80% of total revenues are generated from aerospace and defense markets. The remaining 20% is from the application of these technologies into industrial markets. Esterline's businesses are divided into three segments: Avionics & Controls, Sensors & Systems, and Advanced Materials.

- The Power & Control segment develops, produces, and markets systems and components that predominately provide power to or control power of the aircraft utilizing electronic, fluid, power and mechanical motion control technologies. The Airframe segment develops and produces systems and components that are used in non-power airframe applications utilizing airframe and cabin structure technologies. The Non-aviation segment develops and produces seat belts and safety restraints for ground transportation applications, mechanical/electro-mechanical actuators and controls for space applications, hydraulic/electromechanical actuators and fuel valves for land-based gas turbines, and refueling systems for heavy equipment used in mining, construction and other industries and turbine controls for the energy and oil and gas markets.

Triumph Group (TGI)
Triumph Group (TGI) is an aerospace/defense company whose principal business is the manufacture, repair & overhaul of aerostructures and components for the aviation industry. The company operates in three segments: 1) Aerostructures: design, development, manufacture, repair, and sales of complete metallic structural assemblies, 2) Aerospace Systems: design, development, manufacture, repair, and sales of aerostructure components, and 3) Aftermarket Services: supplier of maintenance, repair, and overhaul services.

RTX (RTX)
RTX is an industrial conglomerate resulting from the merger of Raytheon (previous ticker: RTN) and United Technologies (previous ticker: UTX). In June 2023, the company officially rebranded as RTX (previously Raytheon Technologies) and realigned into three business segments – Collins Aerospace, Pratt & Whitney, and Raytheon (which is comprised of the former Raytheon Missiles & Defense and Raytheon Intelligence & Space). Its commercial aerospace businesses consist of Pratt & Whitney (military and civil aircraft engines and service operations), and legacy UTC's Aerospace Systems (aviation controls and systems and former Rockwell Collins). Raytheon Technologies' commercial aerospace business is now called "Collins Aerospace."

- **Pratt & Whitney** produces commercial, military, business jet and general aviation aircraft engines, parts and services, industrial gas turbines, geothermal power systems and space propulsion.

- **Collins Aerospace** produces integrated avionics systems, aviation systems, communications systems, navigation systems, electric power generation, management and distribution systems, environmental control systems, flight control systems, air data and aircraft sensing systems, engine control systems, engine components, engine nacelle systems, including thrust reversers and mounting pylons, interior and exterior aircraft lighting, aircraft seating and cargo systems, evacuation systems, landing systems (including landing gear, wheels and braking systems), hoists and winches, fire and ice detection and protection systems, actuation systems, and propeller systems. Collins also designs, produces, and supports cabin interior, oxygen systems, food and beverage preparation, storage and galley systems, lavatory and wastewater management systems.

Woodward Inc. (WWD)
Founded as Woodward Governor Company, Woodward integrates technologies into fuel, combustion, fluid, actuation, and electronic control systems for the aerospace and energy markets. Within aerospace, Woodward participates in both propulsion and actuation across a broad spectrum of platforms. Woodward is on fixed and rotary wing aircraft, guided weapons, and associated equipment.

The Aerospace segment provides systems and components for both commercial and defense end markets, including fuel pumps, metering units, actuators, air valves, specialty valves, fuel nozzles, and thrust reverser actuation systems for turbine engines and nacelles, as well as flight deck controls, actuators, servocontrols, motors and sensors for aircraft. The Industrial segment offers applications and control solutions for machines for the energy market as well as combustion control solutions for multiple industrial end markets. Some of its products include actuators, valves, pumps, fuel injection systems, solenoids, ignition systems, speed controls, electronics and software, and sensors. The company is headquartered in Fort Collins, CO.

Zodiac (previously ZODFF; now owned by Safran, SAF)
Zodiac is a major European supplier to Airbus, Boeing, and the military end market. On 13 February 2018, Zodiac Aerospace was acquired by Safran to create the world's third largest aerospace company at the time (excluding aircraft manufacturers).

Other U.S. suppliers: Kaman, Hitco

Kaman provides the fixed trailing edge structure for the 767 and 777. Hitco provides spoilers for the 737 and flap track fairings for the 767.

Japan Aerospace Development Corp

Japan's aerospace industry is a major provider of aerostructures on Boeing twin-aisle aircraft. Japan's largest commercial aerospace relationship is with Boeing via supplier contracts for the 767 and 777.

