Aircraft component Repair

The aerospace component repair industry stands at a pivotal juncture, shaped by decades of regulatory evolution, technological breakthroughs. Today, the industry faces pressing challenges including labor scarcity, fragile supply chains, and unprecedented demand. At the same time, it is experiencing opportunities in predictive maintenance, additive manufacturing repair schemes, and the use of digital tools for maintenance. Looking ahead, the firms best positioned for sustainable advantage will be those that integrate digital capabilities such as the use of artificial intelligence to redesign obsolete components, accelerate repair innovation in advanced materials, and adapt to an aging workforce.

This analysis will explore the aerospace component repair industry across three dimensions: its history, present state, and future outlook. The historical discussion will examine key milestones and external forces that have shaped the industry’s evolution, including risk sharing partnerships that have created a massive increase in suppliers to major aircraft platforms. The analysis of the present will evaluate the industry’s structure through a SWOT framework, identification of current drivers, application of Porter’s Five Forces, and a competitive assessment of leading players. The future outlook will outline what it will take to for companies to be successful in the aircraft component repair industry of the future. Together, this roadmap provides a structured foundation for understanding how historical forces inform the current competitive landscape and how future dynamics will shape opportunities for growth, resilience, and innovation in the component repair industry.

Aircraft Component Repair History

The evolution of the aircraft component repair industry mirrors the dynamic progression of aviation. Aircraft maintenance and component repair was initially rooted in operator led maintenance during the nascent stages of commercial flight. The sweeping deregulation of the airline industry in the 1970's, innovations in aircraft designs, and risk-sharing partnerships created the world of aerospace component repair we know today. This section will consider the history of commercial aircraft maintenance and how it has changed since the first flight in 1903.

Industry History

Early airlines did almost all of their maintenance in house using common tools to work on

the aircraft. If aircrews need repairs far from home base, they would often repair their own aircraft (Wikipedia Contributors, 2020). Northwest Airlines developed in house aircraft maintenance early on. If parts broke on the aircraft they could be replaced with locally sourced replacements. This photo shows an NWA mechanic re-caning the wicker seats of a Ford Trimotor (Northwest Airlines History Center).

Airlines and aircraft continued to develop in the post-world war world. Aircraft were becoming larger and more complex. A major milestone was the beginning of the jet age with the de Haviland Comet in 1949. As these aircraft became more complex and expensive there grew a need to control the costs of planned and unplanned maintenance. Aircraft engine manufacturers began offering "power by the hour" programs for operators. Operators would play a flat monthly fee to engine makers. When airlines on a prefunded maintenance program needed parts or support, they would receive them free as they had already prefunded their maintenance.

Two pivotal events in the 1970s played a crucial role in shaping the modern aircraft component repair industry. The first was the development of the Airbus A300, which made its maiden flight in 1974. The Airbus A300 was the first aircraft that was built with a consortium of risk-sharing partners. The second major development was the Airline Deregulation Act of 1978, which transformed the industry by fostering increased competition and operational flexibility. In response to this legislation, airlines were able to freely compete with each other on fares. The increased competition forced airlines to control their costs. This environmental trend accelerated the creation of third-party repair vendors and encouraged airlines to return components to their vendor rather than investing in the equipment to repair them locally. Together, these events significantly reshaped the aircraft repair market.

The Airbus A300, shown below, introduced in the early 1970s, marked a significant milestone in aviation history by establishing one of the first major risk-sharing partnerships in

aircraft development. This collaborative approach involved multiple European aerospace companies sharing the financial and technical risks associated with the A300's design and production, laying the foundation for Airbus's consortium-based structure (Airbus, 2022). The large dispersed network of suppliers also required a change to aircraft architecture by using modular line replaceable units commonly referred to as LRU.

As commercial aircraft evolved, the number of Line Replaceable Units (LRUs) increased as manufacturers introduced more complex designs to enhance performance and efficiency. The Boeing 777, introduced in the 1990s, featured three times as many systems as its early predecessor, the Boeing 707, reflecting the growing sophistication of modern aircraft. Every aspect of an aircraft now relies on advanced systems to improve safety, extend operational lifespan, and enhance overall performance. To support this complexity, modern aircraft incorporate built-in test equipment (BITE) that continuously monitors system health, diagnoses issues, and quickly isolates defective components. This significantly reduces the troubleshooting workload for airline maintenance engineers, allowing for faster repairs and improved aircraft availability. As technology advances, future aircraft are expected to integrate even more automated diagnostic tools, further streamlining maintenance operations and minimizing downtime.

Legacy of the 1970's

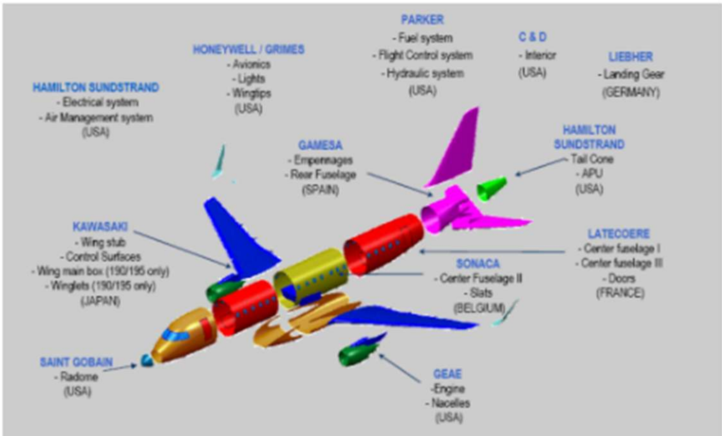


Figure 1. Risk Sharing Partnerships of the ERJ – 170/190 Program
Source: Embraer Company

The trend of aircraft manufacturers sharing risks with their suppliers has continued since the A300. Embraer has many risk sharing partners making components for their regional aircraft. 36% of the aircraft is made up of supplier provided components (Figueiredo, P., 2008) When these suppliers agree to take on the risk of supporting the development of the aircraft they are rewarded with the rights to after sale support of the components they make. Many of these components are in the form of LRU. When these components fail on wing the airline can swap a faulty LRU out with another. The airline can then send the broken LRU out to the supplier who manufactured the component, a 3rd party repair shop, or repair it themselves with subcomponents sourced from the original equipment manufacturer (OEM).

