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Final Thesis

# The Flight of innovation: a comparative analysis of Airbus and Boeing Competition

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# Contents

# Introduction

This thesis will analyse the 53-year-long competition between the world's leading aircraft manufacturers, Airbus and Boeing.

Starting from the birth of Boeing in 1916, this thesis goes through the slow growth that allowed the firm to conquer the majority of the US market and across the increasing thigh competition, started after the Airbus foundation in 1970, which allowed the latter to undermine the rival's dominant position.

The thesis retraces almost all of the history of aircraft development, highlighting the continuous innovations, the strategic decisions and the failures of the two firms that produce together up to 90% of commercial aircraft worldwide.

This analysis will give high importance, along with the historical perspective, to the role and the effects of innovations, not only those applied to planes, like pressurisation, turbojet engines or flight-by-wire, but also those associated with changes in the sale strategy or the supply chain, and in general to the development of a firm capable of keeping up with a constantly growing and evolving sector.

By doing so, the thesis aims to prove that Airbus is winning the competition because it maintained, through the years, the same innovative capabilities that were behind its birth in 1970.

# 1. From 1920 to 1945, the origins of Boeing

## 1.1 From when to start

In order to analyse the competition between the two biggest commercial aeroplane companies, it is crucial to identify a starting point, represented by the birth date of mass commercial air transportation.
While recognising the United States as the country where this change occurred is easy, the title of the moment is more challenging. There are at least three moments in the twentieth century in which we can collocate that birth, and in all three cases Boeing, one of the two firms we are analysing, was involved.

The first option is related to the airline company Pan Am.
Between 1927 and 1948, Pan Am was the first company to operate international mail and passenger flights.[1] This kind of flight required the introduction of bigger planes capable of transporting both cargo and passengers comfortably on longer distances, overcoming the usage of small, short-distance seaplanes.[2]

On this occasion, Boeing created the seaplane Model 314, which represented 12 of the 28 "Clippers"[3] that made up the Pan Am fleet between 1939 and 1946.[4]

Without underestimating the significant boost given to airliner and commercial aeroplane manufacturers by Pan Am innovation, the impact of the Pan Am 28 planes

[1] DELTA FLIGHT MUSEUM, *PAN AM family tree*, https://www.deltamuseum.org/exhibits/delta-history/family-tree/pan-am, accessed 02/04/20203.
[2] NATIONAL AIR AND SPACE MUSEUM, *The Early Airlines You Might Not Have Heard Of,* https://airandspace.si.edu/stories/editorial/early-airlines-you-might-not-have-heard, accessed 02/04/2023.
[3] PAN AM CLIPPER FLYING BOATS, *The Pan Am Clippers*, https://www.clipperflyingboats.com/, accessed 02/04/2023.
[4] DELTA FLIGHT MUSEUM, *PAN AM family tree.*

fleet, capable of transporting a maximum of 74 passengers per flight using Boeing Clipper, was not so vital to unleashing the global transportation revolution that commercial flying represents, so we cannot consider this as the birth moment for the commercial aviation industry.

The second option is strictly connected with Boeing. On 1938 New Year's Eve, Boeing Model 307 Stratoliner, the first pressurised commercial aircraft, made its first flight.[5] Capable of reaching a 6,096-meter altitude, avoiding all discomforts that not pressurised aircraft suffer, from wind and rain effects to lack of oxygen and low temperatures onboard that make flights dangerous and uncomfortable, this aircraft «provide its 33 passengers with a smoother and quieter ride»[6] than any other plane, assuring the connection between New York and Los Angeles and from the US to Latin America.[7]
The glorious perspectives of Model 307, like his production, were, tragically, stopped by World War II.
Between 1939 and 1941, all American manufacturers stopped commercial aircraft production and put all effort into military models, forcing us to move on to the last case, the one that can be effectively considered the commercial aircraft industry's birth moment.

The third option is located immediately after the war. Between 1945 and 1948, the aircraft manufacturers had to manage two different stresses and make crucial decisions.

On the one hand, the incredible growth in plant dimensions and people employed, allowed during the war by military plane orders, were not sustainable.
Within two years, all major companies were forced to reduce their workforce and manage the severe cash flow and order loss. Boeing fired 14.028 employees between 1945 and 1948, cutting its workforce in half,[8] North American Aviation, the P-51

[5] BOEING, *Model 307 Stratoliner*, https://www.boeing.com/history/products/model-307-stratoliner.page, accessed 02/04/023.
[6] NATIONAL AIR AND SPACE MUSEUM, *Making the modern airliner*, https://airandspace.si.edu/stories/editorial/making-modern-airliner, accessed 02/04/2023.
[7] BOEING, *Model 307 Stratoliner.*
[8] MYERS, P. R., (2007), "Boeing Aircraft Company's Manpower Campaign during World War II", *The*

Mustang producers, lost 86.000 employees between 1945 and 1946,[9] while Douglas laid off more than 100.000 employees.[10]

On the other hand, a new request for commercial planes capable of connecting the world and allowing more people to fly was emerging on the horizon, forcing the manufacturer to choose which sector to focus on between commercial and military and generating a race in the development of new aircraft.

The years between 1945 and 1948, which saw the development and production of those planes that set the standard and forms of civil aviation for decades, are probably the best moment to set the actual commercial aeroplane sector birth date, and so the moment in which our analysis begins.

*Pacific Northwest Quarterly*, *98*(4), p.183.

[9] C. MC FADDEN INTERESTING ENGINEERING, *What happened to WWII aircraft manufacturers?*, https://interestingengineering.com/innovation/ww2-aircraft-companies-post-war, accessed 02/04/2023.

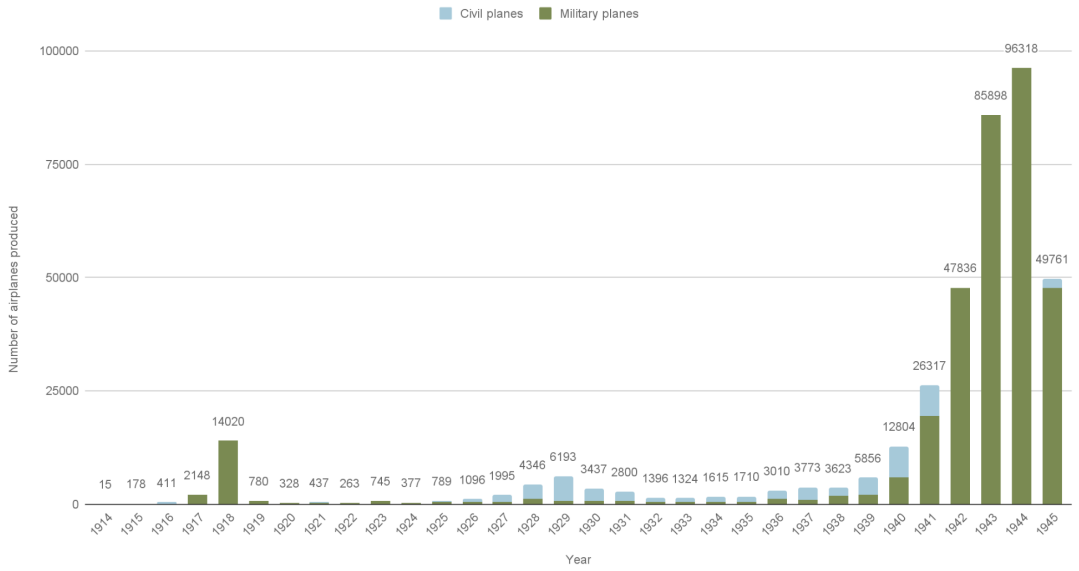
[10] C. MC FADDEN INTERESTING ENGINEERING, *What happened to WWII aircraft manufacturers?*.

## 1.2 The sector before 1945

As we are going to see, the years between 1945 and 1952 saw a dizzying growth of aircraft production and development, but this can be considered as a restart and not as the beginning of the competition between the US aeroplane producers that was only paused by WWII.

As we can see in Graph 1, US production grew almost continuously during the period between the world conflicts, with no secondary space for civil planes, mainly seaplanes and multirole (mail and passengers). With the approaching of the II World War, military production regained importance, leading to a complete stop of civil production and a sudden growth of deliveries and manufacturer dimensions.

Graph 1: US airplane production between 1914 and 1945
Elaboration on Manifacturers Aircrafts Association Inc. data



Along with the production growth, those years saw the establishment of many new manufacturers. According to the Aerospace Industry Association, since 1919 represents the US manufacturers, in 1919, there were eleven manufacturer companies:[11]

- Aeromarine Plane.
- The Burgess Company.
- Curtiss Aeroplane and Motor Corporation.
- L.W.F. Engineering Company.
- Standard Aircraft Corporation.
- Sturtevant Aeroplane Company.
- Thomas-Morse Aircraft Corporation.
- Wright-Martin Aircraft Corporation.
- Dayton Wright Airplane Company.
- Fisher Body Corporation.
- Wright-Martin Aircraft Company of California.

After just one year, with the addition of Boeing Airplane Corporation, Gallaudet Aircraft Corporation, Packard Motor Car Corporation, St Louis Aircraft Corporation, West Virginia Aircraft Corporation and Wright Aeronautical Corporation and the closure of Standard Aircraft Corporation, there were already sixteen manufacturers.[12]

The number of manufacturers kept on growing. In 1925, there were 66 active between aircraft and engine manufacturers,[13] in 1929, 133 and in 1933, 92.[14] Among these the protagonists of the post-war race, Lockheed, Douglas, Martin and Boeing

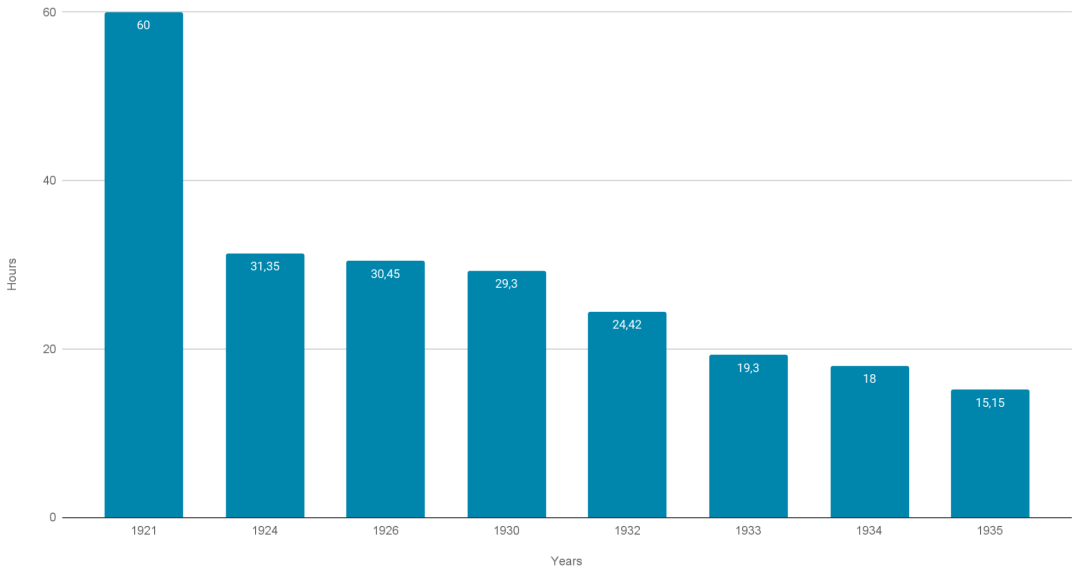
[11] MANUFACTURERS AIRCRAFT ASSOCIATION (1919), *Aircraft Year Book 1919,* Manufacturers aircraft association, New York, p. 39.
[12] MANUFACTURERS AIRCRAFT ASSOCIATION (1920), *Aircraft Year Book 1920,* Manufacturers aircraft association, New York, p. 140.
[13] MANUFACTURERS AIRCRAFT ASSOCIATION (1925), *Aircraft Year Book 1925,* Manufacturers aircraft association, New York, pp. 256 - 257.
[14] MANUFACTURERS AIRCRAFT ASSOCIATION (1935), *Aircraft Year Book 1935,* Manufacturers aircraft association, New York, p 24.

Along with the manufacturer also the value of the production, the export, the infrastructures and the air routes increased during this period.

Just to give some indicative values, the average number of miles flown daily by airlines in the US increased 11 times between 1926 and 1934, going from 11.830 miles per day to 133.435 miles per day, and that is nothing compared to the 92.9 times increase in the number of passengers carried each year (5782 in 1926, 537.637 in 1934),[15] or the decrease in time needed to travel from coast to coast, that felt down between 1921 and 1924 and then keep on decreasing as long as technological improvement of aeroplanes kept on increasing,[16] as can be seen on Graph 2.

Graph 2: Coast to coast travel duration in hours

Elaboration on Aerospace Industry Association data




Among all those signals of the growth of the airline industry, a very important one is represented by the growth of production and export. In fact, already in those years, the US was starting to conquer other European markets, in which, however, every country had, or was developing, one or more national producers, especially for military

[15] MANUFACTURERS AIRCRAFT ASSOCIATION (1925), *cit,* pp.124/125.
[16] MANUFACTURERS AIRCRAFT ASSOCIATION (1925), *cit,* p.130.

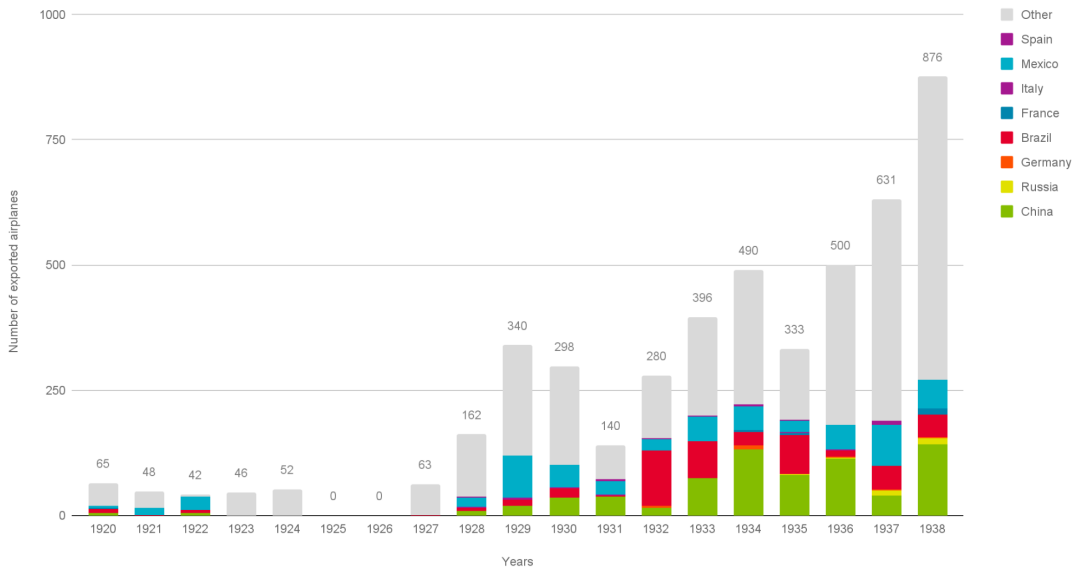
purposes, in South America and Asia. In those two cases, the market entrance was greatly facilitated by the lack of producers.

Once again, thanks to AIA data, we can retrace the sustained growth experienced by the sector between 1920 and 1939, taking into consideration the exports of complete aeroplanes and the more complex element from an engineering point of view, namely the engines.

As we can see in Graph 3, this period can be split in two. Between 1920 and 1927 the production was relatively stable and never exceeded the 65 aeroplanes exported yearly, around 20% of the total annual production. On the other hand, the second period saw constant growth, with an exported amount that stayed quite steadily over 280 units per year, not showing a particular decrease during the 1929 crisis, and arriving to quintuple the yearly export in 1938 with 876 planes shipped abroad (25% of the total US production of the year).
In addition to those numbers it is essential to consider the economic value of the export.