Mitsubishi Heavy Industries, Kawasaki Heavy Industries, and Fuji Heavy Industries are the ones mainly involved in supplying commercial aircraft bodies. They have participated with Boeing in joint development and shared manufacturing since the 767. Japan Aerospace Development Corp., a consortium of KHI, MHI, and FHI, was formed for the 777 and provides bulkheads, wing boxes, and fuselage sections.

- Kawasaki Heavy Industries (KHI) and Mitsubishi Heavy Industries (MHI) provide body panels for the 767. These two firms also provide outboard trailing edges and flaps, respectively, for the 747.
- Fuji Heavy Industries (FHI) provides spoilers and ailerons for the 747. KHI makes flaps and ribs for the 737. On Boeing's 787, the company is giving a significant portion of the total airframe construction to Japanese heavies.
- MHI (Mitsubishi Heavy Industries) makes the main wing box for the 787.

Chinese suppliers

China is emerging as a more important supplier of parts for Boeing aircraft, although its role is currently relatively small. Boeing's principal subcontractors in China are Xian Aircraft Company and Shenyang Aircraft Corporation, an affiliate of China Aviation Industry Corporation (AVIC).

- Xian Aircraft manufactures the empennage for the 737NG family of aircraft and the empennage for the 757.
- Shenyang Aircraft Corp. commonly manufactures tail sections and cargo doors for Boeing, and was selected to build the fuselage for the C Series (now A220).
- In November 2014, Boeing announced that it awarded a contract to Aviation Industry Corporation of China (AVIC), China's largest state-owned aviation company, to produce composite empennage tips for the 777X.
- In September 2015, during president Xi Jinping's visit to Boeing's widebody assembly plant in Everett Washington, a new facility in China was announced to be operated jointly by Boeing and Comac (maker of the C919 single-aisle). The new Chinese facility will operate as a completion center for the 737 family.

European suppliers

There are several European firms that supply Boeing with parts for aerostructures.

- Finmeccanica (now Leonardo) had supplied a large part of the fuselage for the 717 and manufactures fuselage components and control surfaces, such as outboard flaps, for the 767 and 777. Leonardo (formerly Finmeccanica's Alenia) manufactures the center fuselage and horizontal stabilizers for the 787 in Italy.
- GE Aviation Systems (formerly Smiths Industries) supplies the flight management systems for the 737NG, electric load management system for the 777, and common core system, landing gear actuation, and control system for the 787.

- Saab supplies wingtip panels and crew doors for the 737 and large cargo doors for the 787. For the 787, Latécoère is providing passenger doors, Safran the electric brakes and landing gear structure, and Thales the in-flight entertainment system.

- Other Western-European suppliers include BAE Systems, GKN, Meggitt, and Ultra Electronics Holdings. Boeing has stepped up sourcing from Central Europe as well, such as WZK-Mielec of Poland, which provided doors for the 757.

Korean suppliers

In Korea, Korea Aerospace Industries (KAI) and Korean Airlines' Aerospace Business Division supply parts to Boeing and Airbus.

KAI supplies wing ribs to both Boeing and Airbus (A319, A320, A330, A340, A350, 737, and 767), produces the composite fuselage for the Apache helicopter, and supplied the main wing and forward fuselage for Boeing's F-15 Strike Eagle.

KAI currently provides 777 nacelle fittings, 737 empennages, 737-based P-8 empennages, 787 raked wingtips, and 787 pivot bulkheads. KAI also provides major structural component parts as a tier 2 supplier for 747-8, 767, and 787.

KAI also supplies wing panels and the upper shell for the A320 family, the vertical and horizontal stabilizers for the 737, frame assemblies for the 747, and tail backing parts for the 757 and 767. Korean Air provides winglets for the A320, 747, 777, and 787, fairings for the 737, 747, 777, and 787, and fuselage sections for the 767 and ERJ-170/190. Korean Air also supplies wings, horizontal stabilizers, and aft fuselage for Lockheed's F-16 Fighting Falcon and structural components for Boeing's 787 Dreamliner.