The Airbus A350 which is the latest widebody aircraft on the market furthers this trend with almost all of the component LRU sourced externally (see chart). Large components, like engine nacelles, that an aircraft manufacturer would typically build are now outsourced to different risk-sharing suppliers (Mocenco, D., 2021). Risk-sharing developments free up

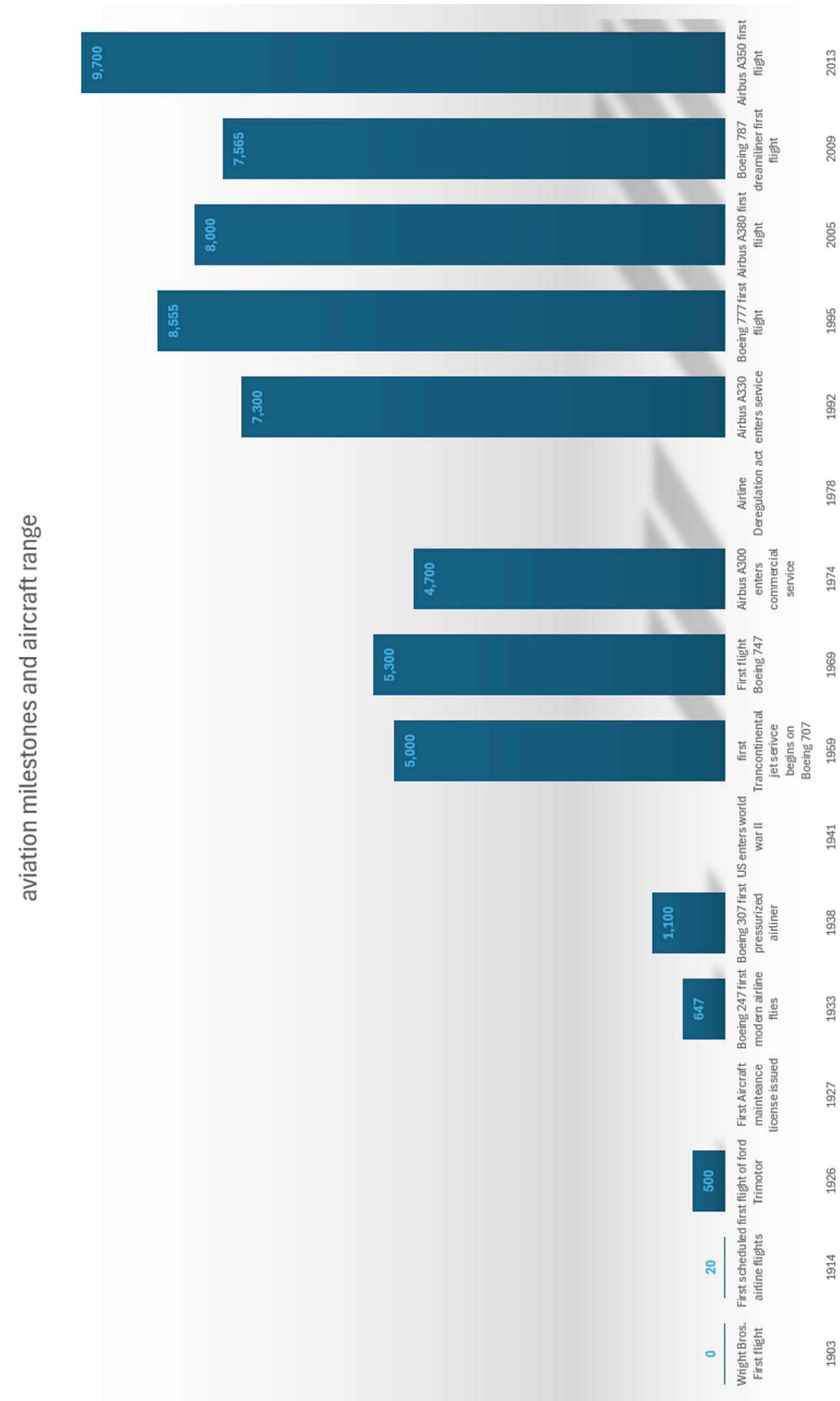
	Supply chain A320 & A330/40	Supply chain A380	Supply chain A350
Platform Assembly	Airbus	Airbus	Airbus
Large-scale Integration	Airbus	Airbus	Airbus / I Tier
Value-added Parts and Assemblies	Airbus / I Tier	Airbus / I Tier	I Tier
Make-to-print Parts and assemblies	Airbus / II Tier	II Tier	II Tier
Raw materials	III Tier	III Tier	III Tier

capital, which improves aircraft manufacturers profits, and allows them to reinvest in the next generation of aircraft.

In an effort to increase profitability and control costs, airlines have continued to outsource aircraft and aircraft LRU maintenance. By 2016, 46% of US airlines maintenance budget went to outside repair vendors, with some airlines spending more than 75% on outside repairs (Jin, L. et. al.,2022). Modern aircraft components have greatly increase in complexity, as has the tooling and test equipment used to repair those components. It makes sense for airlines to return complex components back to their makers for repair as some tooling can cost millions of dollars. Studies have shown that the component repair model has helped airlines reduce their operational costs (Jin, L. et. al.,2022).