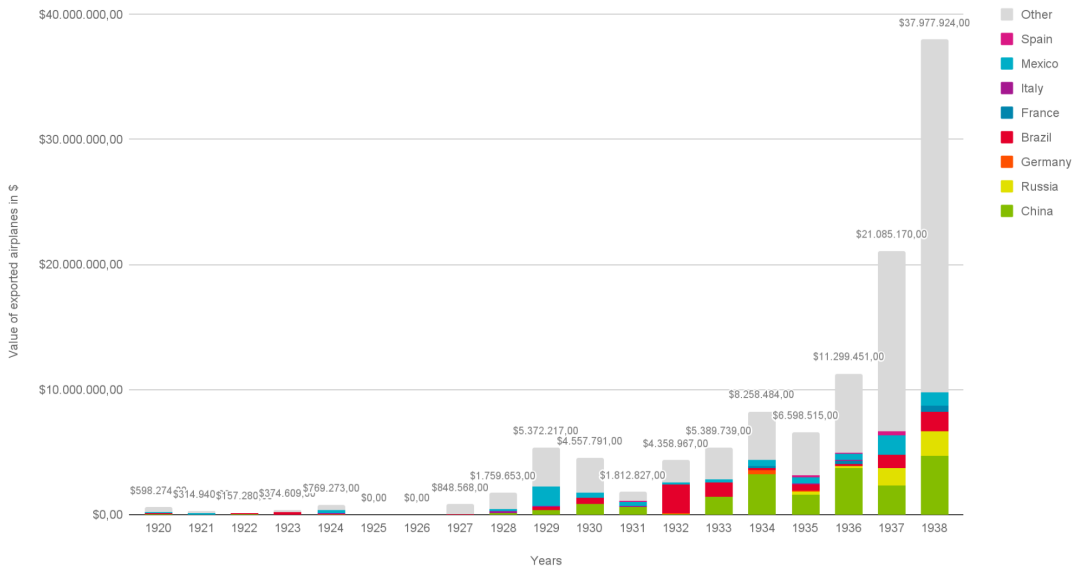
Graph 3: US airplane export in nominal value

Elaboration on Manifacturers Aircrafts Association Inc. data



Graph 4: US airplane export in dollars

Elaboration on Manifacturers Aircrafts Association Inc. data



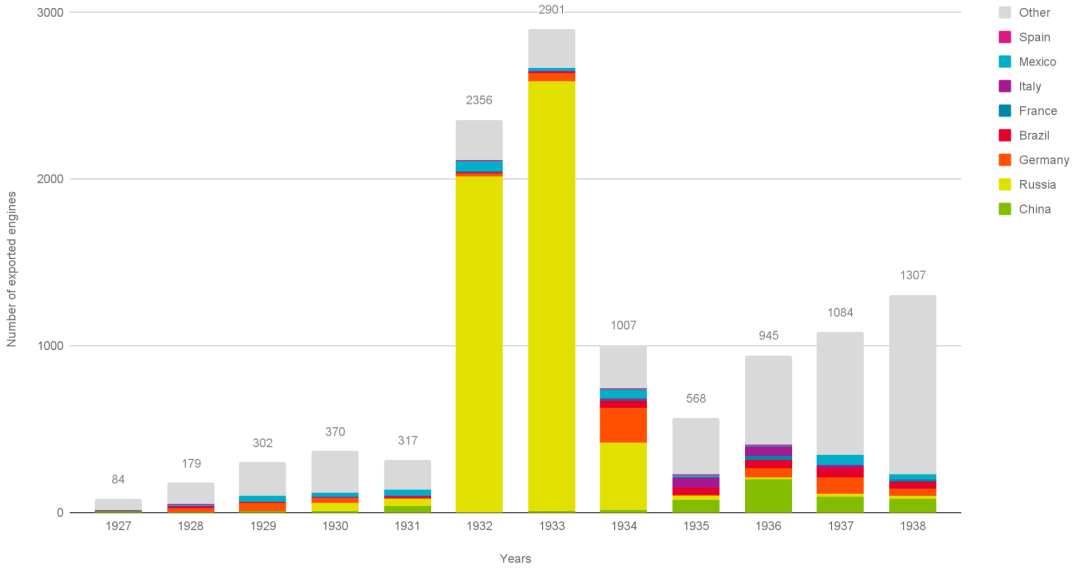

In 1920 the average value for a single exported unit, taking into account also the values of the engine that were counted together with the full planes, was $ 2.274, in 1928 reached the lowest value of $ 420 per unit, and from there, it kept increasing reaching $ 13.825 per unit in 1938. This value can be seen as the representation of a sector not only capable of producing and exporting more but also of producing more complex and sophisticated aircraft. While in 1920, the exported planes were mainly single-seated seaplanes, in 1938, they could easily be Boeing's B-17 16-ton bombers and B-314 super luxurious seaplanes, or Douglas's first prototypes of commercial airlines, the DC-1 and DC-2.

A similar path can be seen for the engines. The growth of complexity and dimension of planes generate the need to separate the producers of aeroplanes and the producers of engines in separated firms, although often in the same group, determining the birth of a brand new sector concentrated on the production, repair and shipment of engines.

As for the aeroplanes, the number and the value of the exported engines grew between 1927 and 1938, going from 84 per year to 1307 and from a complex value of $ 484.875 to a value of $ 7.899.844.

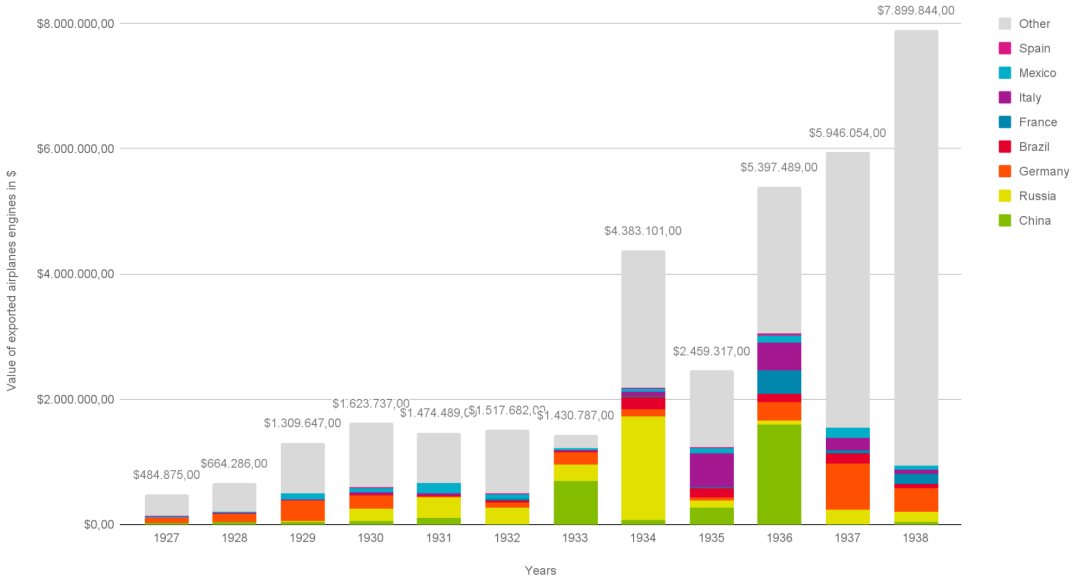
Graph 5: US airplane engine export in nominal value

Elaboration on Aircraft Industries Association of America Inc. data




Graph 6: US airplane engine export in dollars

Elaboration on Aircraft Industries Association of America Inc. data



## 1.3 Boeing

One of the actors of the 1920 - 1945 growth was a company destined to conquer an ever more central role in the US and World aeroplane manufacturer market, but that at the time was a relatively small company, dependent on military contracts and with little ability to enter into the fighter sector that was making the fortune of other producers, the Boeing Airplane Company.

Boeing Airplane Co. was founded, initially with the name of "Pacific Aero Products Co." on 15 July 1916 by William Boeing, a timber merchant, and George Conrad Westervelt, a US Navy lieutenant, two enthusiasts and aircraft designers, in William's timber hangar in Lake Union, Seattle.[17] The company employed Herb Munter as the company's training pilot, James Foley as a mechanical engineer along with Wong Tsoo, Boeing's first aeronautical engineer, and the timber workers of William Boeing's company.[18]

The creation of the company took place just one month after the first flight of the B&W Seaplane, or Boeing Model 1, a seaplane built by Boeing and Westervelt, inspired by the Martin TA trainer.[19] The plane was intended to be a training model for the US Navy, which refused to buy it, and so was sold to the New Zealand Flying School in 1917, becoming both the first sale and the first international sale of the company.[20]

The historical moment favoured Boeing. After one year and two days of operativity, on the 17 of July 1917, two planes of his second model, the Model C, were selected as

[17] BOEING.COM, *Boeing History Chronology,* *https://www.boeing.com/resources/boeingdotcom/history/pdf/Boeing-Chronology.pdf*, accessed 28/04/2023.
[18] BOEING.COM, *Boeing History Chronology.*
[19] BOEING.COM, *B&W Seaplane,* https://www.boeing.com/history/products/b-and-w-seaplane.page, accessed 28/04/2023.
[20] BOEING.COM, *B&W Seaplane.*

training models by the US Navy.[21] The Navy's 50-plane order represents the first military contract for Boeing. In just over a year the two pillars of Boeing's history, international sales and military contracts were already established, albeit in an extremely embryonic form.

1917 and 1918 saw the company engaged in the Model C building, along with the HS-2L, a Curtiss-designed patrol flying boat. On November 11, as the German and allied militaries signed the armistice of Compiègne, Boeing had already delivered 81 aircraft, 56 Model C and 25 Hs-2L, half of the Navy's order.

With the end of the First World War, Boeing experienced the first order cut, suddenly stopping the production of aeroplanes and reconverting to the building of furniture and flat-bottomed boats. The Company's history could have been concluded after just two years, if it had not been for William Boeing's ability to understand the importance that aircraft were acquiring in mail delivery and, of course, for the new military contracts for the modernisation of 50 de Havilland DH-4 fighters.[22]

Between 1919 and 1928, the company focused mainly on those two types of contracts. As we can see in Table 1, Boeing developed seventeen models and worked on assembling or modernising three models from other manufacturers, handling a total of 910 aeroplanes.

[21] BOEING.COM, *Boeing History Chronology.*
[22] BOEING.COM, *Boeing History Chronology.*

Table 1: Boeing production between 1916 and 1928. Elaboration on Boeing and RZjets data

| **Model name** | **Purpose** | **First flight year** | **Quantity produced** |
|---|---|---|---|
| Boeing Model 1 seaplane (B&W) | Prototype | 1916 | 1 |
| Boeing model C (2, 3, 5, 700). | Prototype | 1916 | 2 |
| Boeing model Cs | Military | 1917 | 56 |
| HS - 2Ls (Curtiss designed plane) | Military | 1918 | 25 |
| DH-4 de Havilland (modernised) | Military | 1919 | 298 |
| Boeing Model 6 B-1 seaplane | Private | 1919 | 1 |
| Boeing Model BB-1 seaplane | Private | 1920 | 1 |
| Boeing Model BB-L6 seaplane | Private | 1920 | 1 |
| Model 10 GA-X/GA-1 | Military | 1920 | 10 |
| Thomas Morse MB-3A | Military | 1921 | 200 |
| Model GA-2 | Military | 1921 | 2 |
| Model 15 (PW 9) | Military | 1923 | 157 |
| Model 21 NB | Military | 1923 | 41 |
| Model 40 | Mail/passengers | 1925 | 77 |

| | | | |
|---|---|---|---|
| Model 50 PB-1 patrol flying boat | Military | 1925 | 1 |
| Model 69 F2B | Military | 1926 | 1 |
| B-1 torpedo bomber | Military | 1927 | 1 |
| Model 40As | Mail/passengers | 1927 | 24 |
| Model 77 F3B | Military | 1928 | 1 |
| Boeing Model 204 | Mail/passengers | 1928 | 10 |

In 1927, Boeing started adding a new element to the company by signing a contract with the U.S. Postal Department for the management of the Chicago - San Francisco airmail connection that the US Congress just privatised.[23] The service will be performed by the newly created Boeing Air Transport, Boeing's own airline, with Boeing-built Model 40 planes.[24] The plane also allowed the transportation of 2 passengers in its A version or $ passengers in its C version. On July 1st 1927, Boeing Air Transport made the first airmail connection between Chicago and San Francisco, also carrying the first Boeing passenger, Chicago reporter Jane Eads, marking the company's entry into a new sector, the commercial aeroplane production.[25]

After less than one year, the Boeing Model 80, a commercial plane specifically designed for the Chicago - San Francisco route, made its first flight.[26] From this moment, Boeing stopped the development of mail planes and started replacing them with commercial ones, shifting to a military-commercial binomial, as many other manufacturing companies were doing.

[23] SIMPLEFLYING.COM, *The Boeing Model 40: A Pioneering Interwar Mail Plane,* *https://simpleflying.com/boeing-model-40-mail-plane-story/*, accessed 28/04/2023.
[24] BOEING.COM, *Boeing History Chronology.*
[25] BOEING.COM, *Boeing History Chronology.*
[26] BOEING.COM, Model 80 commercial transport, https://www.boeing.com/history/products/model-80.page, accessed 28/04/2023.

As we said before, in those years, the hours flown and the passengers transported were increasing rapidly, and with them, the organisation of the airliners operating those routes. In 1927 Pan Am started mail and passenger service between Miami and Havana,[27] 1929 TWA was created by the merging of Transcontinental Air Transport, Maddux Airlines and Western Air Express,[28] in 1934 the first were already operating a wide range of intercontinental routes connecting the US with all south America and China,[29] and the latter was doing the same for the US internal connection, grating a coast to coast service in 36 hours[30] (the train connection took more than 3 days).[31]

Along with their growth, those airliners started to ask for planes capable of moving more people with a comfort range going from basic to extremely luxurious and better security standards. This request ignited a reduced version of the post-WWII competition, especially between Douglas and Boeing. While Boeing was able to secure a contract with Pan Am for 12 Clippers (a long-range flying boat for international routes) and to develop a new commercial aircraft (Model 247) selling it to Boeing Air Transport, Douglas was able to secure a much better contract, starting the building of 156 DC-2 for TWA.[32]

TWA had initially signed a contract with Boeing for the 247 but eventually terminated it in 1933 and chose Duglas model.

While having some differences, one for all the passengers carried, 10 for the Boeing model and 14 for the DC-2, both planes presented a lot of technological advances. They were both monoplanes, built all-metal, with retractable landing gear and pilot support equipment.

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[27] PANAM, *A Brief History of Pan Am by Gene Banning* https://www.panam.org/about-pahf/paa-a-brief-history, accessed 29/04/2023

[28] TWA MUSEUM, *TWA history,* https://twamuseum.org/history, accessed 29/04/2023

[29] PANAM, *A Brief History of Pan Am by Gene Banning.*

[30] BRITANNICA, Trans World Airlines Inc., https://www.britannica.com/topic/Trans-World-Airlines-Inc, accessed 29/04/2023.

[31] TRANSPORTATION HISTORY, 1934: The Start of a Record-Breaking Train Journey Between Los Angeles and New York City, https://transportationhistory.org/2021/10/22/1934-the-start-of-a-record-breaking-train-journey-between-los-angeles-and-new-york-city/, accessed 29/04/2023

[32] RZJETS.NET, *Douglas DC-2 production list*, https://rzjets.net/aircraft/?page=4&typeid=334, accessed 30/04/2023

The loss of the TWA contract on the one hand and the dimension of the military contracts on the other forced Boeing to focus intensely again on the military part. Between 1933 and 1935, Boeing was able to develop a brand new heavy bomber, the B-17, with which tried to win a military contract, confronting and losing again against Douglas' B-18 BOLO, a slower but cheaper aeroplane (the selling price for the Boeing model was $99,620 per aircraft, while the price for the Douglas one was $58,500).[33]

Eventually, the navy ordered thirteen B-17s against the 133 Douglas B-18. The order was considered enough for Boeing to start the construction of another plant near the first one in Seattle.[34] This initial order was renowned in 1937 and again in 1938 and 1939 due to the approaching of WWII.
Starting from 1939, the production of the plane, now recognised as clearly superior to the Douglas B-18, which had meanwhile become obsolete thanks to continuous improvement work done by Boeing, was entrusted to all the manufacturers.

The military request had, for obvious reasons, increased dramatically. Between 1939 and 1941 Boeing, along with Douglas and Vega (later Lockheed), produced more than 12.726 B-17s giving a solid boost to Boeing's dimension, reputation and cash flow.[35]

By the end of the war, Boeing produced directly or with permission through other manufacturers 17.080 planes, reaching a total amount of 27.432.
With these numbers behind, in 1945 Boeing started getting ready for the meltdown of the military contracts and the return of the competition with the other manufacturers in the strongly transformed post-WWII commercial sector.