Exhibit 13: Some of Airbus' and Boeing's major suppliers
The aerospace supply chain is highly fragmented with a combination of large suppliers and mom & pop shops

Company	Country	Product or Service provided
Air Cruisers (Zodiac)	France	Evacuation systems
Aircelle (SAFRAN)	France	Structural parts
Alcoa	U.S.	Aluminum sheets and plates
Allegheny Technologies	U.S.	Titanium
Aubert & Duval	France	Metal products
B/E Aerospace	U.S.	Seating products, galley systems, lighting, waste systems
Bombardier	Canada	Structural parts
CFM	U.S. / France	Aeroengines
Crane	U.S.	Brakes
Diehl Aircabin	Germany	Cabin interiors
Diehl Comfort Modules GmbH	Germany	Toilet cabins
Encore	U.S.	Interiors, seats, and composite structures
Fuji Heavy Industries	Japan	Wing box
Finmeccanica	Italy	Fuselage, pilot controls
GE	U.S.	Aeroengines
GKN	U.K.	Engine parts
Hexcel	U.S.	Composites
Honeywell	U.S.	Flight computers, auxiliary power sets
International Aero Engines (IAE)	U.K./U.S.	Aeroengines
Kawassaki Heavy Industries	Japan	Fuselage
Labinal (SAFRAN)	France	Electrical cabinets/design
Latècoére	France	Structural parts
Liebherr Aerospace	Germany	Environmental control systems, secondary flight controls
LISI	France	Hardware
Mecachrome	France	Mechanical parts and subassemblies
Messier-Bugatti-Dowty (SAFRAN)	France	Landing gear, wheels and brakes
Mitsubishi Heavy industries	Japan	Wings, doors
Northrop Grumman	U.S.	Flight computers
Onera	France	Test/design
PFW Aerospace	Germany	Tubes and ducts
Pratt & Whitney (UTC)	U.S.	Aeroengines
Precision Castparts (Berkshire Hathaway)	U.S.	Advanced metal components
Rio Tinto Alcan	Canada	Sheet metal and plates

Exhibit 13: Some of Airbus' and Boeing's major suppliers
The aerospace supply chain is highly fragmented with a combination of large suppliers and mom & pop shops

Company	Country	Product or Service provided
Rolls-Royce	U.K.	Aeroengines
Sonovision	France	Documentation design/printing
Spirit Aerosystems	U.S.	Wing structure
Tata Steel Europe	Netherlands	Aluminum sheets and plates
Thales Avionics	France	Cockpit instrumentation, computers
Toho Tenax (Teijin Group)	Japan	Composites
Toray	Japan	Composites
UTC Aerospace Systems (prev. Goodrich)	U.S.	Landing gear, nacelles, mechanical components, actuators
UTC Aerospace Systems (prev. Hamilton Sundstrand)	France	APU, actuators, valves and controls, electric components
Zodiac Group	France	Electrical components

Source: BofA Global Research, Boeing, Airbus

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Aircraft types

Differentiating aircraft types

Commercial aircraft types are generally differentiated by their range and by the number of persons they seat. There are three broad categories of commercial jet aircraft: single-aisle, twin-aisle, and regional. Cargo aircraft are categorized by the tonnage of freight they can carry.

Classifying aircraft types

Historically, large civil aircraft have been broadly segmented as either widebody or narrowbody aircraft, though over the past five years, market conscious manufacturers decided that "narrow" brought forth the image of tight or cramped. Passenger service aircraft are now commonly referred to as "single-aisle" or "twin-aisle." Within each major segment, aircraft are differentiated by several factors:

Range

Range is generally shown in nautical miles (nm), equivalent to 1.15 statute miles or 1.85 kilometers, at maximum takeoff weight. The listed range for an aircraft is for a "typical" mission, but prevailing winds, cruising altitude, and the altitude and temperature at the airfield from which the aircraft takes off will all impact actual range. So-called "high and hot" airfields affect range because of the greater amount of fuel that is typically needed to takeoff.

Seats

Seats are typically expressed in terms of a standard seating configuration, such as two-class (First and Coach/Economy) or three-class (First, Business and Coach/Economy).

Cargo capacity

Aircraft cargo capacity is typically measured in tons, though volume also matters, particularly for bulky items such as clothing, flowers, or electronics. These products may not weigh as much as machine parts, but they take up space; cargo carriers can charge by both weight and volume. Cargo capacity can also be measured by standard size containers, or "Unit Load Devices," which are used to hold cargo.

Number of engines

Aircraft now in production have either two or four engines. Several other aircraft that are no longer produced, including the 727, L-1011, and MD-11, had three engines.