Aircraft component repair history conclusion

The evolution of the aircraft component repair industry has been shaped by advancements in technology, regulatory changes, and shifting business models. From early in-house airline maintenance operations to the rise of component repair vendors, the industry has continuously adapted to meet the demands of increasingly complex aircraft. The introduction of risk-sharing partnerships, beginning with the Airbus A300, revolutionized aircraft development and component repair, leading to the widespread use of Line Replaceable Units (LRUs). As manufacturers have outsourced more component production and maintenance, airlines have increasingly relied on external repair vendors to manage costs and improve operational efficiency. The growing demand for aircraft component repair has given rise to a significant industry The following section will examine the current state of the component repair market via application of SWOT and Porters Five Forces analysis.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First scheduled airline flights
first flight of ford Trimotor
First Aircraft mainteance license issued
Boeing 247 first modern airline flies
Boeing 307 first pressurized airliner
US enters world war II
first Trancontinental jet serivce begins on Boeing 707
First flight Boeing 747
Airbus A300 enters commercial service
Airline Deregulation act
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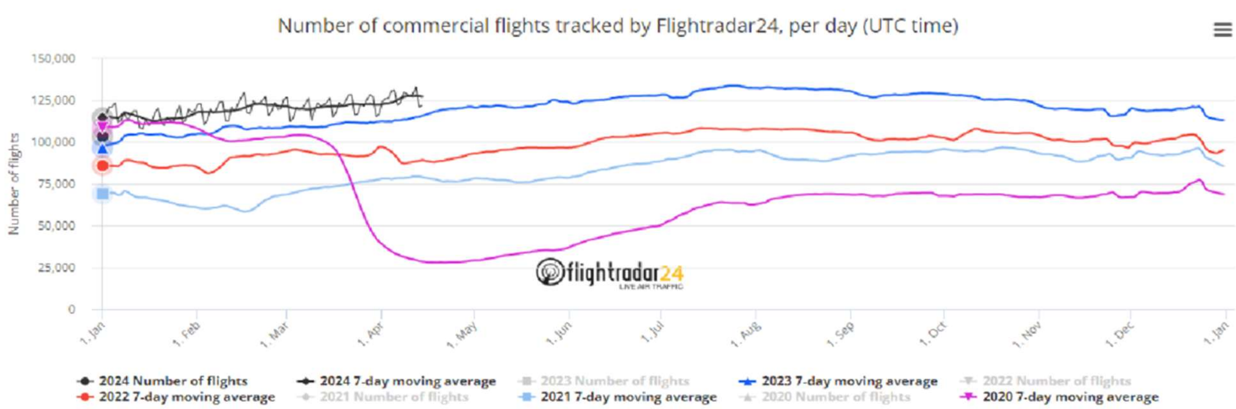
Present drivers of the Aircraft component repair industry

The commercial aircraft component industry is experiencing dynamic growth and even more growth is expected over the next decade. According to Oliver Wyman, the worldwide repair market is estimated to be worth $100 Billion dollars annually. (Prentice, B. DiNota, A. Hayes, L., 2023) The repair market is driven by the size of the commercial airline fleet and the annual hours flown. The bigger the fleet and more hours flown equals more repair revenue. Each day there are more than 120,000 commercial flights flown. (Flightradar24.com, 2024).

Source- https://www.flightradar24.com/data/statistics



In addition to the increase in baseline demand for air travel, one trend that will drive additional repair demand is the Airbus A321 NEO XLR aircraft and others like it. The Airbus A321 NEO XLR is a single aisle aircraft capable of flying up to eight hours in regular operation (Airbus, 2024). Rather than a hub and spoke operation, smaller airlines will be able to fly long haul flights using a narrowbody aircraft. These new aircraft are already in service. This photo shows an Aer Lingus A321 NEO XLR aircraft at Minneapolis International airport in August

2025 as it prepares to depart to Dublin, Ireland as part of its normally scheduled service. More aircraft flying will result in the need for more repair services in the future.

In the following sections we will perform a SWOT analysis of the aircraft component repair industry in its current state. We will also apply porters five forces framework to the component repair industry.

SWOT Analysis

SWOT Matrix	
Critical to Aerospace Industry Cost advantage over replacement Techincal expertise Legacy Support/intelectual property	Regulatory Compliance Burden Capital Intensive Performance Penalties competetive industry
Fleet growth Strong OEM relationships Emerging Markets Digitization	Aging workforce Obsolesence DER developed repairs Geopolitcal risk

Strengths

Aircraft component repair is critical to the success of the commercial aerospace industry. The large variety of components installed on an aircraft combined with the high replacement cost creates the need for component repairs. According to a recent study aircraft component repairs typically cost 40-60% of the cost of new components while delivering serviceable units substantially faster than new unit lead times (PW Consulting Chemical & Energy Research Center, 2025).

The technical expertise of aircraft component repair license holders is a key strength. Each person who is working on aircraft components must: hold an FAA issued repairman license, have 20/20 corrected vision, and must be in a “drugs pool” (Meaning they are prohibited from using recreational drugs and many prescription drugs as well). Each certified repairman must meet with local FAA officials in an interview process to demonstrate their language proficiency, basic math skills, and technical understanding. (FAA, 2024) The incredible knowledge of aircraft component repair license holders is difficult if not impossible to replicate and helps component repair facilities tackle the most difficult challenges.

Aircraft component repair centers are often the last option available for older legacy aircraft. By offering repair services for older components, it can help airlines avoid the costs of upgrading their fleet to newer systems while locking in the business for legacy aircraft repair support.