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[33] R.G. FRANCILLON (1988), *McDonnell Douglas Aircrafts*, Putnam Aeronautical Books, United Kingdom, p.186.
[34] AERO VINTAGE BOOK.COM, *B-17 production list*, https://www.aerovintage.com/b-17-production-list/, accessed 03/05/2023.
[35] AERO VINTAGE BOOK.COM, *B-17 production list.*

# 2. From 1945 to 1970 - The conquest of the US

## 2.1 1945 - 1952 Douglas short reign

*"Because the United States has realized and exploited these characteristics, she is the leading power in the air. [...]Her aircraft industry is the world's largest. In comparison with any other history of military or industrial growth, the United States has achieved this preeminent position in an amazingly short time. [...]. Only 143 military aircraft were produced in the entire month of January, 1939. Five years later, in January, 1944, twice that many planes were being produced every day!"*[36]

As for many other industries, the war represented for aircraft manufacturers a great opportunity to develop and improve their capabilities, dividing and making more efficient the production process, and boosting the R&D in a race to make aircraft less vulnerable and better than German and Japanese models.

Along with it, the entire industry also took advantage of the substantial flow of resources and cash from the government. Making an example staying on Boeing, the

[36] C. H. JONES, G. J. MCALLISTER, T. SMITH, R. MODLEY, J. J. FISHER (1970), *Aerospace facts and figures 1970*, McGraw Hill, New York, p. V, https://www.aia-aerospace.org/wp-content/uploads/aviation-facts-and-figures-1945.pdf, accessed 06/05/2023.

unitary cost of any of the B-17 produced was around 393.000 1945 US dollars,[37] equivalent to 6.590.000 US dollars today.[38]

The end of the war, however, represented a difficult moment for the industry. As seen in the previous chapter in less than two years more than 200.000 employees were fired, only from the top three manufacturers, and their contracts were terminated. All manufacturers have to decide, in a very short period of time, whether to close or stay in activity and in which of the two main sectors to invest, the military or the commercial one.

This last sector surely represented a remarkable opportunity. The amazing growth of the 1920-1945 period seemed extremely constrained even if compared to 1945 - 1946 alone. While in twenty years, the number of domestic passengers carried per year went from 5.782 to 1.343.127,[39] with a 232 times increase, between 1945 and 1946, they went from 6.576252 (1137 times increase compared to 1920) to 12.213.445 (2112 times increase).[40] In a similar way, the international passengers carried reached 1.350.410 in 1947.[41]

For all those firms attracted to these numbers that decided to leave totally or partially the military sector after 1945, the strategic goal became developing a fast, comfortable and mass-producible aeroplane, fulfilling the requests of the airliners, whether it was to convert their military models as for Boeing, to develop projects stopped by the war as for Lockheed or to start a brand new project as for Convair.
Only one company did not have the urgency to win this tender, and indeed would have preferred it not to take place, being the manufacturer of 93.45% of the commercial aircraft flying in the USA in those years, the Douglas Aircraft Company.

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[37] AEROCORNER.COM, *Boeing B-17 Flying Fortress*, https://aerocorner.com/aircraft/boeing-b-17-flying-fortress/, accessed 06/05/2023.
[38] INFLATION CALCULATOR, https://www.usinflationcalculator.com/, accessed 06/05/2023.
[39] MANUFACTURERS AIRCRAFT ASSOCIATION (1939), *Aircraft Year Book 1939,* Manufacturers aircraft association, New York, p.39.
[40] AIRCRAFT INDUSTRY ASSOCIATION OF AMERICA INC., *The aircraft year book for 1948*, 1948, Aircraft Industry Association of America inc, Washington, p.xxiii.
[41] AIRCRAFT INDUSTRY ASSOCIATION OF AMERICA INC., *The aircraft year book for 1948*, p. xxiv.

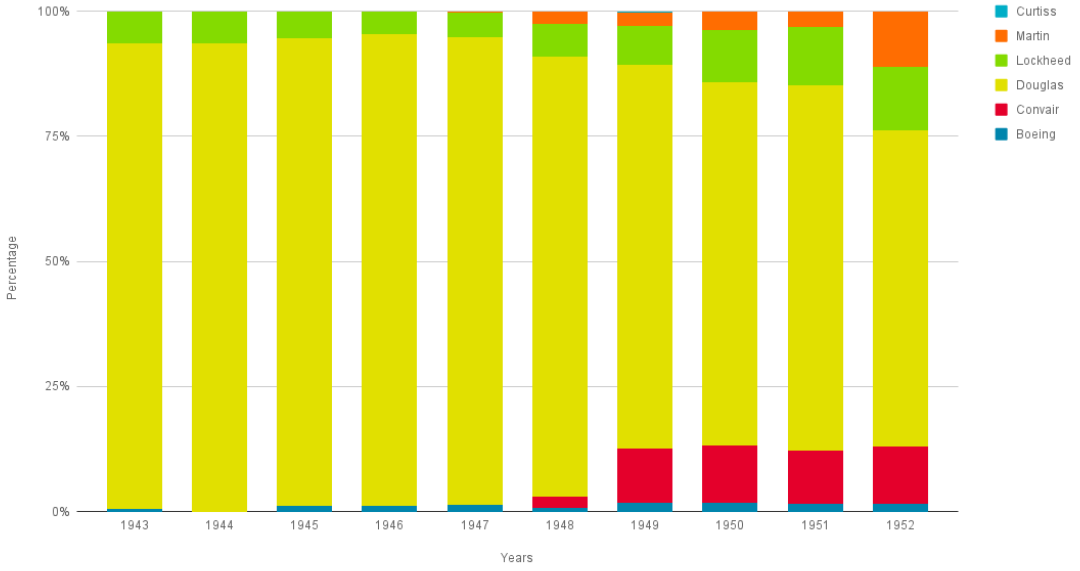
This company had, in fact, saturated the market with its models already before the war and kept on building commercial aeroplanes along with the military ones becoming «the largest aircraft manufacturer in the United States.»[42]

As we can see in Graph 7, more of the 90% of the flying commercial aircraft during the war were Douglas models, mainly DC-2, DC-3 and the recently produced DC-4.

This percentage remained stable for the whole war period and the following two years, even eroding the 6,4% niche of the main competitor Lockheed, until it had to contrast with the factor that most of all determines the success or the failure in this sector, the lack of innovation.

Graph 7: Percentage of aeroplanes flying in the US by manufacturer

Elaboration on Aircraft Industries Association of America Inc. data




Since 1946, in fact, the latest Douglas model, the DC-4, had to start competing with other companies' versions of what he himself should have been, a pressurized plane capable of flying at higher altitudes with a greater level of comfort and lower consumption of fuel.

The pressurisation system development started in the mid-1930s and was carried forward initially by the US Army and then, for the commercial part, by Boeing and

[42] US CENTENNIAL OF FLIGHT COMMISSION.NET, *Douglas Aircraft From the Late 1930s*, https://www.centennialofflight.net/essay/Aerospace/Douglas_later/Aero30.htm, accessed 07/05/2023.

Douglas. Both companies created a pressurisation system, but the Boeing one, created thanks to AiResearch of John Clifford Garrett, was the easier to use and the only one actually applied to a plane, the Boeing 307 Stratoliner, in 1938.[43] On such an occasion, Douglas decided to put aside the project of the pressurised DC-4E and take advantage of the war-connected economic constraints to create the lighter version that ensured the already-seen market control.

Despite this, Boeing also soon shelved the civil use of the system, leaving Lockheed the opportunity to take advantage of it and show up at the end of the war with the L-049 Constellation, a pressurised model with superior characteristics as a top speed of 305 mph against the 207 of the Douglas model[44], hydraulic controls, a basic version of a security and alarm system and the possibility to flight above 10.000 feet stepping over clouds, rain and all those weather conditions which, when they were not dangerous, caused a waste of fuel.[45]

In less than two years, between 1948 and 1949 the Douglas models were being replaced by the Constellation in its stretched or shorter versions or by the Convair 240,[46] which granted the producer a 10% on the US flying aeroplanes in just one year, while the requests for larger aircraft were left to Boeing's 377 Stratocruisers, a 100 passengers plane with a 1.2 million unitary price.[47]

At the end of 1952 30% of the Douglas market was eroded, even though the nominal value of aircraft produced and used had increased greatly, mainly thanks to the DC-6. The Douglas reign lasted less than ten years and left the place to a strong competition based, once again, on innovation.

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[43] CHAPIN S. L. (1966), *Garrett and Pressurized Flight: A Business Built on Thin Air,* in «Pacific Historical Review», Vol. 35, No. 3, pp. 329 - 333.

[44] BOEING.COM, DC-4/C-54 Skymaster transport, https://www.boeing.com/history/products/dc-4.page, accessed 07/05/2023.

[45] SIMPLEFLYING.COM, *79 Years Ago The Lockheed L-049 Constellation Flew For The First Time*, https://simpleflying.com/lockheed-constellation-first-flight-79-years/, accessed 07/05/2023.

[46] SIMPLEFLYING.COM,*Why Did Convair Build The CV-240 Airliner?*, https://simpleflying.com/convair-cv-240-development-history/, accessed 07/05/2023.

[47] BOEING.COM, Model 377 Stratocruiser commercial transport, https://www.boeing.com/history/products/model-377-stratocruiser.page, accessed 07/05/2023.

## 2.2 1952 - 1955 Going Faster, the introduction of jet engines

To contrast the market share reduction registered between 1949 and 1952, and thanks to an almost direct investment of 40 million dollars from American Airlines' president C. R. Smith,[48] Douglas started moving resources and workforce to the development of a new piston engine plane capable of flying non-stop between the east and west coast.

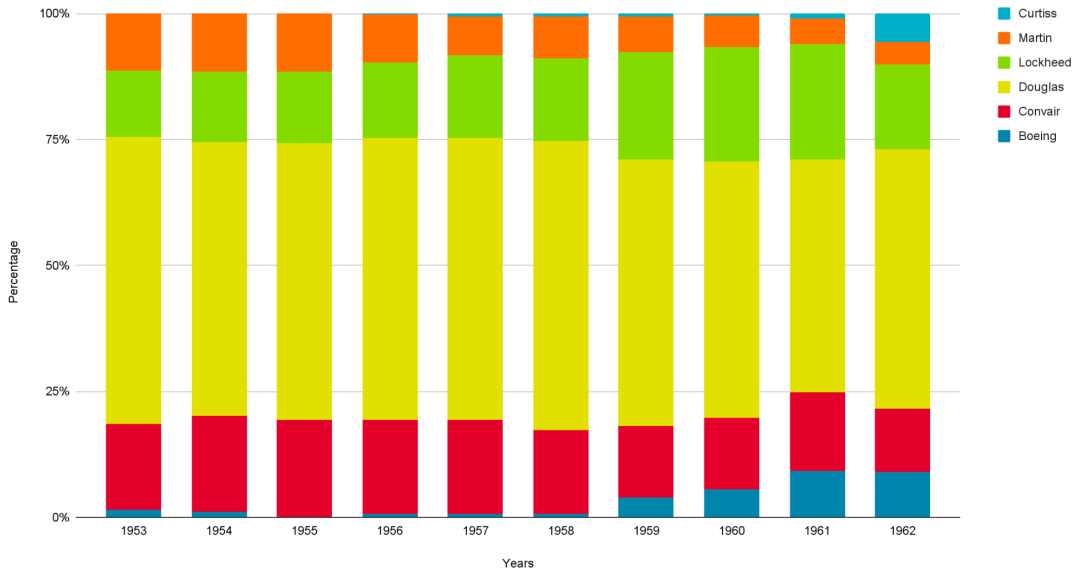
Pan Am immediately considered the capability of transcontinental flights a game-changing aspect, and this forced other manufacturers and airliners, first among all L-1049 Super Constellation and its primary user TWA, to push to the limit the capability of their aircraft to offer the same service and rush to develop a new model.

The DC 7 rapidly became a best-seller aircraft, capable of beating the model of all other producers, connecting far capitals a lot faster than other models (for example the New York - London connection done with a DC 7 lasted almost 2 hours less than doing it with a Boeing 377).[49] Between 1953 and 1958, production continued increasing, and 214 new Douglas aircraft entered service with all American Airliners. The shrink of the previous years was stopped and even reversed in percentage and nominal values.

[48] SIMPLEFLYING.COM,*No Longer In Service: The Story Of The Douglas DC-7*, https://simpleflying.com/douglas-dc-7-history/, accessed 03/06/2023.
[49] SIMPLEFLYING.COM, *No Longer In Service: The Story Of The Douglas DC-7*.

Graph 8: Percentage of aeroplanes flying in the US by manufacturer

Elaboration on Aircraft Industries Association of America Inc. data




With this strength, the Douglas family, who owned and ran the company, could focus the attention on the military contracts, which represented 2,123 million dollars in income for Douglas in 1952, and 13,559 million dollars for the whole manufacturing sector.[50]

The possibility to steal a part of those contracts, starting from the new air tanker for strategic bombers whose contract was on renovation in 1954, has concentrated all the forces not used in the DC-7. By the end of 1954 Douglas had modified a DC-6 and created the DC-188, which would become the news tanker, except that the contract was entirely won, with great surprises for all the participants, by Boeing for a major reason.

[50] MODLEY R., CAWLEY L. T. (1953), *Aviation Facts and Figures 1953*, Lincoln Press Inc., Washington,
p.19.

While all other aircraft proposed had piston engines (that allowed a max speed that was half of the speed of the bombers they had to refuel), the Boeing model used a jet engine and a jet engine suitable for commercial airline transport. All of Douglas's advantages disappeared immediately. Boeing was capable of identifying, securing and developing the new disruptive technology of the aeroplane sector.

The usage of jet engines on commercial planes was already tempted by De Havilland in 1949 with the Comet model. It was a great success, containing all the aspects of modern aircraft: jet engines, capable of reaching a speed of 800 km/h, 200 more than the last piston-engined plane, pressurisation and a high level of comfort for the passengers. It also had at least two deadly design issues. Between 1952 and 1954 five accidents, 4 of which were fatal, happened and all the Comets were landed.[51]

This could explain why Douglas was so confident that a jet plane «would not have been a very good aircraft»[52], and that Douglas' superiority would not be contested. By the end of 1955 this belief had been largely superseded by reality, and Douglas was cashing Boeing in what would be the company's last ride.

The Boeing development of a jet engine suitable for commercial use and a plane to use it was decided in 1950, on the wave of the presentation of the De Havilland Comet and started in 1952.[53]

Boeing already had experience with jet engines for military use. Between 1943 and 1949 Boeing engineers studied this type of propulsion, trying to apply it to existing models and discovering the right shapes and arrangements in an endless number of wind tunnel tests. In 1947 they created the B-47 Statojet, a medium bomber with an early version of jet propulsion that didn't guarantee enough thrust for take-off but allowed the

[51] BBC.COM, *The British airliner that changed the world*, https://www.bbc.com/future/article/20170404-the-british-airliner-that-changed-the-world, accessed 04/06/2023.
[52] AIRLINERATING.COM, *History of the magnificent DC-8,* https://www.airlineratings.com/news/history-of-the-magnificent-dc-8/, accessed 04/06/2023.
[53] AIRLINERATING.COM, *History of the magnificent DC-8.*

plane to reach the incredible speed of 978 km/h.[54] In 1948 they applied an improved version of this technology to the already "piston-designed" B-52 Stratofortress bomber, demonstrating not only that jet engines could be quite easily applied to planes but that Boeing was able to adapt better and follow the requests of the market and contractors.[55]

Thanks to those experiences Boeing acquired enough know-how to start contaminating the commercial market. The project's development began in 1952 with a 16 million dollar budget, almost all the company profits since the end of WWII. All parts of the Company well understood the importance of the effort. While technicians and engineers were developing the 367-80 prototype, communication officers were already planning a great campaign to persuade the public that the plane would not randomly explode like the Comet, but that was safer than all other alternatives.

*«The campaign also included a film shown to airline customers titled "Operation Guillotine." The film of a Boeing test showed a conventional, fully pressurized airplane fuselage being pierced by two metal blades, resulting in a catastrophic failure and disintegration of the structure. Next, the 707 fuselage was put to the same test; this time, five blades pierced the pressurized fuselage, resulting in wisps of air escaping from the punctures — but no cracks and no structural failure.»*[56]

In five years all the objects were reached: the plane was working, secure and approved by airliners and customers, and to top it all off Douglas's alternative, the DC-8, was not up to par with the 707.