Aircraft nomenclature

Pointers on deciphering aircraft designations

There is no simple guideline for deciphering how OEMs designate aircraft. Boeing has stuck with the "7XX" designation for its aircraft, and Airbus uses the "AXX" designation. The numbers that follow the "7XX" or "AXX" can range from –50 to –900 and are used to identify different variants of the same basic aircraft model. Bombardier previously used "CRJ" to designate its regional aircraft and "CSXXX' for the C Series, while Embraer uses "E-XXX."

Each derivative typically provides some varying combination of range and/or capacity, which is achieved by lengthening or shortening the fuselage, or making modifications to the wing or the propulsion system and the total weight of the aircraft. When developing a new aircraft family, a manufacturer will typically introduce one variant with the intention of eventually offering both larger and smaller derivatives. Other points regarding aircraft naming methodologies include:

- For each derivative, in general, the higher the series number after the dash, the larger the aircraft, or the longer the range. Thus, the 737–800 is larger than the 737–600 version.

- Boeing sometimes uses "ER" to indicate an extended range version of a particular derivative, where the required modifications are not substantive enough to warrant a new derivative classification.

- The "X" designation is sometimes used to indicate aircraft that are in development. Some examples of this are the Airbus A380 when it was previously called the A3XX and the Boeing 777X which is expected to be formally re-named.

Single–aisle jets

Single-aisle jets comprise the majority of the world's in-service fleet of commercial aircraft.

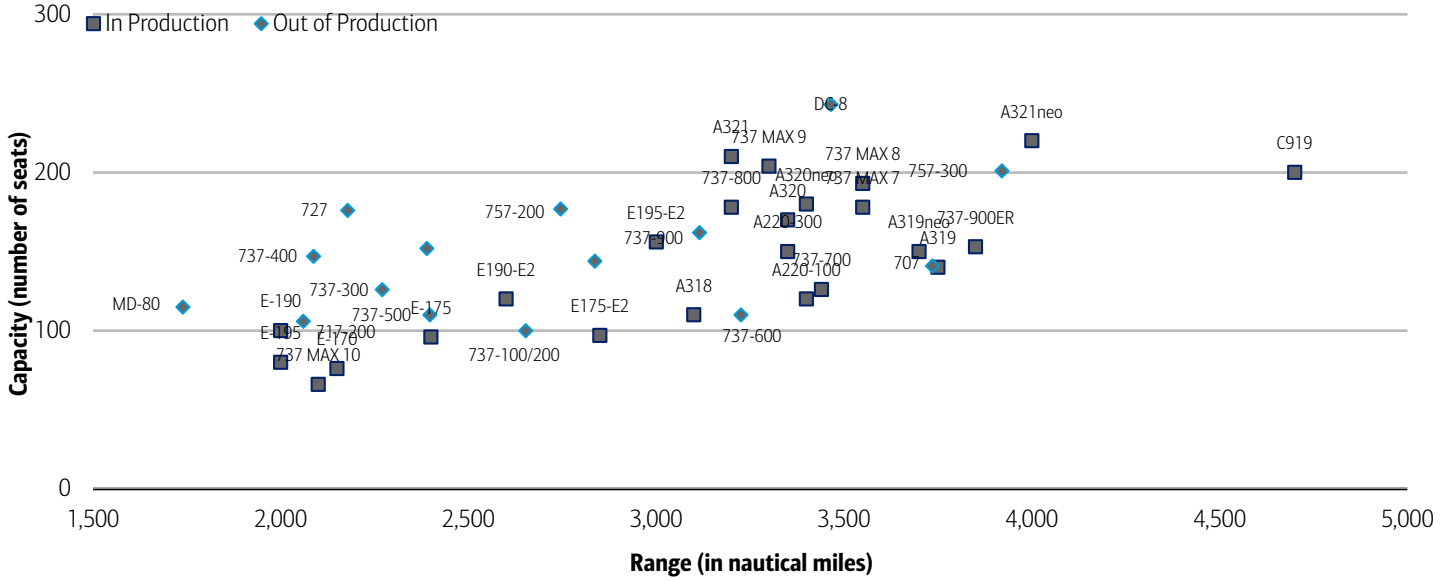
Single-aisle aircraft seat 100 to 200+ passengers

All single-aisle jets currently in production have two engines, though several out-of-production aircraft have either three engines (727-100/200) or four engines (DC-8). Several versions of these older aircraft operate with three flight crew members – pilot, co-pilot, and flight engineer. Advances in avionics have automated the flight engineer functions, and all large civil aircraft currently in production, both single-aisle and twin-aisle, operate with only a two-person flight crew. Take a look at the flight deck of a 727 and you will see three people – a pilot, co-pilot, and flight engineer.