Weaknesses

Aircraft component repair is a heavily regulated industry. Companies wishing to repair aircraft components must obtain approval from the relevant airworthiness authorities in their country. In the United States the Federal Aviation Administration (FAA) is responsible for granting licenses to each repair facility. Each repair shop must have a repair station quality control and safety management system. The repair shop must demonstrate that they have the capabilities to repair each individual component they support. So rather than simply stating that a shop can repair anything, the shops must specialize in repair of specific types of components that they have demonstrated capability to repair. In addition to FAA oversight, aircraft component repair shops are also audited on a regular basis by airlines, aircraft manufacturers, and foreign aviation authorities. Compliance with airworthiness authority requirements costs money and adds complexity that prevents component repair shops from being nimble.

Aerospace is notoriously capital hungry. The timeline to develop and manufacture a new aircraft takes decades. The Boeing 777X aircraft was announced in 2011 and 15 years later is still one year away from in service operation (Wikipedia contributors, 2025). According to a report by the Aerospace Technology Institute, aircraft manufacturing and component repair is not popular with short term investors due to the long program times and increases the costs of borrowing for aerospace companies (Aerospace Technology Institute & PwC, 2022).

Many of the commercial MRO shops have a guaranteed turnaround time to process a return. The turn times are short- usually within 15-30 days- so that the airlines can keep their spares inventory at a minimum. The longer it takes to turn repairs the more spares an operator must keep in stock. Considering the complexity and sheer volume of components on an aircraft, the manufacturers of commercial aircraft create documents known as master minimum equipment lists commonly referred to as MEL (FAA, 2024). These lists provide guidance on what minimum equipment a commercial airliner can fly with for limited periods of time and with restrictions. This ensures high dispatch reliability without impacting safety. Consider an example of MEL in practice: An Air France Airbus A350 lands in Paris with a report from the crew that one of the three airspeed sensors is nonfunctional. Per the MEL, the airline can dispatch the aircraft with one of the three airspeed sensors inoperative, provided the other two systems are functional. The airline has ten days to remedy the defect. They dispatch the aircraft on a flight to New York. On the return trip the next day to Paris they have the replacement part and engineer ready to perform the removal, replacement, and test of the air speed sensor. Often temporary delays at airports to address a mechanical issue involve a technician diagnosing a problem and filing MEL paperwork stating that the airline knows there is a problem with the plane, and they intend to fix it within the MEL period. In other words, the issue may not have been resolved, but the paperwork has been submitted stating the defect *will* be remedied. If an aircraft needs a specific part, the airline tries to get the aircraft to a base with the replacement parts before the MEL expires. The availability of repaired parts is critical as once the MEL expires the aircraft must not fly again until the defect is remedied. It is common for airlines who work with component repair shops to have some financial penalty provisions into their contract that allow them to fine the repair shop per transaction for each day they are late. Given the high cost of components airlines want to hold minimal inventory. Component repair shops have to either ensure they have sufficient labor and piece parts to meet the market demand, ensure they have exchange units or risk paying large claims. The additional inventory and exchange assets add to the capital requirements of the industry.

Aircraft makers want a vibrant aftermarket for their products. It is easier to sell an aircraft when you can show perspective buyers that there are many suppliers to support their aircraft. Many suppliers suggest competition and cost control, thus reducing the total cost of ownership for an airline. Aircraft manufacturers build this competition into their agreements with suppliers by requiring them to make LRU repair manuals and spare parts available for purchase by airlines and 3rd party repair shops. While this is good for airlines and 3rd party repair shops it requires all repair vendors to tightly control their costs as they are in competition with one another.

Opportunities

The commercial aerospace market is experiencing remarkable growth throughout the world, with some regions like Asia experiencing massive increases in air travel demand. Analysts from *The Economist* project that passenger demand will quintuple in India the coming years (*The Economist*, 2023). To meet this surge, Indian carriers Air India and IndiGo have collectively placed orders for over 1,000 new aircraft, and the Indian government is investing heavily in airport construction and expansion. There are similar expansions in aviation throughout emerging markets. All these new aircraft will have components that ultimately need repair.

Aircraft component suppliers who are selected as the OEM fit often invest in the platform by covering a portion of the development costs of getting the part certified for use on the aircraft. In exchange they get the coveted OEM fit position which offers better aftermarket margins compared with aftermarket products. One of the stipulations OEM fit suppliers are often held to is to agree to a Product Support Agreement (PSA). The PSA defines the rights of the aircraft operator and the responsibility of the OEM supplier. The PSA requires the component supplier to support the fleet regardless of obsolete components for periods of time, often exceeding 30 years. In exchange for the obligations the OEM fit suppliers are given a great deal of information about how the aircraft are used and by whom, which help them further refine their product offerings. Savvy suppliers can use this market position to secure their component repair position from competition.

New changes in technology including AI and additive manufacturing will help component repair shops do more with less labor and costs in the future as we will discuss in later chapters. New technology enables changes that were unfathomable a few years ago and will enable component repair vendors to execute to an increased customer base.

Threats

Like many industries, the commercial aircraft component repair industry has an aging workforce that will be difficult to replace. Another threat to the aerospace component repair industry is the risk of component obsolescence. Most airliners are designed to fly for 30+ years. Many of the subcomponents used in the aircraft LRU face diminishing suppler bases. Take for instance the Tube TVs used in the displays of most Boeing 757/767 in service. There are only a small handful of companies left in the world who still make tube TV's and can make them to aerospace standards. Another threat to the component repair industry is tied to the development of 3rd party repair shops overseas. The last threat is the risk of geopolitical destabilization. Given the long lead times to develop new aircraft programs and the long lead times for spare components, geopolitical risk from tariffs and embargoes make it difficult for companies to plan for the future. This paper will discuss how to counter these threats in later chapters.