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[54] BOEING.COM, 737 commercial transport, https://www.boeing.com/history/products/737-classic.page, accessed 01/07/2023.

[55] BOEING.COM, *B-52 Stratofortress*, https://www.boeing.com/history/products/b-52-stratofortress.page, accessed 04/06/2023.

[56] BOEING.COM, *707/720 commercial transport, https://www.boeing.com/history/products/707.page*, accessed 04/06/2023.

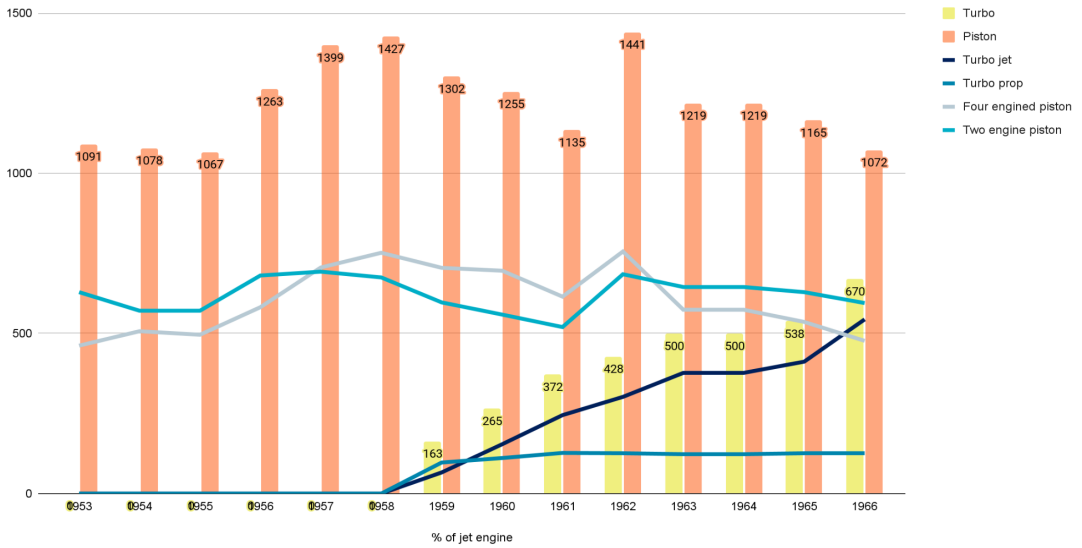
## 2.3 1955 - 1970 The winner takes it all

*«Boeing Company President William Allen and his management are said to have "bet the company" on a vision that the future of commercial aviation was jets [...] In just two years, the 707 would help change the way the world traveled.»*[57]

The introduction of jet engines represented a very significant leap forward for the whole commercial sector. In 1962, one-third of the 1611 planes operated by American airliners were jet-engined, and those planes transported more than 50% of the passengers, thanks to the great increase in speed and security,[58] in 1966, considering also the Turbo-prop planes, that combined piston and jet engines, those new planes represented the 47% of US airliners fleets as represented in graph 9.

Graph 9: US arliners fleets by aircraft propulsion

Elaboration on Aircraft Industries Association of America Inc. data




[57] BOEING.COM, *707/720 commercial transport.*

[58] MODLEY R., HINCKS B. E., SMITH T., FISHER J. J., FRAZIER R., LEE S. B. (1962), *Aviation Facts and Figures 1962*, American Aviation Publications Inc., Washington, p. 106.

The speed aspect is the key element that can explain why those new planes, which consumed a much larger amount of fuel, surpassed the previous models. While a DC-7 takes more or less eight hours for a coast-to-coast flight (which means a whole day), the 707 takes less than five hours, potentially half of the time. For a hypothetical businessman, for whom time is money, the advantage was unsurpassed for both goods and people

This leap was dominated by Boeing already in the planning stages. As we have seen before, the development of the 707 started in 1949, incorporated the jet engines in 1952 after the Comet's first flight and started the testing flights in 1955.[59] Meanwhile, Douglas' top managers were discussing the "impossibility of substituting piston-engined planes for the airliners" due to the significant investments they made to create their fleets, and only a little thinking was done for developing a jet-engined plane.

When the Boeing Dash 80 test plane took off in 1954, and a few months later Boeing won the military contract, the shock at Douglas was remarkable.
All resources were collected and pushed to the DC-8 project, which passed from a 3 million budget at the beginning of 1954 to 450 million in 1955. Along with this money push also the relations with airliners were put into play. To beat Boeing's order Don Douglas invited executives from 20 world airlines to Santa Monica to convince them at all costs. This action secured the orders from United Airlines, National Airlines, Delta and seventeen other US and non-US airliners, among which Alitalia, but was not enough to keep all the supporters in the line, with Pan Am and American Airlines ordering the 707, because it already physically existed and was flying.[60]

For the first time in Douglas's history, the magnitude of the resources was not able to compete with the technological advantage and the capability of reading and anticipating

[59] BBC.COM, *Boeign 707: The aircraft that changed the way we fly*, https://www.bbc.com/culture/article/20141020-the-plane-that-changed-air-travel, accessed 10/06/2023.
[60] AIRLINERATING.COM, *History of the magnificent DC-8.*

the market of Boeing. Not only that, resources pushed engineers to dive into elaborate solutions to simple problems, slowing down production and spending much more: 10 million dollars were spent for the design of the plane seat, which in the end, was equal to the already existing ones, another unidentified amount of money, and trust, was invested in a revolutionary airfoil that could guarantee a, not reached, Mach 84 speed, which was promised and never delivered to the airliners.[61] The result was a beefed-up and botched version of the DC-7.

In addition to all those "features", the 707 presented many advantages besides the "already existing" one.

First of all, it was produced by a company with specific competencies in the jet sector and with two models already built and positively evaluated by the US Army, in the second place the price of the plane was slightly lower than the price of the DC-8 (500.00 dollars against 550.000), while the top speed was 20 miles per hour higher than the DC-8 thanks to a micro variation of the sweepback of the wings, obtained without any magical airfoil.[62]

For those companies for which these characteristics were not enough, Boeing introduced the embryo of what will become a key element for all manufacturers: customisation.[63]

In addition to the basic model, in fact, Boeing created a special long-range one, built for the necessities of Qantas Airways, and another one capable of reaching higher altitudes for Braniff's South American route, taking high risks but ensuring the loyalty of many airliners. Between 1958 (Boeing 707) and 1959 (Douglas DC-8), both planes entered service with the US and European airliners, and both production numbers ramped up, as shown in Table 2.

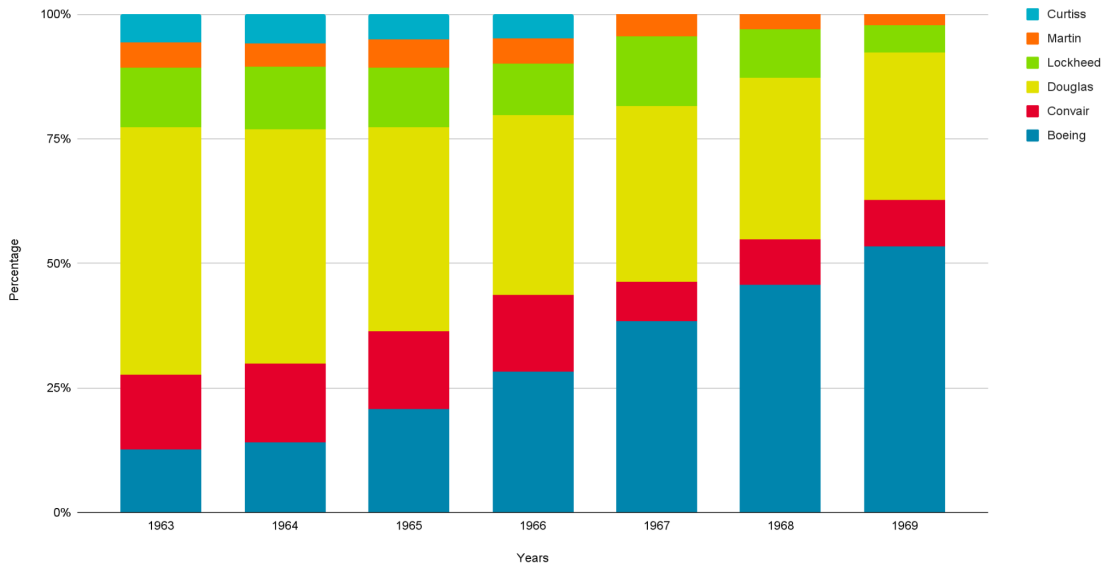
[61] AIRLINERATING.COM, *History of the magnificent DC-8.*
[62] AIRLINERATING.COM, *History of the magnificent DC-8.*
[63] BOEING.COM, *707/720 commercial transport.*

| Table 2: 707 and DC - 8 production list 1958 - 1968: Aircraft Industries Association of America Inc. data. | | | |
|---|---|---|---|
| Year | Boeing 707 | Douglas DC8 | Total |
| 1958 | 7 | 0 | 7 |
| 1959 | 73 | 21 | 94 |
| 1960 | 68 | 91 | 159 |
| 1961 | 11 | 42 | 53 |
| 1962 | 38 | 22 | 60 |
| 1963 | 28 | 19 | 47 |
| 1964 | 32 | 20 | 52 |
| 1965 | 54 | 31 | 85 |
| 1966 | 77 | 16 | 93 |
| 1967 | 113 | 41 | 154 |
| 1968 | 111 | 102 | 213 |
| Total | 612 | 405 | |

Unfortunately for Douglas, Boeing's production went better in almost all years, eroding any form of advantage in term of position or economical resources. By the end of 1967, Douglas was bankrupt, and Boeing took almost completely the US market and started looking around for another place to flood with 707, 727 and 737.

Graph 10: Percentage of aeroplanes flying in the US by manufacturer

Elaboration on Aircraft Industries Association of America Inc. data



# 3. From 1970 to 1999. A new actor emerges

## 3.1 Is anyone out there?

Until now, we have concentrated our analysis on the US market, representing at the time the actual engine of the aircraft sector in terms of production, innovation and aircraft usage (the US alone were responsible for almost half of the miles flown yearly).[64]

We have seen how much the exported value of aircraft, engines and parts grew at the beginning of the century, reaching 68 million dollars at the brink of WWII in 1938. This level was immediately and extensively surpassed during the War since the US was the leading supplier to all the Allied powers, reaching the top value of 2.8 billion in 1944.[65] Neither the post-war shrink of production stopped the growth: in 1946 the value was 115 million dollars, in 1950 242 million dollars, in 1955 728 million dollars and in 1956 it overcame the billion dollars.[66]

It is now necessary to introduce the other countries touched by this competition.

The productive capability of the US was giving a great push to its economy (aeroplane export was stable at around 6% of the total US export in the ‘60) while cutting all space for the manufacturers of other western countries, except for the UK, that was able to

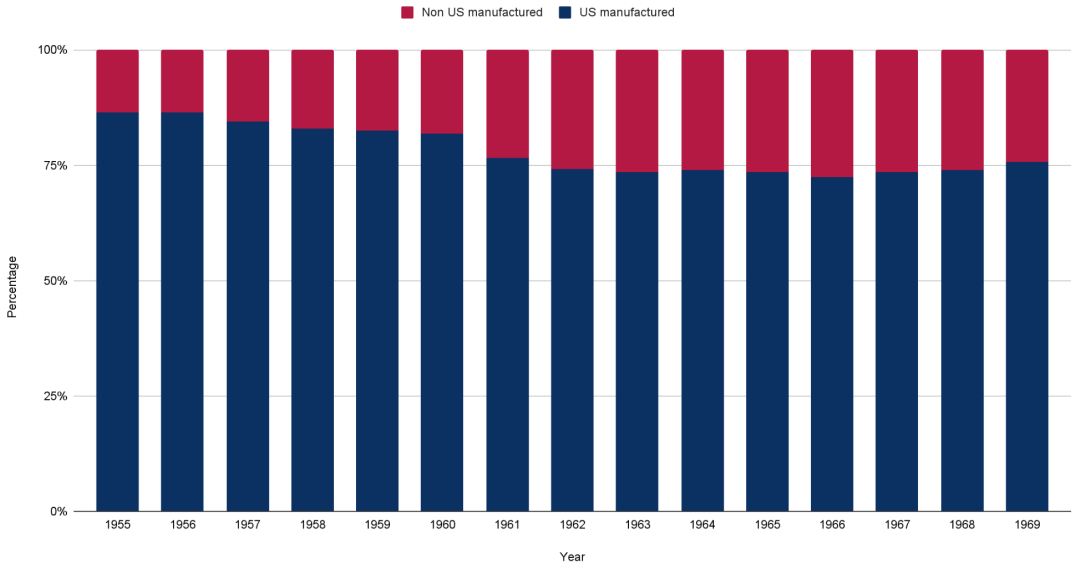
[64] MODLEY R., CAWLEY L. T. (1953), *cit,* pp. 169 - 172.
[65] MODLEY R., CAWLEY L. T. (1953), *cit,* pp. 161.
[66] BAYLESS G., MCALLISTER J. G., CHANOWITZ G., SMITH T., LEE J. J., BALENTINE R., SHURNEY C., MODLEY R., FISHER J. J. (1967), *Aviation Facts and Figures 1967*, Aerospace Industries Association Inc., Washington, p. 18.

maintain a good production and export level (95 million export in 1950,[67] 181 million in 1955[68] and 397 in 1960[69]).

This substantial supremacy of the US manufacturer can be understood by analysing the composition of the airliner fleet. After starting the jet age with the Comet, European manufacturers could not keep up. DeHavilland (a UK-based manufacturer) was not able to recover from the Comet failure and was acquired in 1960, Sud Aviation (a France-based manufacturer) produced the Caravelle, which sold a total of 282 planes between 1960 and 1973, a very small number if confronted with Boeing.[70] This inability to compete gave the US manufacturer a great advantage, as shown in Graph 11.

Graph 11: Aircraft operating on world civil airliners by manufacturer country

Elaboration on Aircraft Industries Association of America Inc. data




Except for a little push between 1961 and 1966, which can be reconducted to the Caravelle model, the US manufacturer produced almost two-thirds of the flying planes.

[67] MODLEY R., CAWLEY L. T. (1953), *cit,* pp. 174.
[68] MOODLEY R., HINCKS B. E., LEE S. B. (1956), *Aviation Facts and Figures 1956*, Lincoln Press inc, Washington, p. 83.
[69] MODLEY R., HINCKS B. E., SMITH T., ARNOW K. P., FRAZIER R., LEE S. B. (1961), *Aviation Facts and Figures 1961*, American Aviation Publications Inc., Washington, p. 131.
[70] RZJETS.NET, *Sud SE-210 Caravelle production list*, https://rzjets.net/aircraft/?page=1&typeid=1, accessed 24/06/2023.

For the European producers, the perspective of being more or less rapidly thrown out of the market was very real, even because the manufacturers situation in the US, which was quite turbulent in the previous years, was stabilising around Boeing thanks to the progressive exit of the weaker companies (Glenn L. Martin Company, Convair, Lockheed ) and the merger of the exhausted Douglas with McDonnell.

Filled with the impression of having seized control of the world market and with the sense of power that filled above all the top management of Boeing, who was preparing to launch the largest passenger plane in the world, the American manufacturer failed to consider one last element that would have been necessary for them to "win in Europe", and that represented the element of survival and then of redemption of the European manufacturer: the European market and the US market were not equal at all.

The US airliner had, generally, three kinds of necessity: they needed to connect the two coasts of the country, covering the highly trafficked routes between New York, Washington or Miami to San Francisco and Los Angeles, more than 2,000 nautical miles every time. To do so, they needed planes with a high range (which means more fuel and fuel weight), powerful engines to reduce the time and manage the weight, and possibly capable of carrying many people. They need a DC-10, or a 747, with three or four engines and a transport capability of 400 and 660 passengers.

The same models were useful for the second need, international (almost always transoceanic) routes that presented even longer distances (3000 nautical miles between New York and London, 4483 between San Francisco and Tokyo).

The third necessity was radically opposite. How to connect all the US minor cities scattered throughout the whole country with each other and with the main cities? A 747 would not be the efficient choice to do so, but a 737, which was built specifically to «operate self-sufficiently at small airports and on remote, unimproved fields»,[71] carrying

[71] BOEING.COM, *737 commercial transport, https://www.boeing.com/history/products/737-classic.page*, accessed 01/07/2023.

only one hundred passengers and two pilots in the place of three and using only two 14,000-pound-thrust P&W engines against the three ones of the 727,[72] which guaranteed a higher speed, the advantage of which on short-haul flights did not exceed the higher cost of fuel.