There are substantial variations in the range and capacity of single-aisle jets. Newer aircraft designs, in general, offer slightly better range-capacity combinations than aircraft produced in the 70's. Airline strategies have evolved over the years to favor frequency strategies (more flights per day to a particular destination) over capacity strategies, which use fewer, larger capacity flights.

The newer aircraft designs also tend to offer better economics, due to factors such as advanced avionics and systems, lighter materials, improved aerodynamics, more efficient engines, and reduced maintenance characteristics. Newer aircraft are also typically more environmentally friendly with reduced noise and emissions.

Exhibit 14: Single-aisle aircraft
These models tend to seat between 100-200 passengers and fly 2,000-4,000 nautical miles range



Source: Airbus, Boeing, Embraer, Cirium

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Exhibit 15: Statistics on single-aisle aircraft
Single-aisle jets comprise the majority of the world's in-service fleet of commercial aircraft

	Seats[1]	Number of Engines	Engines: CFM	Engines: Rolls-Royce	Engines: Pratt & Whit.	Engines: IAE	List Price2 Avg	Range (nm)	Year of 1st Delivery	Number in Service[3]	Total Delivered[3]
In Production/Development											
Airbus quoted data											
A220-100	120	2			PW1500G		$81	3,400	2016	56	47
A220-300	150	2			PW1500G		$92	3,350	2016	209	186
A319neo	150	2	LEAP-1A	-	PW1100G	-	$102	3,700	2022	10	4
A320neo	180	2	LEAP-1A	-	PW1100G	-	$111	3,400	2016	1657	1519
A321neo	220	2	LEAP-1A	-	PW1100G	-	$130	4,000	2017	1095	974
Boeing quoted data											
737 MAX 7	153	2	LEAP-1B	-	-	-	$100	3,850	2022E	NA	NA
737 MAX 8	178	2	LEAP-1B	-	-	-	$122	3,550	2017	1076	838
737 MAX 9	193	2	LEAP-1B	-	-	-	$129	3,550	2020E	192	126
737 MAX 10	204	2	LEAP-1B	-	-	-	$135	3,300	2023E	NA	NA
Embraer quoted data											
E-175	76	2	CF34-8E	-	-	-	$53	2,150	2005	690	725
E175-E2	80	2	-	-	PW1700G	-	$60	2,000	2027/28E	1	NA
E190-E2	97	2	-	-	PW1900G	-	$69	2,850	2018	21	12
E195-E2	120	2	-	-	PW1900G	-	$78	2,600	2019	71	59
Comac quoted data											
C919	156	2	LEAP-1C	-	-	-	NA	3,000	2022E	NA	NA
Out of Production											
Airbus											
A318	110	2	CFM-56	-	PW6000	-		3,100	2003	16	60
A319	140	2	CFM-56	-	-	V2500		3,750	1996	958	1,410
A320	170	2	CFM-56	-	-	V2500		3,350	1988	3,310	4,733
A321	210	2	CFM-56	-	-	V2500		3,200	1993	1,435	1,783
Boeing											
707	141	4	-	-	JT3D	-		3,735	1954	NA	721
717-200	106	2	-	RB700	-	-		2,060	1999	99	155
727	176	3	-	-	JT8D	-		2,178	1964	36	1,815
737-100/200	92-110	2	-	-	JT8D	-		2,652	1967	30	1,106
737-300	126	2	CFM-56	-	-	-		2,270	1984	242	1,108
737-400	147	2	CFM-56	-	-	-		2,087	1988	234	485
737-500	110	2	CFM-56	-	-	-		2,397	1990	63	386
737-600	110	2	CFM-56	-	-	-		3,225	1998	11	69
737-700	126	2	CFM-56	-	-	-		3,440	1997	796	1,127
737-800	162	2	CFM-56	-	-	-		3,115	1998	4,104	4,977
737-900	177	2	CFM-56	-	-	-		2,745	2001	37	52
737-900ER	178	2	CFM-56	-	-	-		3,200	2006	442	505
757-200	201	2	-	RB211	PW2000	-		3,920	1982	478	983
757-300	243	2	-	RB211	-	-		3,465	1999	49	55
Embraer											
E-170	66	2	CF34-8E		-	-		2,100	2004	124	188
E-190	96	2	CF34-10E	-	-	-		2,400	2005	382	565
E-195	100	2	CF34-10E	-	-	-		2,000	2006	137	172
McDonnell-Douglas											
DC-8	259	4	-	-	JT8D	-		5,217	1959	4	555
DC-9	90-129	2	-	-	JT8D	-		1,739	1982	24	929
MD-80	144	2	-	-	JT8D	-		2,836	1980	95	1,189
MD-90	152	2	-	-	JT8D	V2500		2,389	1995	NA	116