Porters Five Forces Aerospace Component Repair

Porter's Five Forces is a strategic tool used to assess the competitive dynamics within an industry. It analyzes the key factors that influence the level of competition and, by extension, the potential profitability of a business. The more intense the competition within an industry, the greater the pressure on profit margins. The five force threat of new entrants, threat of substitutes, bargaining power of suppliers, bargaining power of buyers, and competitive rivalry serve as critical indicators of competitive intensity. This paper applies Porter's Five Forces to the aerospace component repair industry to evaluate its competitive landscape and provide key insights into the industry's structure and challenges.

Threat of New Entrants

The threat of new entrants in the aerospace component repair industry is relatively low. This is largely attributable to the inherent characteristics of aircraft development. Aircraft manufacturers engage in risk-sharing agreements with their primary suppliers, who finance component development and deliver products to the final assembly line at competitive prices. In return, these manufacturers grant their primary supplier's control over the aftermarket for spare parts and repair support, subject to contractual conditions. Typically, prime suppliers are contractually required to produce a Component Maintenance Manual (CMM), which details the procedures for repairing and returning components to service. Additionally, they must supply piece parts and tooling to airlines or third-party entities to enable in-house repairs. Regardless of who performs the repair, all parties must ultimately rely on the prime supplier for access to piece parts, CMMs, and tooling.

If the prime supplier decides to engage in the component repair business, they can adjust piece part pricing to discourage third-party repair operations. In instances where third-party component repair vendors exist, their participation is contingent on the choice of the prime supplier to support it. Moreover, aircraft manufacturers face significant costs and challenges when considering the replacement of prime suppliers, effectively locking in the component repair market for the prime supplier. Ultimately, it is at the discretion of the prime supplier to determine whether to participate in the component repair business or to focus solely on new component production by supplying piece parts. There has been recent examples of 3rd party repair shops developing overseas. These 3rd party shops, while required to purchase piece parts from the component OEM and are thus low risk pose a particular problem for aircraft component makers. Particlerly that their domestic component repair facility has to compete with 3rd party shops overseas. The 3rd party has to purchase the piece parts at inflated rates compared with an internal shop, but if the overseas labor is substantially cheaper than domestic labor the cost differential will disappear. This is not a major concern yet but could be an issue in future years as the domestic US labor force ages out and costs rise.

Threat of Substitutes

In the aerospace component repair industry, the threat of substitutes is a moderate risk. There are two common types of substitutes that go by the industry acronyms DER and STC. A designated engineering representative (DER) is a person or organization approved by the FAA or local airworthiness authorities to return a product to service using alternative means. A DER could reverse engineer a component and come up with their own repair procedure provided the component gives the correct output per a given input. It is up to the end user airline to determine if this part is acceptable for use on their fleet. Given the need for extensive engineering evaluation, only the most capitalized airlines have the appropriate engineering suitable to analyze these products. As these components are not the original equipment manufacturer (OEM) fit and there may be radiality concerns, DER repairs are priced well below what a prime supplier would offer. Another substitute would be a component approved under a Supplemental Type Certificate (STC). These are parts created by a supplier who is not the OEM fit vendor. An STC supplier develops a product for use on a particular aircraft without the approval or support of an aircraft manufacturer. The STC supplier must get their products approved for use on the aircraft by the FAA or local airworthiness authority. The market penetration of STC components on commercial aircraft are limited.

The integration of DER and STC components presents only a moderate risk to prime suppliers. Approximately 45% of the global commercial aircraft fleet is leased, and lease agreements frequently include provisions prohibiting the use of DER or STC components. These restrictions are designed to protect the residual value of the aircraft, thereby limiting the market for DER and STC components to a small segment of the non-leased commercial market that owns their aircraft and have the engineering resources needed to use these alternates.

Bargaining Power of Suppliers

In the post-COVID recovery period, the aerospace supply chain has undergone intense scrutiny, with prime suppliers facing significant challenges related to sub-supplier reliability and availability, posing a moderate level of risk. In the United States, one critical issue is the decline of foundries producing investment castings, which are essential for aerospace components and their repair. Research from the Federal Reserve Bank of St. Louis indicates that employment in foundries has decreased by 50% since 1998, leading to increased competition among aerospace companies for limited foundry capacity. (Federal Reserve of St. Louis, n.d.) This competition becomes even more intense when considering specialty metals, such as beryllium copper, which are crucial in aerospace manufacturing and repair.

Similarly, the market for circuit card assembly vendors is highly competitive. To illustrate, consider the difference between aerospace and consumer electronics demand. Approximately 8,000 Boeing 737 aircraft are currently in operation, with another 5,000 on order. A prime supplier producing a component for this aircraft, requiring a circuit card, may need around 20,000 circuit cards for initial production, plus another 10,000 for repairs over a 30-year lifecycle, totaling 30,000 units. This volume is relatively low compared to consumer electronics, where manufacturers can produce circuit cards in million-unit runs. Circuit card manufacturers prioritize high-volume production to maximize economies of scale and minimize setup costs, making aerospace orders less attractive. As a result, aerospace companies must pay a premium to compensate for the costs associated with reconfiguring production lines for lower-volume circuit card manufacturing.

Bargaining Power of Customers

Airlines and other aerospace customers like the federal government can leverage their size and purchasing power to negotiate favorable contracts. The bargaining power of these customers is high. In response to these customers, vendors must come up with offers that meet the financial needs of the customer while still protecting margin. One strategy is a "power by the hour" type agreement where the customer prefunds their maintenance with the prime suppliers. This helps the airline even out their costs and locks up the customer from competition.

Competitive Rivalry

The aerospace component market is competitive, with rivalry among suppliers. To secure a position on an aircraft platform, prime suppliers must demonstrate exceptional delivery performance and engineering expertise. Failure to meet these standards can result in exclusion from future programs, significantly jeopardizing long-term business prospects. Most commercial aircraft manufacturers implement supplier ranking systems, which guide procurement teams in reducing engagement with underperforming suppliers. A recent example is Boeing's acquisition of Spirit AeroSystems, which stemmed from Spirit's ongoing quality control issues. Persistent manufacturing defects, including those linked to the Alaska Airlines door blowout, ultimately led Boeing to take control of the company to address and rectify these quality concerns. If a company is excluded from participating on future aircraft programs they not only lose the new part business but the coveted OEM aftermarket position.