In the American mentality and necessity, there was a gap between long and short, big heavy and expensive planes and light planes capable of hopping between minor cities and large country towns. In this space there were not only the needs of European companies, there was the conformation of Europe itself: a continent in which the major cities are not far enough to use a 747 efficiently, but with a traffic level that requested a more capable plane that the 737, whose routes was threatened by trains and cars, which were already valid alternatives for European distances. This gap, ultimately, contained another thing as well, the opportunity for the European manufacturer to resist, compete and possibly beat the supremacy of the US.

[72] BOEING.COM, *727 commercial transport,* https://www.boeing.com/history/products/727.page, accessed 01/07/2023.

## 3.2 The European organising

*«Only if Europe combined the considerable talents and expertise which existed in individual companies and nations and put them into one aircraft to compete directly against the Americans.»*[73]

As we have said previously, at the beginning of the ’60, there were three attempts from as many European manufacturers to develop a euro-fitted plane, one developed by the French company Sud Aviation, one by British Aircraft Corporation and the last one by Hawker Siddeley Aviation and Nord Aviation. Although suitable, an insurmountable problem weighed on these planes, the division between European countries. Would Lufthansa ever buy French planes? Moreover, sales to Air France would have been enough for Sud Aviation to break even?
Luckily for all those companies, their sales offices were not the only ones asking this question: also their government was concerned, along with engineers and european airliner directors, mainly due to the temporary lack of American medium-range aircraft (a request has been made to the new merged McDonnell - Douglas, but they still had not seemed interested being concentrated in losing the race of the three-engines planes with Boeing).

The necessity and the actual characteristics of a hypothetical european medium-range aircraft were discussed, by the airlines themselves, at the 1965 Paris Airshow. What emerged from the meeting was the necessity of a plane capable of transporting more than a hundred people, keeping the fuel and operative costs down on medium-haul routes.

[73]AIRBUS.COM, *Early days (1967) commercial aircraft history*, https://www.airbus.com/en/who-we-are/our-history/commercial-aircraft-history/early-days-1967, accessed 01/07/2023.

This concept of plane, which resembled a bus for the air, was then discussed again by the representatives of the British, French and German governments in 1967. During a first meeting in July, the three countries, of which two, France and Britain, were already cooperating on the Concorde project, decided to give the idea a try, and in September, they signed a Memorandum of Understanding.[74] The French engineer Roger Béteille was indicated as the project's technical director, Henri Ziegler, already president of Sud Aviation, as general manager, and Franz-Josef Strauss, a German politician, as chairman of the supervisory Board. The project was very imaginatively called "Airbus" and set itself the goal of designing and building a specific type of aircraft, referred to as the A300, according to the indications of the european airlines.[75]

The design of the plane itself was not the only important element that needed a clear definition in the memorandum: also, the productive organisation and the assignments distributions between the various countries were strategic for the success of the project. None of the partners would ever allow a too prominent role to the others. National interests were always lurking.

To avoid the failure of the project and the possible bankruptcy of all manufacturers, the Memorandum strictly divided the roles: the design and building of the engines were given through the English government to Hawker Siddeley Aviation (HSA), the airframe to the French Sud Aviation, while for the German government was created a domestic consortium between manufacturers which shared with France and Britan the estimated 190 million dollars development costs mainly to acquire the necessary technical knowledge (German aircraft production had been stopped after WWII).[76] The agreement also included the airliners of the three governments, Lufthansa, AT&T (British Airways) and Air France, thus paving the way for the A300 from production to sale.

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[74] HAYWARD K. (1987), *Airbus: Twenty Years of European Collaboration*, in *International Affairs,* in «Royal Institute of International Affairs», vol. 64, no. 1, p. 12.
[75] AIRBUS.COM, *Early days (1967) Commercial aircraft history.*
[76] HAYWARD K. (1987), Airbus: Twenty Years of European Collaboration, in International Affairs, in «Royal Institute of International Affairs», vol. 64, no. 1, p. 13.

The physical design of the plane started right after the signing of the memorandum. HSA and Rolls Royce pledged to deliver a better version of the RB211 engine that was being developed for the American market, capable of giving enough thrust to the plane without mounting a third engine under the vertical stabiliser. The engine development was the main expense of the project. Meanwhile, the French designers were trying to understand how to integrate the engine with the airframe and how big it would be. The original idea, plotted on traffic growth forecasts for the '70, had indicated in 300 the right number of passengers (form here the A-300 name), but those numbers appeared overrated. At the end of 1968, the project was reduced, reaching a maximum of 250 passengers and 1200 nautical miles of autonomy.[77]

The redesign of the nacelle was not the only or the main problem of the first stages of the project. In March 1969, the A300 faced the possibility of total failure when the British government, who kept losing interest since 1967, decided to withdraw from the Memorandum, also due to the bankruptcy of Rolls Royce, caused by the non-fulfilment of orders for Lockheed.[78] All of a sudden, the plane had no engine.

In front of the British withdrawal, the West German government decided to improve the engagement and become a partner at 50% of the consortium, also providing HSA, which remained as an independent manufacturer in the project, a 35 million £ loan for the development of the plane wings.[79]

After the initial panic, Rolls Royce's withdrawal revealed a great opportunity. As we have said before, engine development had to absorb much of the resources, however, without the developing firm, and with a reduced need for thrust tanks to the scale reduction of the plane, the necessity of a brand new engine disappeared, leaving Airbus the opportunity to simply pick one of the less-powerful but already existing engines

[77] AIRBUS.COM, *Trouble and strife (1968-1969),* https://www.airbus.com/en/who-we-are/our-history/commercial-aircraft-history/trouble-and-strife-1968-1969, accessed 02/07/2023.

[78] HAYWARD K. (1987), Airbus: Twenty Years of European Collaboration, in International Affairs, in «Royal Institute of International Affairs», vol. 64, no. 1, p. 13.

[79] AIRBUS.COM, *Trouble and strife (1968-1969).*

available. The choice fell on the General Electric CF6-50, which was made in the US but with the participation of the French firm Snecma.[80]

The development of the plane and the construction of the consortium advanced at the same pace until December 1970, when the consortium between Aerospatiale (a new French manufacturer born from the merger of Nord Aviation, Sud Aviation and SEREB) and Deutsche Airbus (born from the merge of Messerschmittwerke, Hamburger Flugzeugbau, VFW GmbH and Siebelwerke ATG), both with a 50% participation, was finally created as a *Groupement d'Intérêt Économique* (Economic Interest Group), named Airbus Industries. The headquarter, in charge of granting a «single interface for design, development, flight testing, sales, marketing and customer support, as well as media relations and publicity»[81] was initially set in Paris, then in Toulouse in 1974. Franz-Josef Strauss was confirmed as President and Chairman of the supervisory board, and Roger Béteille technical director of the project, with the support of the German engineer Felix Kracht.
Just one year later, in 1971, Construcciones Aeronáuticas S.A, a Spanish manufacturer, joined the consortium.

The productive cycle was organised between the different countries: the cockpit, the lower centre section of the fuselage and the control systems would be made by France, the rear, the upper part of the central and forward part of the fuselage by Germany, the wings by HSA, flaps and spoilers by the Dutch and the horizontal tailplane by the Spanish. The final assembly would be done in the main production site, as well as the headquarters of the consortium, in Toulouse.[82]

On specific indication of Roger Béteille all the manufacturers had to pay much attention to the material used to insert into the aircraft a high level of technology in all aspects.

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[80]AIRBUS.COM, *First order, first flight (1970-1972),* https://simpleflying.com/airbus-a300-first-flight-50th-anniversary/, accessed 02/07/2023.
[81] AIRBUS.COM, *First order, first flight (1970-1972).*
[82] AIRBUS.COM, *Trouble and strife (1968-1969).*

Thanks to this effort, the A300 was the first aircraft to use lighter composite materials in the primary and the secondary structure and to apply specific devices to the wingtips to reduce drag.[83] Also, the wings design played an important role, in fact HSA created a new model of wings capable of providing greater lift, allowing the A300 to reach the cruise level altitude faster than any other commercial aircraft.[84] The focus was not on «[incorporating] new technologies for their own sake but to carefully select meaningful applications which produce clear pay-offs in safety, operational capability and profitability benefits.»[85]

Béteille also proposed to raise the cabin floor, allowing the transportation of standard LD3 freight containers under the passengers, making every flight more profitable (the Boeing models were still using a plane division method that forced to reduce the passengers carried to stow goods at the same level of the passengers).[86] When the A300 made its first flight in Toulouse in 1972, it was not only the first Airbus plane, it was the technologically more advanced commercial plane flying, waiting only to be sold to european enthusiastic airliners, and to be shown in a six-week flight throughout America to their US counterparts. It was Béteille again who forced this decision, understanding that, in order to succeed and grow, Airbus needed to enter the American market defeating the US manufacturer.

While presenting the new plane in Dakarao Paulo, Florida, Mexico City, Chicago, and other cities along the American continent, Airbus started thinking about new versions of the plane that could be used to enter different markets.

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[83] SIMPLEFLYING.COM, *50 Years Ago Today The Airbus A300 Made Its First Flight,* https://simpleflying.com/airbus-a300-first-flight-50th-anniversary/, accessed 02/07/2023.
[84] AIRBUS.COM, *First order, first flight (1970-1972).*
[85] AIRBUS.COM, *Champagne... and drought (1973-1977), https://www.airbus.com/en/who-we-are/our-history/commercial-aircraft-history/champagne-and-drought-1973-1977, accessed 03/07/2023.*
[86] SIMPLEFLYING.COM, *50 Years Ago Today The Airbus A300 Made Its First Flight.*

Specifically, Air France asked for a more extended version of the plane, capable of carrying 20 people more than the first version. The first flight of this longer A300B1 took place in October and was followed by a six planes order by Air France.[87]
This first development was followed, in 1974, by an even more extended version, the A300B4, ordered by Korean Air Lines. This order represented the first non-European sales of the plane.[88]

Despite the initial push, the sales of the new planes were not going well. Between 1972 and 1976, only 9 A300S were delivered, of which three to Air France, two to Korean Air Lines and the other four to India and South Africa, and only eight planes were ordered in America.[89]

Only in 1976 the six-week travel really create the hoped effect. In April the ex Astronaut Frank Borman, who, after having spent 14 days around Earth with Gemini 7, and having orbited around the moon ten times with Apollo 8, became the director of Eastern Air Lines (EAL), one of the leading four American airliners operating at the time, amazed by the performance of the A300, decided, against the pressures of many colleagues, administrative officers and Douglas representatives, to buy 23 A300B4s. For Airbus, the news was so positive that they gave EAL four new aircraft for six months, for free, just for trying.[90] Just four years after the first flight, the A300 started creating the first cracks in Boeing's control of the US, even if the path was still long, as can be seen from the amount of aircraft produced by Boeing operating in those years shown in Table 3.

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[87] PETRESCU R. V., AVERSA R., AKASH B., CORCHADO J., APICELLA A., PETRESCU F. I. (2017), *Home at Airbus*, in «Journal of Aircraft and Spacecraft Technology», 1(2), p. 99.
[88] AIRBUS.COM, *Champagne... and drought (1973-1977).*
[89] PLANETSPOTTER.NET, *Airbus A300 production list*, https://www.planespotters.net/aircraft/production/airbus-a300-a310?sort=dd&p=2, accessed 03/07/2023.
[90] PETRESCU R. V., AVERSA R., AKASH B., CORCHADO J., APICELLA A., PETRESCU F. I. (2017), *cit,* p.99.

Table 3: Boeing planes operating in the US 1970 - 1976. Elaboration on Aircraft Industries Association of America Inc. data.

| Year | Boeing 707 | Boeing 727 | Boeing 737 | Boeing 747 | Total |
|---|---|---|---|---|---|
| 1970 | 604 | 671 | 143 | 89 | 1507 |
| 1971 | 584 | 713 | 154 | 163 | 1614 |
| 1972 | 568 | 738 | 160 | 192 | 1658 |
| 1973 | 570 | 870 | 170 | 211 | 1821 |
| 1974 | 741 | 1032 | 333 | 232 | 2338 |
| 1975 | 733 | 1140 | 399 | 253 | 2525 |
| 1976 | 719 | 1185 | 436 | 268 | 2608 |
| Total | 4519 | 6349 | 1795 | 1408 | 14071 |

Perhaps attacking Douglas, or better said McDoneel-Douglas was easier because the merger of the two companies, which started in 1967, was not creating the positive effect they both aimed for. While Boeing had started filling the shorter-range market segments with the 737 (not in a perfect way, having left space for Airbus), McDoneel-Douglas was still chasing fairy tails by competing with Lockheed (another company ready to leave the commercial market) in building big three-engined planes that were simply obsolete for the market, too big for the short-range, too small for the long, and too little efficient for the medium.

The sales of the DC-10 were good for the first years and then started deteriorating during 1979 due to the entrance of other models in the market and a series of accidents, some of which were fatal. For all, the ‘80 McDoneel-Douglas would be mostly limited to regional aircraft in a long and slow decline that would have led it to be incorporated into Boeing in 1997. Before that, almost all of its market share had been devoured in an indirect competition between Airbus and Boeing.

## 3.2 Expanding and renewing the family

Despite the lack of a unique definition, it is possible to divide commercial aircraft into three or four families. According to the International Air Transport Association, it is possible to divide them according to the type of flight they may sustain: [91]

- Long haul flights (that require long-range aircraft): 6 hours or plus;
- Medium haul flights (that require long-range aircraft): 3 to 6 hours;
- Short haul flights (that require long-range aircraft): up to 3 hours;

At the end of the ‘70 the division between those planes saw a significant imbalance towards the longer range aircraft, which were more heterogeneous and more modern, while the medium and short range were few and older, as we can see in table 4.

[91] INTERNATIONAL AIR TRANSPORT ASSOCIATION.ORG, *FHT flight haul type*, https://guides.developer.iata.org/archive/docs/fht-flight-haul-type, accessed 08/07/2023.

| Table 4: Planes operating in 1975 by range. Elaboration on data from BERGER R. 1000 Aerei. | | | |
|---|---|---|---|
| Airplane | Short Range | Medium Range | Long Range |
| Airbus A300 | | x | |
| B707 | | | x |
| B720 | | | x |
| B747 | | | x |
| Boeign 727 | x | x | |
| Boeign 737 | x | | |
| Convair 880 | | x | x |
| Convair 990 | | x | x |
| DC 10 | | | x |
| DC 8 | | | x |
| DC 9 | x | | |
| DC4 | | | |
| DC6 | x | | |
| Electra | x | x | |
| L 1011 | | x | x |
| Total | 5 | 6 | 8 |

In particular, the medium-range branch was suffering of a great lack of new models. The Convair 880 and 990 were projected at the end of the ‘50 to be very fast (880 and 990 feet per second) but were also extremely less efficient and noisier than the Boeing and Douglas models. The Lockheed L1011 was halfway long and halfway medium range, and for a mix of design delays and lack of capability to convince the airliners was the last Lockheed civil model and never sold more than 250 units. The 727 was the true best-selling aeroplane for the medium range, with a limitation. It was a three-engine aircraft in a moment when the oil price exploded after the 1973 crisis. The low limit of the branch was occupied by the 737 - 200, which was small (120 people) and with little

autonomy. This distance between the 727 and 737 allowed Airbus to create its first model without internally filling the gap.[92]

As for the A300, between 1974 and 1975 Airbus started collecting indications from airliners to build another plane with a range similar to the A300 but with a capacity between the A300 and the 737 to connect medium cities. This second Airbus model that would start the creation of the first Airbus family was the A310.

The A310 integrated many innovations as compared as the previous model. The first main aspect was connected to the materials. As we said the oil price was rising, so it was necessary not only to use efficient engines (as the one mounted to the A300), but also to reduce the weight of the plane to use less fuel. To obtain this objective the A310 used a larger amount of composite materials than the previous model, as for the vertical stabiliser, an 8.3 m high and 7.8 m wide primary structural part, that was fabricated in carbon composite materials, saving 400 kilos.[93] At the end, 7% of the whole structure will be composite.[94]

Another aspect that was improved was the cockpit design, configuration and instruments. The A310 was the first plane to equip a Forward-Facing Crew Cockpit that, through display and electronic instruments, allowed the crew to operate the plane without a flight engineer.[95] This new model had 100 orders before the first flight in 1982 and a total of 255 units delivered between 1982 and 1998. While the deliveries of its main rival, the Boeing 767, were firmly higher this Airbus model achieved its primary objective, which was not profit, but the recognition of Airbus as a player capable of producing suitable aircraft, and therefore able to remain in the market. Furthermore, the challenge represented by the design of the plane allowed Airbuys to settle some of the critical points of its whole approach: the incremental and piecemeal

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[92] HAYWARD K. (1987), *cit*, p. 14.