Source: BofA Global Research, Boeing, Airbus, Cirium
1: Two-class configuration
2: in $mn
3: As of September 2023

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Twin-aisle jets

Twin-aisle jets comprise the balance of the world fleet of large civil aircraft. Twin-aisle jets in production are powered either by two engines or four engines. While the vast majority is used on long-haul routes, some jets are used for high-density short routes. For example, Austrian Airlines operates 767 jets on Vienna-Frankfurt service and operates other widebodies such as 777 aircraft on other short- and medium-haul routes, in addition to traditional long-haul service.

Exhibit 16: The Airbus A300
The first twin-aisle, twin-engine passenger jet

Source: Wiki Commons

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Exhibit 17: The Boeing 777
The first ultra-long haul twin-aisle aircraft

Source: Wiki Commons

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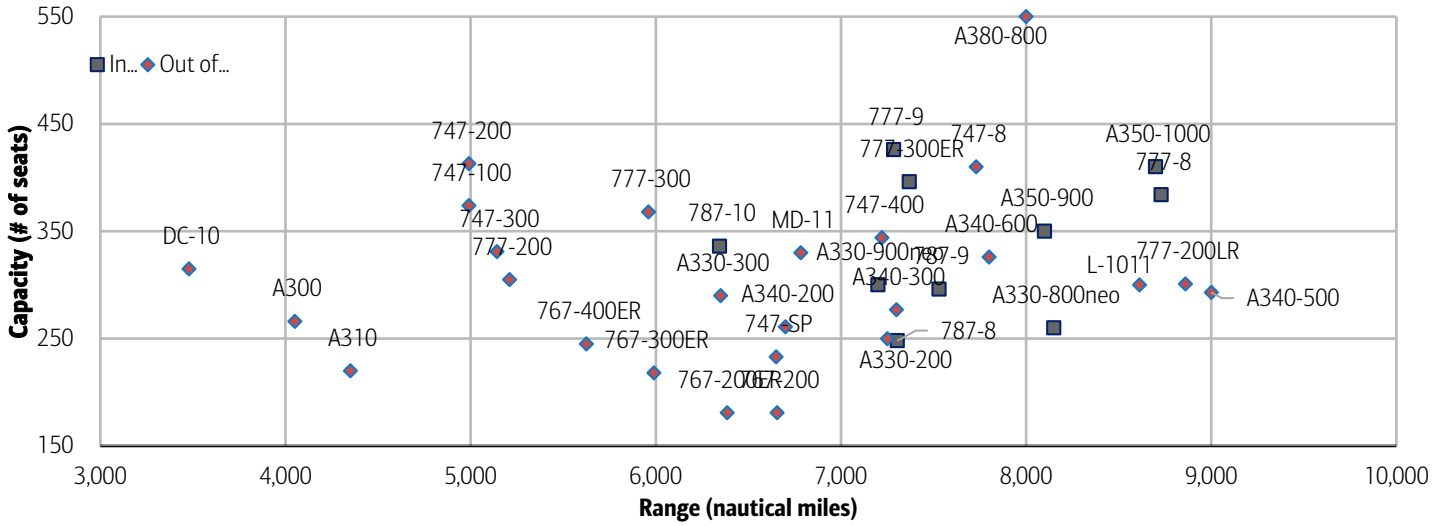
Exhibit 18 illustrates the ranges and passenger capacity of twin-aisle. Most twin-aisle aircraft offerings fall into the 250-to-400-seat and 5,000-to-7,500nm range category. Range and capacity listings are for a standard three-class seating arrangement.