Key Takeaways and Conclusion

The application of Porter's Five Forces to the aerospace component repair industry reveals several key takeaways. The prime suppliers maintain significant control over the repair markets contracts, access restrictions, and pricing strategies. Another takeaway of this analysis was the risk of supply chain on profits. The reduction in sub component suppliers poses a risk to aerospace companies as they begin competing with others for supplier capacity. This analysis also revealed the importance of working with customers to find innovative solutions to help them control costs without jeopardizing revenue or losing a customer to an alternative repair vendor.

Force	Competitive Analysis
Threat of New Entrants	**Low –** Prime suppliers are protected by contract. Further new suppliers must establish FAA credentials and are forced to use OEM components limiting potential margins and discouraging entry.
Bargaining Power of Suppliers	**Moderate –** Suppliers of sub components are becoming increasingly scarce and the aerospace industry with low run volumes is not attractive.
Bargaining Power of Buyers	**High –** Airlines are able to leverage their buying power to negotiate favorable pricing.
Threat of Substitutes	**Moderate –** DER and STC components have limited exposure as they are barred from use on leased fleets. The engineering expertise required to use these parts is reserved for only the most experienced airline engineering teams.
Competitive Rivalry	**High –** The industry is highly competitive, with OEM's competing for the opportunity to become the prime supplier and win the aftermarket.

Future of the Aircraft Component Repair Industry

The future looks bright for the aircraft component repair industry. Analysts expect that by 2034 the commercial demand for MRO is expected to exceed 125 billion dollars. (Prentice, B. DiNota, A. Hayes, L., 2023). With a massive backorder of aircraft and a large in-service fleet the table is already set with baseline demand is already in place or on order. Given that we already have a good idea of the future demand we will focus on how to prepare for this increase in demand.

To remain competitive in the future, the commercial aircraft repair industry must address several critical challenges. These include increasing shop throughput through additive manufacturing and design changes that reduce human input. The industry will also need to streamline training programs to accelerate effective employee onboarding. Embracing artificial intelligence and automation will be essential, as will improving shop flow through predictive analytics. Additional priorities include enhancing ERP systems, advancing digitization, and transitioning to paperless operations. Finally, the industry must strengthen supply chain resilience and maintain support for legacy aircraft as fleets continue to age.

Aerospace Human Resources

The Indian aerospace market is experiencing remarkable growth. Analysts from *The Economist* project that passenger demand will quintuple in the coming years (*The Economist*, 2023). To meet this surge, Indian carriers Air India and IndiGo have collectively placed orders for over 1,000 new aircraft, and the Indian government is investing heavily in airport construction and expansion. There are similar expansions in aviation throughout emerging markets This paper will consider several facets of HR management that aerospace companies will need to employ to be successful in the years to come. To meet the demand for commercial aerospace products the aerospace companies Human Resources teams will need to work thoughtfully to ensure it has a strategy for future success, the aerospace industry is counting on it.

Workforce Planning

To meet the needs of their customers aerospace manufacturers will need to be able to produce more products faster than ever. To do so they need strategic workforce planning. The three critical aspects of workforce planning that pertain to aerospace manufacturing are the ability adapt to future skill needs, creating a talent pipeline, and successful employee retention.

Ensuring there are enough candidates will be a strategic challenge. As the demographics in the US change companies must adapt and add as many talent pipelines as possible, and reconsider what would make a good candidate. According to a study in *The Harvard Business Review,* 62% of careers were less likely to require a college degree than in 2017 (Fuller, J. & Sigelman, M., 2021). BAE, a UK based aerospace and defense contractor has a program to onboard youth without a degree and provide specialized training to learn while they are working. In 2024, they had 20,000 applicants for the 1,300 apprentice roles they were looking to fill (The Economist, 2024). Creative programs like that used by BAE can help ensure a strong talent pipeline of motivated employees. BAE is not unique in this scheme. Target and Amazon also have programs to develop candidates with the specific skills they will need to be successful in those companies (McRae, E. R., et. al., 2024). The nonprofit organization called Opportunity At Work estimates that there are more than 70 million workers in the US that are considered STARS- Skilled Through Alternative Routes. These are workers that do not have college degrees but do have relevant experience and are ready for higher wage work. Actively seeking out talent that would have previously been considered unconventional can help HR leadership ensure the company has a robust workforce.

HR leaders will need to help develop management policies and tools that help ensure leaders are successful custodians of talent. According to *The Economist*, the cost of replacing employees is equal to 35% of their annual pay. Companies that make specific efforts to retain staff have a 71% chance of keeping employees at least three years compared to 45% for companies that do not actively engage in retention activities (The Economist, 2024). HR talent retention programs should be holistic in design so that training and incentives encourage the employee to stay with the company (Mello, J. A., 2019 P. 447). Employes who learn and contribute should also be compensated accordingly. A clear and equitable compensation package can significantly improve employee retention. Studies show that when companies fail to communicate their compensation strategy effectively, employees are less motivated, feel undervalued, and are more likely to leave the organization (Mello, J. A., 2019 P. 360). Failure to retain talent will likely result in failure to meet the specific business output goals.