[93] SOUTIS C. (2005), *Fibre reinforced composites in aircraft construction*, in «Progress in Aerospace Sciences», Volume 41, Issue 2, 2005, p.149.

[94] PETRESCU R. V., AVERSA R., AKASH B., CORCHADO J., APICELLA A., PETRESCU F. I., *cit,* p. 100.

[95] AIRBUS.COM*, Technology leaders (1977-1979),* *https://www.airbus.com/en/who-we-are/our-history/commercial-aircraft-history/technology-leaders-1977-1979*, accessed 16/07/2023.

accumulation of strategic assets that contribute to Airbus' competitive advantages and the centrality of the 'maximum commonality' strategy in this asset accumulation.[96]

The A310 brought one last advantage to Airbus: England's return inside the consortium. BAE, the conglomerate of British aerospace companies created by the labour government in the 1970s, was seeking an alliance with a major producer and the possibility to design the new plane's wings was an opportunity not to be missed. On 28 October 1978, the British, French, German and Spanish governments signed an agreement, the new quotas division was 37,9% for the Germans and the French, 20% for the British and 4,2% for the Spaniards.[97]

As we said, the great technological improvements applied to the A310 project allowed Airbus to accumulate a large amount of knowledge and technological resources, as well as plans and ideas on how to use them to reinforce the whole consortium. The update of the A300 was the first step: tail, empennage and cabin from the A310, as well as the composite materials utilised, were applied to the A300 fuselage, resulting in a plane at the same time more capable and lighter, the A300-600. Sharing such a high level of components between the planes resulted in another great advantage that Airbus maintained in all its planes: *commonality.* The A310 and the A300 model «were the first two Airbus aircraft to feature commonality, sharing the same electronic flight instrument system (EFIS) flightdeck, the same basic engine models, and many of the same rotable components»[98] reducing the costs for construction, maintenance and management of the planes as well as the training required for airliners' pilots to switch from a plane to another.

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[96] KAZEMINIA A. (2021). *Unfolding the airbus' strategic growth: A successful case,* in «Scandinavian Journal of Management», *37*(1), p. 17.
[97] PETRESCU R. V., AVERSA R., AKASH B., CORCHADO J., APICELLA A., PETRESCU F. I., *cit*, p. 100.
[98] AIRCRAFT-COMMERCE.COM, *A300-600 & A310 specifications, https://www.aircraft-commerce.com/wp-content/uploads/aircraft-commerce-docs/Aircraft%20guides/A300-600%20A310/ISSUE%2053-A300-600%20A310%20SPECS.pdf*, accessed 05/08/2023.

This level of commonality determined the birth of the A300-310 family, composed of four main models (A300-600, A300-600R, A310-200 and A310-300) and 27 other subvariants with little differences in terms of range, passengers or freight transportable but with the same commonality and, as a consequence, almost interchangeable. All the planes of the family are presented in Table 5.

| Table 5: A300-A310 family planes. Elaboration on Airbus data | | | |
|---|---|---|---|
| Aircraft model | Aircraft sub-model | Configuration | Engine variant |
| A300-600 | A300-601 | Passenger | CF6-80C2A1 |
| | A300-603 | Passenger | CF6-80C2A3 |
| | A300-620 | Passenger | JT9D-7R4H1 |
| | A300-622 | Passenger | PW4158 |
| | A300-622F | Freight | PW4158 |
| A300-600R | A300-622R | Passenger | PW4158 |
| | A300-622RF | Freight | PW4158 |
| | A300-605R | Passenger | CF6-80C2A5 |
| | A300605RF | Freight | CF6-80C2A5 |
| A300-600R | A300F4-605R | Factory freighter | CF6-80C2A5/ A4F |
| | A300F4-622R | Factory freighter | PW4158 |
| | A300C4-605R | Convertible | CF6-80C2A5 |
| | A300C4-605R | Convertible | JT9D-7R4H1 |
| A310-200 | A310-221 | Passenger | JT9D-7R4D1 |
| | A310-222 | Passenger | JT9D-7R4E1 |
| | A310-222F | Freight | JT9D-7R4E1 |
| | A310-203 | Passenger | CF6-80A3 |
| | A310-203F | Freight | CF6-80A3 |
| | A310-204 | Passenger | CF6-80C2A2 |
| | A310-204F | Freight | CF6-80C2A2 |
| A310-300 | A310-322 | Passenger | JT9D-7R4E1 |
| | A310-324 | Passenger | PW4152 |
| | A310-324F | Freight | PW4152 |
| | A310-304 | Passenger | CF6-80C2A2 |
| | A310-325 | Passenger | PW4156A |
| | A310-308 | Passenger | CF6-80C2A8 |
| | A310-308F | Freight | CF6-80C2A8 |

Just after the A300-310 family launch, Airbus started the development of its third aircraft, the A320, again responding to a need emerged from the airliners and for the first time competing directly with an already existing Boeing model, the 737.

This new plane would carry almost the same number of people as the 737 (around 150 people) but will incorporate all the already existing technological improvements and more. This model was the first plane to use a full Fly-By-Wire system after the Concorde. Unlike other previous models like the 757, 767 or A310, which had a partial Fly-By-Wire system that could control only some of the aeroplane elements, this Fly By Wire system allows the pilots to control all the surfaces of the plane, from flaps to altitude and direction controls. The flight control computer analyses all the pilot's inputs transforming them into electronic impulses and sending them to the specifi c part, where a hydraulic system will move the part. In a moment, all the complicated and heavy hydraulic elements directly connecting the cockpit to all parts of the aircraft were substituted by cables.[99] All the innovations were reversed to the previous models.

This plane, which can consume half the fuel of a 737 while carrying the same amount of people over the same distance, was the first true selling success for Airbus, also thanks to the second surge in oil prices of 1979/1980. Before the first flight in 1984, there were already 80 orders, and before the first delivery in 1998, it signed a strong point against Boeing winning an order from Pan Am and reaching a total of 400 pre-delivery orders.[100]

With three main models and many variations under development at the end of the 80s Airbus had demonstrated its capability to enter and remain in the market, improving a strategy strongly based on collaboration between the many actors of the consortium and on the capability of answering with technology to the requests of the airliners. Every new plane presented a breakthrough innovation, and each of them was implemented in the previous models to keep them up to date. This granted Airbus 907 sales in the

[99] TRAVERSE P,. LACAZE I., SOUYRIS J, (2004). *Airbus Fly-By-Wire: a total approach to dependability.* In « Building the Information Society. IFIP International Federation for Information Processing», vol 156, p.192.

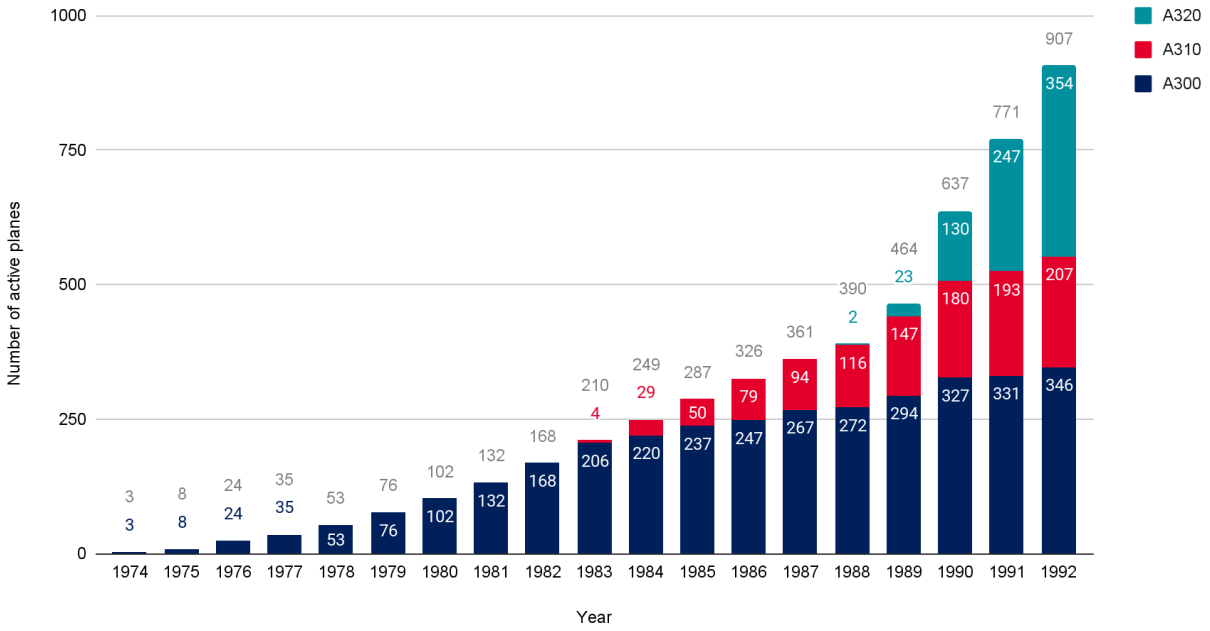
[100] PETRESCU R. V., AVERSA R., AKASH B., CORCHADO J., APICELLA A., PETRESCU F. I., *cit* p. 102.

period, which may not look a lot compared to the 6627 active planes of Boeing but represents a great goal for a brand new manufacturer born from the remnants of European producers, which only twenty years earlier seemed on the verge of being absorbed by the Americans. The A320 rampage is, in particular, very significant. In less than four years, Airbus produced as many A320s as all the A300S built between 1974 and 1992, proving its productive capabilities too.

All the active Airbus planes of the period are presented in Graph 12.

Graph 12: 1974 - 1989 active Airbus' planes A300, A310, A320 and variants

Elaboration on Aerospace Industry Association data



## 3.3 Cutting out dead weights

While Airbus was proving its point, mainly but not only in Europe and in the East (between 1974 and 1992 at least 78 A300 and A310s were delivered to Pakistan, South Korean, Iranian, Indian and other near countries airliners,[101] along with at least 10 A320), Boeing was eroding McDonnell Douglas control of the US skyes, fighting a battle based on engines, and in particular on the capability of making long-range planes eliminating the tail engine, a symbol of the aircraft of the 70s and of the enormous fuel costs that the airlines that used them had to bear.

Confident in its choice to abandon the three-engine sector at the end of the 70, Boeing started concentrating on two new planes, nominated 7X7 and 7N7, respectively, for the long-range and middle-range sectors. Between 1981 and 1982 both planes, with their final names of Boeing 767 (from 174 to 290 passengers with 4566 nautical miles range) and Boeing 757 (190 passengers and a range between 3000 and 4600 nautical miles)[102] made their first flights, starting the final attack on a rival still lost between new, competitive, short-range planes like the MD80 and the MD90 and long, not efficient planes like the DC-10, developed ten years earlier and lacking several technological advances that Boeing was instead adopting, from a basic Fly By Wire system, less developed than the Airbus one, to a glass cockpit that allows the removal of the Flight Engineer.

The competition between those two manufacturers was simply not possible. Over the years, the already declining position of McDonnell-Douglas kept falling, with its planes being actively substituted by Boeing planes in the US and Airbus models in Europe.

Between 1972 and 1992, a period characterised by the sustained growth of the airliner fleet, with an average increase of plane numbers of 3,57% each year, MD growth was

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[101] PLANESPOTTER.NET, *Airbus A300/A310 Family Production List*, https://www.planespotters.net/aircraft/production/airbus-a300-a310?sort=dd, accessed 08/08/2023.

[102] HAYWARD K. (1987), *cit,* p. 14.

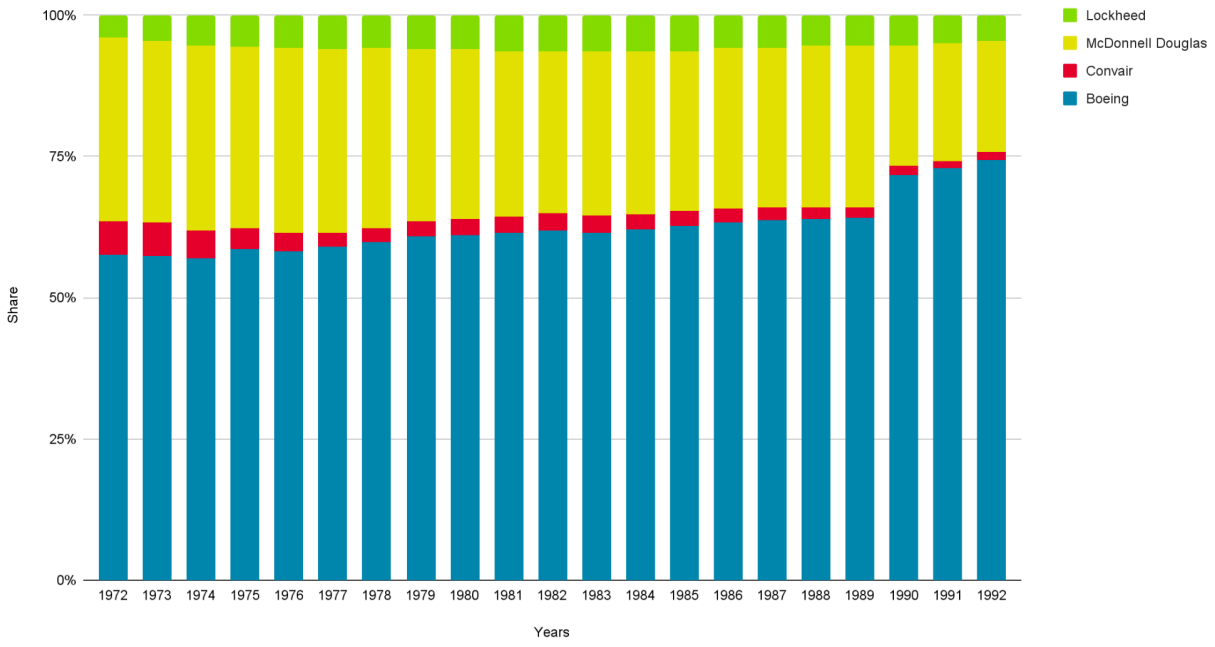
stuck at 1,28%, with a high discontinuity and three years of negative growth, underlined by the remarkable 29% drop of 1990 due to the withdraw of 588 DC-8. At the end of 1992, MD's contribution to the World fleet was increased of only 243 planes.

Analysing the same elements for Boeing we can easily understand the difference. The average growth of 4,89% was above the sector growth and showed no negative year. At the end of the period, 3359 new Boeing planes were flying worldwide.

The evolution of the World fleet composition, only for US manufacturers, is shown in Graph 13.