Several of these aircraft are offered in various configurations that result in different range/capacity combinations, though we have only listed the most popular arrangements. For example, Boeing offered the 747-400 in a domestic version with a capacity of 568 passengers in a two-class configuration or 660 passengers in a single-class configuration, though with a range of only 1,800nm. This aircraft was used primarily in dense, short-haul Asian markets, such as on Japan Airlines' Osaka-Tokyo route. The 747-400D variant was retired in March 2014.

Exhibit 18: Twin-aisle aircraft
Newer models tend to enable longer ranges



Source: Airbus, Boeing, Cirium, Air Monitor

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Exhibit 19: Statistics on twin-aisle aircraft
Widebody recovery post-pandemic has lagged narrowbody recovery

	Seats[1]	Number of Engines	Engines: Rolls-Royce	Engines: Pratt & Whit.	Engines: GE	List Price2 Avg	Range (nm) Max	Year of 1st Delivery	Number in Service[3]	Total Delivered[3]
In Production/Develop.										

Exhibit 19: Statistics on twin-aisle aircraft
Widebody recovery post-pandemic has lagged narrowbody recovery

	Number of	Engines			List Price2	Range (nm)	Year of	Number in	Total
Airbus									
A330-800neo	260	2	Trent 7000	-	-	$260	8,150	2020E	7	4
A330-900neo	300	2	Trent 7000	-	-	$296	7,200	2018	99	77
A350-800	280	2	Trent XWB	-	-	$281	8,200	2016E	NA	NA
A350-900	350	2	Trent XWB	-	-	$317	8,100	2015	454	407
A350-1000	410	2	Trent XWB	-	-	$367	8,700	2018	79	64
Boeing									
777-300ER	396	2	-	-	GE90-115B	$376	7,370	2004	741	874
777-8	384	2	-	-	GE9x	$410	8,730	2025E	NA	NA
777-9	426	2	-	-	GE9x	$442	7,285	2025E	3	NA
787-8	248	2	Trent 1000	-	GEnx	$248	7,305	2011	382	370
787-9	296	2	Trent 1000	-	GEnx	$293	7,530	2014	585	561
787-10	336	2	Trent 1000	-	GEnx	$338	6,345	2018	89	84
Out of Production									
Airbus									
A300	266	2	-	JT-9, PW4000	CF-6		4,050	1974	185	558
A310	220	2	-	JT-9, PW4156	CF-6		4,350	1985	16	252
A330-200	250	2	Trent 700	PW4000	CF-6		7,250	1998	337	624
A330-300	290	2	Trent 700	PW4000	CF-6		6,350	1993	533	772
A340-200	261	4	-	-	CFM-56		6700	1993	1	22
A340-300	277	4	-	-	CFM-56		7,300	1993	41	217
A340-500	293	4	Trent 553	-	-		9,000	2003	NA	29
A340-600	326	4	Trent 556	-	-		7,800	2002	15	95
A380-800	550	4	Trent 900	GP 7200	-		8,000	2007	101	251
Boeing									
747-100	374	4	-	JT-9	-		4,991	1970	NA	205
747-200	413	4	RB211	JT-9	CF-6		4,991	1971	8	383
747-300	331	4	RB211	JT-9	CF-6		5,142	1983	2	80
747-400	344	4	RB211	PW4056	CF-6		7,221	1993	215	687
747-8	410	4	-	-	GEnx-2B		7,730	2011	28	36
747-SP	233	4	RB211	JT-9	-		6,650	1976	NA	43
767-200	181	2	-	JT-9	CF-6		6,655	1998	1	130
767-200ER	181	2	-	PW4000	CF-6		6,385	1982	6	105
767-300ER	218	2	RB211	PW4000	GE80C2		5,990	1988	211	579
767-400ER	245	2	-	PW4062	CF-6		5,625	2000	32	37
777-200	305	2	Trent 877	PW4077	GE90-77B		5,210	1995	NA	88
777-200LR	301	2	Trent 877, 895, 890, 892	PW4090	GE-90-115B		8,860	2006	253	278
777-300	368	2	Trent 892	PW4098	-		5,960	1998	8	60
Lockheed									
L-1011	217-362	3	RB211	-	-		8,612	1972	NA	248
McDonnell Douglas									
DC-10	315	3	-	JT-9	CF-6		3,478	1971	NA	364
MD-11	330	3	-	PW4460	CF-6		6,783	1990	NA	138

Source: BofA Global Research, Boeing, Airbus, Cirium
1: Three-class configuration
2: In $mn
3: As of September 2023

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