The Grey Elephant in the Room

In the US, many senior engineers and technical staff are set to retire over the next decade. While the company has historically managed retirements smoothly, the volume of upcoming departures makes this situation unprecedented. The loss of so much experience and institutional knowledge could impact operations, innovation, and productivity. To address this, proactive planning and knowledge transfer strategies will be essential. Preparing for this wave of retirements will require identifying key roles, developing succession plans, and capturing the expertise of retiring staff before they leave. Commercial aircraft are designed to operate for 30 years or more, meaning many airliners still in service feature older technology, such as CRT displays on the flight deck. New workers entering the

Tube TV displays in an airline cockpit industry may have little to no personal experience with tube TV’s or the intricacies of maintaining these systems. Because thousands of flights still rely on these displays every day, it is crucial for senior employees to transfer their knowledge to the next generation of engineers and technicians. Without effective knowledge sharing, the risk of maintenance errors or delays increases, potentially impacting flight safety and operational efficiency. Companies must prioritize documentation and mentorship to ensure critical expertise is preserved.

Employees can look at drawings and maintenance manuals, but “tribal” knowledge continues to persist as there are some aspects about products that do not fit easily into manuals. To capture “tribal” knowledge, the World Bank HR Management team created a program called Smart Lessons that captures knowledge in the form of human stories. This type of learning is native to younger generations who learn via visual mediums such as YouTube and provides a method to preserve this hard-earned knowledge. (Morris, S., & Oldroyd, J. B., 2009).

Human Resource leaders should establish mentorship programs to ensure the seamless transfer of knowledge from retiring employees to new workers. By pairing experienced employees with new hires, mentorship can accelerate skill development, fostering confidence and competence in younger team members. This approach will also enhance collaboration, reduce the risk of operational disruptions, and maintain high standards of quality and innovation. Investing in mentorship programs will ultimately support business continuity, and will ensure that the airline industry can be supported in the years to come. Research by Harvard Medical School professor George Vaillant shows that older employees who mentor younger colleagues are more likely to be satisfied with their jobs, improving retention rates. Younger employees gain valuable skills, boosting their job performance and loyalty. Companies that promote these mentorships benefit from increased productivity, knowledge retention, and overall employee morale, leading to stronger business outcomes. (Freedman, M., & Stamp, T., 2016). According to a recent study 25% of the workforce in Aerospace manufacturing are at or beyond minimum retirement age (Berckman, 2024). When retirees go, they take their knowledge with them, and they are becoming harder to replace with new long-term employees. In 2023, aerospace manufacturing companies had a 13% turnover rate, which is much higher than the manufacturing industry average of 3.8%(Beckerman, 2024). As a result of high turnover and an aging workforce, many repair stations are looking to automation not as a luxury, but as a necessity to sustain output and maintain compliance without overburdening their limited human resources.

Embracing Automation

In addition to the workforce challenges discussed, component repair shops in the future will need to scale up to meet the growing needs of the flying public. By embracing automation in work tasks, it should be possible to replace the output of lost workers, train new ones faster, and scale to meet the future aviation demands. There are three areas in Component repair where automation can have very positive near-term impacts, these are in inspection support, decision support, and administration support.

Component inspection can be very labor intensive. Visual inspection of large surfaces often requires a technician to look at a surface closely under different light angles often at unusual or uncomfortable angles. There are several companies who offer component inspection technology for aircraft. According to the Royal Aeronautical society at the airframe lever they are able to reduce inspection times by 90% without the need for additional labor (Read, 2023).

Using automation and AI in decision support can greatly help cut down on the time it takes to troubleshoot and repair components. For an MRO to be successful in the future they should work to automate decisions as described above. According to a recent study in Aviation Week there are several novel ways that companies are using AI and machine learning. For example, Air France has developed a tool that technicians can use to find all the documents and supporting materials needed to perform repairs. They estimate that this saves them at least one hour per component repair (Bjerregaard, 2025).

ERP management

To provide world-class customer service in a global environment, repair shops must maintain constant, real-time communication with their customers. One effective way to achieve this is by leveraging digital customer portals such as Aeroxchange. Aeroxchange enables automated, 24/7 updates between MROs and airlines, allowing customers to receive regular repair status notifications without the need for manual intervention. Acting as a centralized hub, Aeroxchange collects electronic order updates from suppliers and translates them into standardized electronic business documents that are compatible with the customer's ERP system (AeroExchange, n.d.). This centralized approach simplifies onboarding new customers, as the ERP integration is already in place. By using Aeroxchange, MROs can redirect their limited human resources from routine updates to addressing more complex, value-added tasks. Additionally, it enhances transparency and customer satisfaction by ensuring accurate, timely information is always available. In an industry where downtime is costly, this level of connectivity is no longer a luxury—it's a competitive necessity.

Going Paperless

Going paperless offers significant operational and financial benefits to commercial component repair providers. Traditional paper-based systems are labor-intensive, error-prone, and slow down approvals. By digitizing maintenance records, work instructions, and quality forms, repair shops can streamline operations, improve data accuracy, and reduce administrative overhead. Electronic recordkeeping enables real-time access to maintenance history, part traceability, and technician certifications, which enhances efficiency on the shop floor and minimizes downtime. This digital transparency also improves collaboration across departments and sites, creating a more agile and responsive maintenance organization.

The FAA provides clear guidance supporting electronic recordkeeping and paperless operations. According to FAA Advisory Circular 120-78A, titled “Electronic Signatures, Electronic Recordkeeping, and Electronic Manuals,” the agency permits and encourages the use of digital systems provided they meet regulatory requirements for security, traceability, and data integrity (FAA, 2016). Repair shops must ensure that digital signatures are legally binding, that data is backed up and protected against unauthorized access, and that electronic records are retained and retrievable for regulatory audits. Compliance with these standards enables repair shops to fully replace paper documentation while maintaining airworthiness standards, ultimately modernizing their quality systems without sacrificing regulatory alignment.