Graph 13: Share of the World Airliners fleet build by each US manufacturer

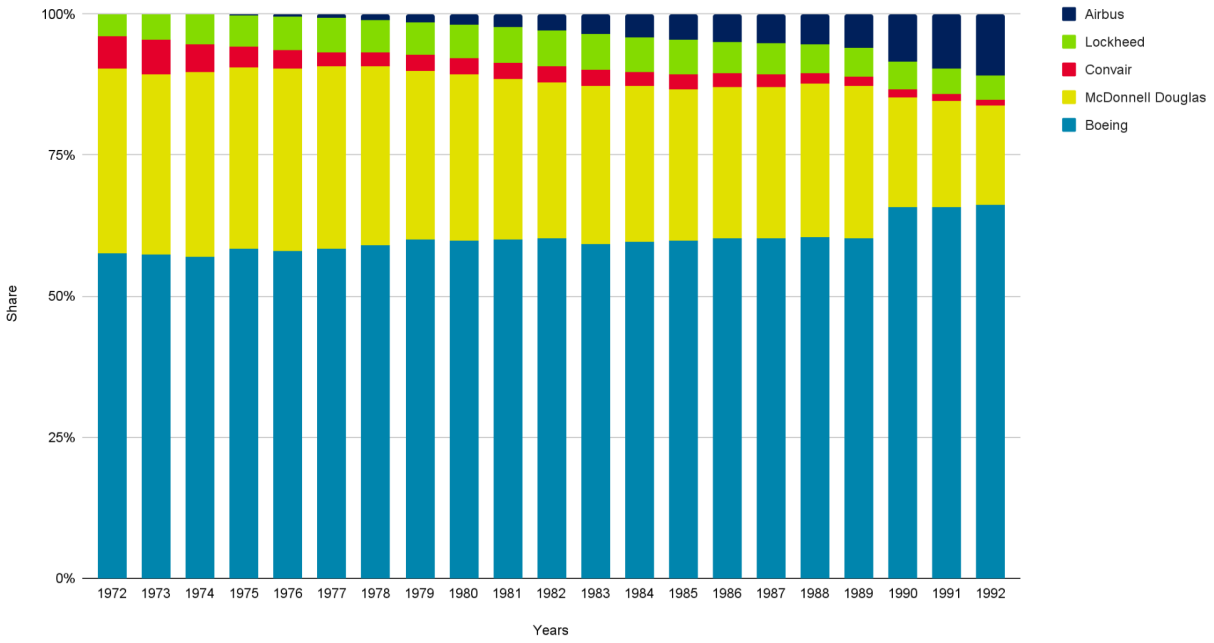
Elaboration on Aircraft Industries Association of America Inc. data




This path shows Boeing's superior capability but does not consider the non-US manufacturer. Inserting Airbus into the equation, we can see a constant change which, if it does not undermine Boeing's growth, was further reducing MD, pushing it towards the third position in the ranking of the main producers. After all Airbus' growth was a staggering 43% per year. This more complete picture is shown in Graph 14.

Graph 13: share of the World Airliners fleet build by main world manufacturer

Elaboration on Aircraft Industries Association of America Inc. data




At these conditions, at least half of the ‘90s saw Boeing and Airbus engaged in eating Douglas to strengthen before the direct confrontation. In order to do so, both companies started filling the holes left by MD planes.

MD offered at the time only three families of planes

- MD - 11 for long-range flights
- MD 80, derived from the DC - 9, for medium and short-range flights.
- MD 90, derived from the DC - 9, for medium and short-range flights.

The DC - 8, DC - 9 and MD - 10 models exited from production respectively in 19872, 1982 and 1988, while there were still operative planes. In addition, the vast majority of the planes were produced before the birth of Airbus or any way in the ‘70 and almost all of them were near disinvestment.

Boeing, on the one hand, had four plane families in production:

- Boeing 737 for short and medium-range flights
- Boeing 757 for medium-range flights

- Boeing 747 and 767 for long-range flights

The 777 plane, meant to fill the space between the 747 and the 767 was in development

Airbus on the other hand had five active planes:

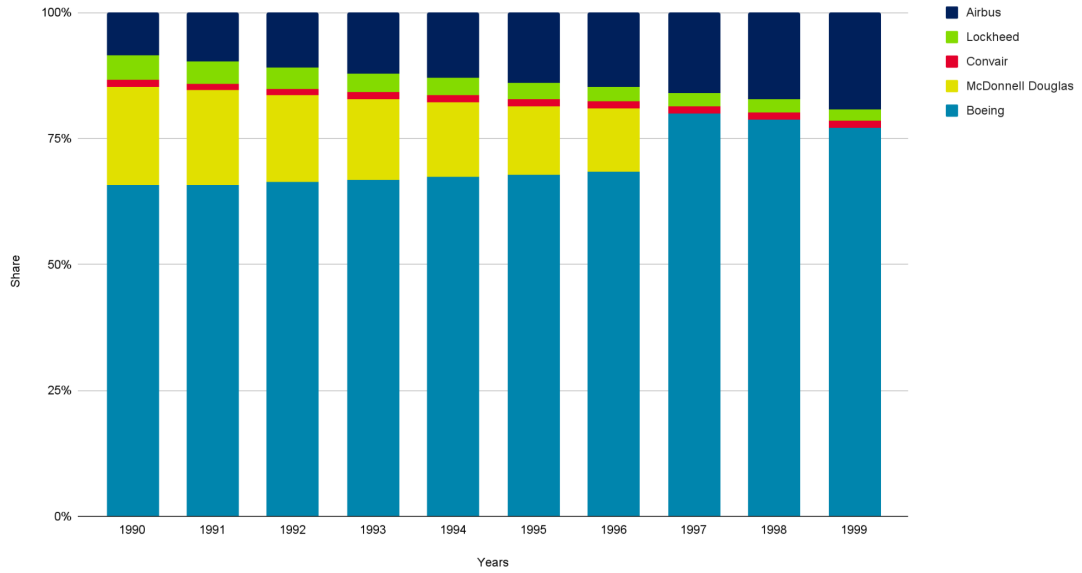
- A300 - 600 for long-range flights
- A310 and A340 for medium and long-range flights
- A320 and A319 for short and medium-range flights
- A330 for medium-range flights

Airbus was moving for both short and long range with the A330 and the A319, Boeing was filling the long range with B767 and B777, forcing out the MD models. Eleven years after its last long-range aircraft and just three years after its last new plane in 1997 McDonnell Douglas was incorporated inside Boeing for 13 billion dollars, definitively losing a competition that began 52 years earlier.

This acquisition left the market to only two leading producers, Boeing and Airbus, that contributed at the time respectively to 76% (including MD share) and to 15,9% of the World Fleet, as we can see in Graph 14, and that were ready to erode each other's market.

Graph 14: share of the World Airliners fleet build by main world manufacturer

Elaboration on Aircraft Industries Association of America Inc. data



# 4. Zooming in. How Airbus and Boeing arrived so far

The analysis of the competition between Boeing and Airbus may be easily reduced to a list of aeroplanes overlapping one another. By doing so we can say that Boeing "won" because delivered more planes, or that Airbus "won" because managed to survive and grow, and so on and so forth without reaching a definitive conclusion and without understanding anything about the two companies. All the elements seen before had to be traced back at least to the organization, the structure, the ideas and objectives of the companies, with all the choices, some immediately important and other only apparently secondary that characterized the period between 1957 and 1999.
This deepening in the analysis allows the fixation of the key points of the competition so far, and the understanding of what comes next. We will start with the entrance in the sector and the key guide perspective of both companies.

The first 30 years of Airbus can be seen as a race generated by an impellent need to stop the US manufacturers' growth and kept alive by both the succession of new challenges related to the evolution of the airliners' industry and the not-too-good results of the first models. This sense of haste was particularly strong at the end of the 1990s when Airbus started testing and producing three new planes (with all the sub-variations) in less than five years. Actually, a similar pattern can be seen in the first year after Boeing's entrance into the sector. Between 1957 and 1969 five planes did their first flight, one of which was the 747, the biggest commercial aircraft at that time. This rapidity can be explained by the need to exploit a new technology - the jet engine for Boeing - in the shortest possible time to obtain a strong position in the market before other manufacturers developed new aircraft or updated previous models.

| Table 6 First flight year and time distance from the previous model for Airbus and Boeing models until 1995. Elaboration on data from BERGER R. 1000 Aerei. | | |
|---|---|---|
| Model | First flight year | Delta with previous plane |
| A300 | 1972 | first commercial model |
| A310 | 1982 | 10 |
| A320 | 1987 | 5 |
| A340 | 1991 | 4 |
| A330 | 1992 | 1 |
| A319 | 1995 | 3 |
| Boeing 707 | 1957 | first commercial model |
| Boeing 720 | 1959 | 2 |
| Boeing 727 | 1963 | 4 |
| Boeing 737 | 1967 | 4 |
| Boeing 747 | 1969 | 2 |
| Boeing 767 | 1981 | 12 |
| Boeing 757 | 1982 | 1 |

Between 1957 and 1970 Boeing was capable of exploiting the technological breakthrough in a very effectively way, producing five new models while in the same period, Douglas was capable of producing only two models, chasing the development ridden by Boeing and being forced to use the body of the DC7 in order not to lose all the development costs, therefore without being able to produce a truly new aircraft. The distance between Boeing's new models and all previous aircraft was massive. Plotting the technological level trend of the aircraft transport sector is possible to see a great leap forward, from an average technological level of 0.45, on a scale from 0 to 1, to an average level of 0.55.[103]

[103] ESPOSITO E. (2004), *Strategic alliances and internationalisation in the aircraft manufacturing industry,*
*Technological Forecasting and Social Change,* University of Naples, Naples*, p. 452.*

This event allows us to underline the first key element that composed Boeing's culture: the relevance given to technology in a company that «regarded itself - and described itself - as a company of engineers».[104]

Boeing based its remaining in the very fruitful military sector on technological capabilities, with the same optic entered and gave its contribution to the space sector producing five lunar orbiters that mapped the moon's surface and contributing to the development and construction of Saturn V launch vehicle and building the Lunar Roving Vehicle.

After this strong advance, Boeing started exploiting a new element of novelty, not merely technological, that we have already seen: the "family" approach. Why have only a few 737 versions, with little differences between them, as it was for the DC models when you can develop 22 different versions with a large amount of differences and advancements at a reduced cost?[105] For Boeing the answer was "for no reason in the world" and so it started developing and developing all its planes adding little and big elements, like the characteristic second floor of the 747 that was absent in the first version,[106] stretching and reducing the fuselage, changing the engines etc. Doing this Boeing was capable of producing, with seven main planes, 44 different variations between 1957 and 1999.

Almost each of those variations met the needs of a specific airliner. By doing so Boeing was capable of conquering and retaining its customers, providing not only planes but also all the services connected, from spare parts to revisions and improvements.

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[104] NEWHOUSE J. (2007), *Boeing versus Airbus,* Random House inc., New York, p. 96.
[105] SIMPLE FLYING.COM, *Boeing Has Built 22 Variations Of The 737*, https://simpleflying.com/boeing-has-built-22-variations-of-the-737/, accessed 26/08/2023.
[106] SIMPLE FLYING.COM, *How To Tell The Differences Between The Boeing 747's Main Variants*, https://simpleflying.com/boeing-747-variants-recognition-guide/, accessed 26/08/2023.

| Table 7: Boeing's families. Elaboration on Boeing data. | | |
|---|---|---|
| Plane family | Variation name | Developement year |
| Boeing 707 | 707 | 1957 |
| | 707-120 | 1958 |
| | 707-320 | 1958 |
| | 707-320C | 1958 |
| | 707-138 | 1959 |
| | 707-220 | 1959 |
| | 707-420 | 1960 |
| | 707-320B | 1962 |
| Boeing 720 | 707-020 (720) | 1959 |
| Boeing 727 | 727-100 | 1963 |
| | 727-100C | 1963 |
| | 727-100QC | 1963 |
| | 727-100QF | 1963 |
| | 727 C-22A | 1963 |
| | 727 C-22B | 1963 |
| | 727-200 | 1967 |
| | 727-200C | 1967 |
| | 727-200 Advanced | 1970 |
| | 727-200F Advanced | 1981 |
| Boeing 737 | 737-100 | 1967 |
| | 737-200 | 1968 |
| | 737-300 | 1979 |
| | 737-400 | 1985 |
| | 737-500 | 1987 |

| | | |
|---|---|---|
| | 737-600 | 1995 |
| | 737-700 | 1997 |
| | 737-800 | 1998 |
| | 737-900 | 2000 |
| Boeing 747 | 747-100 | 1966 |
| | 747-SR | 1973 |
| | 747-100B | 1978 |
| | 747-SP | 1976 |
| | 747-200 | 1971 |
| | 747-300 | 1980 |
| | 747-400 | 1989 |
| Boeing 757 | 757-200 | 1983 |
| | 757-200PF | 1987 |
| | 757-200M/CB | 1988 |
| | 757-300 | 1991 |
| Boeing 767 | 767-200 | 1982 |
| | 767-200ER | 1984 |
| | 767-300 | 1986 |
| | 767-300ER | 1993 |
| | 767-300F | 1999 |

Those two elements, the technological research and the family development, combined with the decision to produce only in the United States, defined the strategy of Boeing and made it the preferred choice of US carriers and the Government.

The Airbus entrance-in-the-sector path was similar in many aspects, but with a diverging element.

While Boeing developed all its best-known aircrafts almost immediately, in a twelve years span, Airbus waited for fifteen years before embarking on massive construction.

This element is crucial and cannot be explained only by the fact that Boeing has already been in the sector for 41 years or with the problems encountered by Airbus in organising its productive or support service system. Airbus' idea of development can be identified in Roger Béteille choices: «[helding] up the decision on the A320 until there was something new and remarkable with which to challenge Boeing.»[107]

Finding a technological advantage and using it for the planes was not enough, the goal was to find something for every plane and then update everything to the new state of the art. For the A300 the innovation was flying with two engines, for the A310 the cockpit and the usage of new composite materials, for the A320 was the fly-by-wire. Unite those three elements and you have a new breakthrough, as it was for the jet engines, capable of making the technological average level jump up to 0.66, giving Airbus the same push that Boeing had in 1957 and leaving the possibility to focus on creating a whole family for each model.[108]

It's at this point clear that the approach to technology and family in the entry period was similar but not equal, as for many other aspects of Boeing and Airbus lives, and in those little differences lies the reason for successes and difficulties encountered by both.

[107] NEWHOUSE J. (2007), *cit,* p. 99.
[108] ESPOSITO E. (2004), *cit p. 453.*

## 4.1 Internal structure and organisation

A second, important, difference can be found in the organization. Boeing started with a single productive centre in Seattle and then started adding new structures and opening new plants, focusing each of them on a specific plane.

The first Seattle facility, built on the Duwamish River in 1910 saw a continued expansion, with the creation of new spaces for manufacturing and an airstrip and focused mainly on seaplanes. This first manufacturing plant lost importance just before WWII, becoming a parts-production facility, while the main productive site was moved to a newly bought 28-acre terrain along Marginal Way in Seattle.
In 1930 Boeing incorporated Stearman Aircraft along with its plant in Wichita, Kansas. The plant was focused on the production of Stearman Kaydets trainers planes until 1942 when a second plant was added and the production switched to B-29 Superfortress. Despite this new plant, the war demand was too high so Boeing started building new plants in five different localities along the State of Washington.
Meanwhile, in 1941, the production of the Model 344 XPBB-1 Sea Ranger was moved to a new plant in Renton, Washington. In 1951, the same plant developed the first commercial jet prototype and then specialised for an initial period in 707 and then in 737.
From this date on the company started a process of partitioning the planes production and assembly between two plants:

- Everett plant in Washington, created in 1967 for the production of Boeing 747. It then took up the production and assembly of 747, 767, 777, and finally of 787 aeroplanes.[109]

[109] BOEING.COM, *Everett production facility,* *https://www.boeing.com/company/about-bca/everett-production-facility.page*, accessed 27/08/2023.

- Renton plant in Washington, already established in 1941, from 1967 started specialising in producing 737 and 757 planes.[110]

Those sites were responsible for the main construction phases of parts and components, along with other secondary sites scattered throughout the US and the assembly of the final product. The use of outsourcing was strongly limited. By organising the company in such a way Boeing was surely capable of maintaining the strategic knowledge and the R&D inside the firm, avoiding the share of information that could be beneficial to other manufacturers, but also losing a great opportunity for specialization. While it is true that each plant focused on one aircraft, thus improving its production capacity thanks to economies of scale and scope at the assembly level, this "large" division made it very difficult to translate these advantages on specific parts, reducing the amount of development and technological advancement possible.

On the other hand, Airbus' peculiar structure went in the opposite direction. The presence of different manufacturers, each one with a specific focus area could generate delays and frictions, as in many cases did, but left to each part of the consortium the capability to focus on their field of interest and achieve new technological advancement. Aerospatial, BAE, DASA and CASA were allowed to start cooperation programs with other producers for non-Airbus planes, as they regularely did, entering into contact with partners like General Electrics, Alenia, Industri Pesawat Terbang Nusantara, McDonnell Douglas, Tupolev, Turkish Aerospace Industries, Flabel etc… or developing their own projects with only one of the consortium partners as for the Panavia Tornado.[111]

The European and US approaches to other players in the industry could not be more different. Boeing was proceeding by merging and incorporating, using such a strategy to obtain the necessary knowledge to enter into specific sectors, such as for the acquisition of Vertol in 1960, which then became Boeing Helicopters, or the acquisition of the Aerospace section of Rockwell American Aviation - the company that build the Shuttles

[110] BOEING.COM, Renton production facility. https://www.boeing.com/company/about-bca/renton-production-facility.page, accessed 27/08/2023.
[111] ESPOSITO E. (2004), *cit,* p. 456.

- to boost its capabilities in Aerospace sector.[112] Altogether Boeing acquired up to 9 different companies with different sizes and specializations.

| Table 8: Boeing acquisitions. Elaboration on Boeing data. | |
|---|---|
| Company name | Year of acquisition |
| Stearman Aircraft | 1934 |
| Vertol | 1960 |
| Rockwell aerospace and defense units | 1996 |
| McDonnell Douglas | 1997 |
| Jeppesen Sanderson Inc | 2000 |
| Hawker de Havilland | 2000 |
| Insitu | 2008 |
| Argon | 2010 |
| Aurora | 2017 |

The Airbus approach, as we have seen before, was completely different and focuses on collaboration rather than the acquisition and integration of skills. This allowed the growth of the partners during the 80s, with «DASA [...] aimed at expanding into all segments of the market [and] CASA [that] used the know-how acquired through its network of relationships in the higher technological levels to gain the leadership in the lower level segment».[113] At the same time, this approach generated various needs for reorganisation, also linked to the change in internal weight and specialisation, which were however manageable thanks to the specific organisation of Airbus, that left room for improving the balance of the network.

This was particularly true at the verge of the 2000s when Airbus started to suffer from the impossibility of having control of the workforce, scattered into four countries with different labour laws and high labour costs. This aspect may be secondary in the first years, but with six productive lines and the number of orders increasing it became

[112] THE BOEING COMPANY, *Boeing History Chronology.*
[113] ESPOSITO E. (2004), *cit,* p. 458.

strategically relevant. To complicate the situation Airbus was preparing itself to launch a brand new, anything but simple, carrier. As for many european matters, the initial decision announced by the Airbus Industry Supervision Board to unify the assets and create a new singular Airbus entity was received badly by all the national actors. The French feared an approach between the English and the Germans, BAe and DASA felt the French filibuster was offensive and so on. Luckily if the various companies had not yet managed to achieve an adequate level of diplomacy, the states they represented did, and so the industry ministers traced the path of this integration that brought Aerospatial, DASA (Deutsche Aerospace AG) and CASA (Construcciones Aeronáuticas SA) to merge into EADS (European Aeronautic Defence and Space Company) taking control of the 80% of Airbus share, leaving to BAE Systems the remaining 20%.[114]

This difference in approach determined various advantages and disadvantages for both companies. It generated on the one hand a higher rapidiy in responding to the changes in the market for Boeing, while Airbus had to overcome difficult internal negotiations while on the other hand allowing Airbus to focus more on technological development.
However, this difference will generate another effect, less visible in the early stages of the competition, which will then become of radical importance for both companies starting from the early 2000s when the complexity and the costs of developing and producing planes started growing. In front of the need to enlarge the relationships and enter in contact with new firms, outsourcing part of the work, Boeing will find itself in a disadvantaged position compared to Airbus, both in terms of difficulty in managing relationships with suppliers and in terms of technical means necessary to move the intermediate stages of the aircraft produced between the various plants.

[114] PETRESCU R. V., AVERSA R., AKASH B., CORCHADO J., APICELLA A., PETRESCU F. I. (2017),
*cit,* p. 103.

## 4.2 The approach to technology

We have already presented some of the main technological advantages used by both Boeing and Airbus during their earlier phases, and it's now necessary to focus on the key elements that characterized the approach of the companies to that matter. Boeing, especially on its first commercial planes placed great emphasis on the capability to innovate, starting form the combination of jet engines and commercial aircrafts. This search for innovation was driven by three elements:

- The ability to make the developments of one of the sectors permeate into the others, using the advantages typical of each sector: the jet engine wasn't developed directly for the commercial sector but it came out from the military section of Boeing, well funded and supported also for the R&D by the government - at least 8 billion dollars spent each year by the Department of Defense on R&D and tests which were allocated to the various companies operating in the sector[115] - and protected by an higher level of secrecy. This has allowed the study and improvement of the engine without excessive fear of being overtaken by competitors.

- The capability of identifying innovations started from other companies and sectors, integrating and makeing them better, as for the jet engine recovered from the British failures. This allowed Boeing to avoid the lack of information that had anchored Douglas to piston models.

- The capability of creating, especially in the case of fundamental choices such as that of building a new aircraft model, many different alternatives and then

[115] SKAGGS H. A., BATH H. S. MODLEY R., *Aerospace facts and figures 1976/1977,* 1976, McGraw Hill publications, New York, p. 92.

comparing them and put them to the test, on paper, with the requests of the market.

This focus was extremely strong during the first phases of the competition with Douglas but started decreasing after it began to wane after it became clear that Douglas couldn't do any of these things and that therefore its capabilities of maintaining the sector dominance was nil. After realizing this the focus on innovation drifted towards a more conservative approach, which placed great value on the results obtained and looked suspiciously at novelties that were too invasive.

Airbus took back those focused, adding two new elements: the patience on establishing new models in case of lack of a significant technological improvement, as for the A320 case and the decision of going for small products to sharp the technological advantages, reducing the complexity of all the other activities in order to concentrate on the main innovation and avoiding a too big loss in case of failure.[116] Furthermore Airbus kept on uploading the old models, evolving its capability by simplyinserting those technologies in planes not created for them.

Both Airbus and Boeing paid a lot of attention on the reduction of operating cost for the airliners, offering new engines version with reduced consumptions and using composite materials to eliminate weight.

Airbus however spotted and exploited since the beginning an important element of cost reduciton that Boeing was more or less ignoring, *maximum commonality* that is to say the greates level of equal elememts between different aircraft types of the same producer[117]. The costs sustained by an airliner that buy a new model of plane are various, spanning from the price of the plane itself to the maintenance tools needed at the airliner's hub. However one of the most important one regards the pilots. Flying a

[116] KAZEMINIA A. (2021), *cit,* p. 16.
[117] SIMPLEFLYING.COM, *What Does Commonality Between Aircraft Types Mean?, https://simpleflying.com/aircraft-type-commonality/*, accessed 29/08/2023.

two engine or a four engine aircraft is clearly not the same so specific new training program, that block the pilot for a long amount of time is needed. The same rules applies when you switch between models that are more similar outwardly but that presents different instruments, cockpit, reactivity and procedures. For all those changes the pilots have to be retrained. For the airliner it means an investment of money and a strategical, well paid employee stuck for several weeks, stalled for several weeks, with the routes it usually covered being followed by others or not being followed at all. For the Airbus models this bottleneck simply doesn't apply, the cockpit and the main sistems of each plane are, in fact, equals. This will allow a great advantage for the airliner in terms of costs reduction and a minor pressor on the pilot while for the manufacturer will generate an exit barrier from changing airplane supplier.
Going into detail, the presence of a high level of commonality allows for:

- Reduce the need of having large reserve crews due to the fact that each pilot can fly a larger variants of planes
- Reduce the need of different spare parts and as a consequence the stocking space used and the weight of of obsolences
- Standardize the activities related to maintenance, that will be equal for different planes and the requirement fot ground service structures.

With those configurations and approaches Airbus and Boeing carved their positions out, leaving companies with lower levels of attention to technological advances behind and made the airplanes more complex and capable, reaching a level so high that their main capabilities start becoming not enough. the beginning of the new millennium was about to present new challenges that would force both manufacturers to come to terms with their own strengths and weaknesses.

# 5. Conclusion - a whole new world

This analysis, and the whole commercial plane sector, started with a two-seat biplane, made of wood and fabric in 1916, grew along with the dimension and the complexity of the first pressurised models, the jet engines and the Fly By Wire and reached, at last, a critical size at the beginning of 2000. In font of the need to build new aircraft both Airbus and Boeing realised that they were not big enough, both in technical and financial terms. The need for an evolution in the organisation became more pressing.

Boeing wanted to substitute the outdated 767 and 747 while Airbus was ready to enter definitely in the large long range aircraft sector, ending the 747 control, but the development costs of their new planes, respectively the 787 and the A380 were notable from the start. The initial hypothesis for the 787 was $8 billion,[118] and the final expenses of $22 billion.[119] Along with this barrier, there was also the necessity to find suppliers capable of granting the high level of difficulty and complexity reached by the components of the new aircraft, which saw ever-increasing levels of composite materials, electrical tools and micro-components. The possibility of developing new aircraft internally was over, along with the organisation of both companies.

Boeing, ending its life-long refusal of outsourcing entered into contact with Mitsubishi Heavy Industries, Fuji Heavy Industries and Kawasaki Heavy Industries for the design and the construction of wings, wing box, landing gear integration and cockpit fuselage.[120] After this first leap, and always with a sense of internal bewilderment, the

[118] NEWHOUSE J. (2007), *cit,* p.27.
[119] SIMPLEFLYING.COM, *The Development Cycle And Cost Of Modern Commercial Airliners*, https://simpleflying.com/modern-airliners-development-cycle-cost-guide/#:~:text=Timeline%20and%20cost&text=The%20development%20of%20the%20Boeing,expenditure%20of%20over%20%2422%20Billion., accessed 05/09/2023.
[120] NEWHOUSE J. (2007), *cit,* p.28.

use of outsourcing began to grow dramatically, reaching a percentage close to 70% of the 787 parts, creating a model very similar to Airbus' ones but without the experience for making it work.[121] Airbus, on the other hand, gathered all the historical suppliers, adding a series of new industrial partners from « Australia, Austria, Belgium, Canada, Finland, Italy, Japan, South Korea, Malaysia, Netherlands, Sweden, Switzerland and the United States.»[122] As before the parts, produced in many different plants and countries will be assembled in Toulouse.

For both companies, this new challenge was an almost total failure. Both planes encountered great delays in development and saw the initial budgets replaced with higher and higer ones, while the supply structures were put on the spot. This friction was particularly true for Boeing, which was testing the new first-tier supplier delegation model for the first time, in particular a series of elements inserted by Boeing into the outsourcing organisation to reduce possible risks created several problems, in particular the following two points:[123]

- Supplier integration system: in order to reduce the supply chain breaks Boeing, along with Advanced Integration Technologies, developed an IT integration system that required tier-2 and tier-3 suppliers to provide information on the state of the production. In many cases the system was used by the supplier to lie to the company, inserting false informations and avoiding in such a way any control. This created delays also for tier-1 suppliers and a general inability to understand where the development was.
- Financial delay: in order to avoid missing deadlines Boeing imposes the delayment of tier-1 strategic suppliers payments until the first 787 was delivered. This decision created many problems for the most important suppliers due to the overall delay of the project.

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[121] NEWHOUSE J. (2007), *cit,* p.29.
[122] TZU-CHING H. (2007), *A Comparative Analysis of Supply Chain Management Practices by Boeing and Airbus: Long-term Strategic Implications,* Massachusetts Institute of Technology, Massachusetts, p.84.
[123] TANG S. C., ZIMMERMAN D. J. (2009), *Managing New Product Development and Supply Chain Risks: The Boeing 787 Case,* in «Supply Chain Forum» vol 10 n 2 2009, pp.78 - 80.

Those problems forced Boeing to react in a known way, that is, by buying and acquiring the main suppliers as for Vought Aircraft Industries or entering in a more indirect way in the management as for Spirit Aerosystems' worker's salary increase, directly paid by Boeing.[124]

Airbus, for its part, encountered less strange but equally difficult problems that forced several delays and created a temporarily crack between the German and the French partners.

Despite that, both companies were able to overcome the difficulties, albeit in a different way, and modify their structure to fit the needs of an air sector in rapid change.

In particular, the effects of 9/11 on the commercial plane sector were not ignorable, as they brought a substantial improvement of the expenses and a significant decrease in the revenue of the carriers. According to CNBC «U.S. airlines lost $8 billion in 2001. The industry was not profitable again until 2006. Losses topped $60 billion over that five-year period and airlines again lost money in 2008 during the Great Recession.»[125]

In such a situation, with growing costs for both airlines and the passengers, the low-cost carriers gained centre stage, and found in Airbus a very reliable supplier thanks to the versatility of the A320 family, which made it possible to effectively manage the multitude of new routes that low-cost airlines were opening between cities considered secondary by national airlines. In fact the need of those airliners was the same that had justified the birth of the company itself, short-haul, cheaper and highly customisable airplanes. Starting from 2003 almost all the main low-cost carriers started substituting their aeroplanes, mostly Boeing, with Airbus models except fo Ryanair and some other US carriers.

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[124] TANG S. C., ZIMMERMAN D. J. (2009), *cit.,* p. 81.

[125] CNBC.COM, *How the Sept. 11 terrorist attacks forever changed air travel,* https://www.cnbc.com/2021/09/11/how-9/11-forever-changed-air-travel.html, accessed 05/09/2023.

| Table 9: Fleet composition of the seven main low-cost airlines. Elaboration on Planespotter data. | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Airliner | Type of planes | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
| Easyjet | Boeing | 82 | 72 | 53 | 34 | 34 | 29 | 17 | 8 | 0 |
| | Airbus | 0 | 22 | 49 | 77 | 89 | 121 | 145 | 150 | 160 |
| JetBlue | Boeing | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Airbus | 47 | 63 | 79 | 95 | 103 | 107 | 110 | 116 | 120 |
| IndiGo | Boeing | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Airbus | 0 | 0 | 0 | 6 | 14 | 19 | 24 | 34 | 48 |
| AirAsia | Boeing | 35 | 25 | 22 | 18 | 11 | 3 | 0 | 0 | 0 |
| | Airbus | 0 | 0 | 0 | 3 | 5 | 9 | 12 | 17 | 23 |
| JetStar | Boeing | 0 | 9 | 2 | 6 | 0 | 0 | 5 | 0 | 0 |
| | Airbus | 0 | 9 | 27 | 42 | 45 | 50 | 56 | 76 | 85 |
| Ryanair | Boeing | 65 | 81 | 95 | 121 | 147 | 163 | 207 | 251 | 276 |
| | Airbus | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Frontier | Boeing | 18 | 18 | 10 | 2 | 0 | 0 | 0 | 0 | 0 |
| | Airbus | 27 | 41 | 49 | 55 | 60 | 58 | 51 | 52 | 62 |

This change gave new impetus to the 737 and the A320 families, starting a great effort to innovate both models which exposed Boeing's growing nervousness through the 737 MAX 8 scandal, caused also by Boeing's difficulties in reproducing Airbus commonalities in its aircrafts.[126] The old Airbus models instead underwent a process of improvement, particularly concentrated on the engines and the consumptions which resulted in the presentation of three NEO (*New Engine Option*) models, the A320neo in

[126] BBC.COM, *737 Max: Boeing to pay $200m over charges it misled investors*, https://www.bbc.com/news/business-63003632, accessed 05/09/2023.

2014, the A321neo in 2016 and the A319neo in 2017, all characterized by a 15% fuel consumption reduction that allows both fuel saving and improving the plane range of operativity while maintaining the prices below the Boeing's ones, at least in the medium short range sector. The price tag of an A320neo is 110.6 million dollars while the price for the shortest version of the Boeing 737 MAX can reach 248 million dollars.[127][128] Thanks to this capability of keeping its aeroplanes upgraded planes Airbus orders reached and steadily overcame Boeing ones.

Between all the elements treated during this analysis, one emerged as the key factor, that characterized all the crucial moments in the evolution of the sector and of the companies that operated in it: technological innovations, specifically those inserted in a strategic plan capable of looking at the long term.

Douglas had the innovation when it created the pressurized planes but lacked the strategy and the ability to move forward in the path of innovation. This lack left room for another company with a technology, Boeing, that reached enormous dimensions thanks to the jet engine, but once again, also due to the apparent complete control of the market and a predatory approach towards it, the lack of strategy undermined its capabilities.

So far Airbus is the only aircraft manufacturer that was capable of keeping together the ability to innovate and the ability to maintain this skill and fit it into a larger vision, creating a path that led her, not without stumbles, to become the aeroplane manufacturers' leader.

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[127] SIMPLEFLYING.COM, *Money Talks: A Look At The List Prices Of Boeing Aircraft*, https://simpleflying.com/how-much-do-boeing-aircraft-cost/, accessed 05/09/2023.

[128] SIMPLEFLYING.COM, *How much do Airbus cost?*, https://simpleflying.com/how-much-do-airbus-aircraft-cost/#:~:text=It%20is%20also%20part%20of,jets%2C%20goes%20for%20%24101.5%20million.&text=Not%20surprising%2C%20seeing%20as%20the,expensive%20part%20of%20an%20aircraft., accessed 05/09/2023.

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