From a financial perspective, going paperless offers both cost savings and competitive advantage. Eliminating physical paperwork reduces printing, storage, and labor costs while accelerating workflows and shortening aircraft turnaround times directly benefiting customers. Digital systems also reduce the risk of lost records or compliance errors, which can result in costly delays or penalties. Moreover, repair shops that offer real-time visibility into repair status and digital access to compliance documentation create added value for airline customers, improving transparency and trust. In a competitive and capacity-constrained market, paperless operations help differentiate providers while unlocking measurable operational efficiencies.

Predictive analytics

Predictive analytics is becoming an essential tool for commercial repair shops to forecast shop demand with greater accuracy and confidence. By analyzing historical repair data, fleet utilization trends, environmental conditions, and failure modes, predictive models can estimate when specific components are likely to require maintenance or overhaul. These insights allow repair shops to proactively manage labor, tooling, and parts inventory, ensuring they have the right resources in place ahead of time. This not only helps balance workloads across high- and low-demand periods but also improves turnaround times and reduces unplanned work, which is especially important in maintaining service level agreements (SLAs) with airline operators.

The international Air Transport Association (IATA) consolidates removal data from participating airlines in a program called Aircraft Maintenance Cost Data Exchange (MCX). The goal of MCX is to consolidate the worldwide fleet of maintenance cost and component reliability (IATA, n.d). Combining the IATA MCX data with in-house removal data should give repair shops a very clear picture of the fleet component removal data. This data can then be used to perform a predictive analysis of the aircraft fleet.

Using predictive analytics as a sales tool also enables repair shops to move toward more contract-based, subscription-style service models. Rather than reacting to failures or operating solely on a time-and-materials basis, repair shops can offer customers proactive maintenance planning and guaranteed turnaround times, backed by data. These predictive service agreements appeal to airline operators looking to minimize downtime and streamline maintenance costs. With the right data infrastructure and analytics capabilities, repair shops can not only optimize their own operations but also create differentiated, value-added offerings that improve customer retention and drive long-term growth.

Blue Ocean

As we have discussed, the future of aircraft component repair will be a future of unprecedented fleet size and demand for repair services. One way for component repair vendors to create a blue ocean for themselves will be to ensure that they have a supply chain that is ready for the future. In doing so they will be able to differentiate themselves from competitors due to faster turn times and the ability to support aging aircraft fleets, which in addition to being differentiators will also demand a premium price. This section will review two key areas in supply chain where component repair facilities can differentiate themselves.

Metal Casting Supply Chain Broadening

Beryllium copper presents serious health hazards, including a restrictive lung disease called Berylliosis, which can occur if dust from grinding or machining is inhaled. It is also recognized as a carcinogen (Wikipedia Contributors, 2025). Due to these risks and the stringent safety regulations required, only a small number of investment casting facilities in the United States are willing to pour this material (Aero Metals, n.d.). Although metal 3D printing offers a modern alternative, it remains cost-prohibitive for high-volume production compared to traditional investment casting. Until 3D printing achieves cost parity with casting, Component repair shops should focus on diversifying their supply base. Engaging multiple casting suppliers can help mitigate the risk of part shortages and ensure more reliable long-term component availability.

Pouring an Investment Casting

Obsolescence Management

All aircraft systems require a great deal of engineering labor hours to create, test, and finalize component configurations. In addition, all systems must undergo a series of rigorous, independently conducted environmental qualification tests to ensure they function reliably under all operational conditions. The engineering hours and testing is costly, making it more economical in many cases to continue producing outdated aviation components rather than redesigning and requalifying new ones. As a result, many aircraft in service today still rely on obsolete electronics, such as Pentium processors and cathode-ray tube (CRT) displays. However, the availability of these outdated components is steadily declining. This creates a growing challenge for repair providers, as parts shortages become more frequent when replacements are needed for aging systems.

In the inset photo you can one of the avionics racks on an airbus A330. Each of these removable boxes is an avionics component such as a radio or computer that is comprised of several circuit cards. Each of these circuit cards is populated with hundreds of individual components such as diodes, resistors or chipsets. If any of these individual components is no longer available then the avionics component cannot be repaired and must be redesigned to use available parts. Given that commercial aircraft are designed to last at least 30 years component obsolescence is a major problem. Most chip suppliers want to keep up to date with the latest trends and therefore do not wish to make obsolete chips in the low quantity needed to sustain aircraft repairs. This has been a persistent problem for the aviation community and will increase dramatically in the years to come as aircraft become more advance and use more electronic

components. This is one area where aircraft component repair shops can use new tools like AI to create a Blue Ocean that separates themselves from competitors.

One emerging solution to address this challenge is the use of AI. Several companies now offer AI-powered services to redesign circuit cards with updated, readily available components. These systems often integrate with product lifecycle management software to ensure that redesigned boards use components with long-term availability. This approach allows suppliers to create alternative PCB designs much more quickly and cost-effectively. In fact, a recent study found that AI-assisted PCB redesigns can be completed up to ten times faster than traditional methods (Fouche, 2025). Once a new part is developed it must be qualified for use on an aircraft using procedures described in specification RTCA-DO-160 (RTCA, 2025). The component is subjected to environmental stresses such as simulated lightning strikes, salt fog exposure and harmonic vibration. The qualification testing of components is where the cost and delays come in. Testing is typically performed by an independent laboratory. If a unit fails during testing it must be redesigned and the environmental testing begins again. AI can be used to simulate the environmental stress testing and predict failures so that they can be corrected before testing to ensure that the test articles have a 100% pass rate (Ansys, 2025). AI can also be used to simulate demand so that a repair shop can simulate anticipated demand of components that are known to be going obsolete soon to purchase enough inventory to support the fleet. The use of new technologies like AI will help a repair shop differentiate itself from competitors and will create a Blue Ocean for the companies that engage with this technology.

Conclusion

From humble beginnings, the aircraft component repair industry has developed into a large industry that exists in a symbiotic nature with aircraft manufactures. The future of commercial aircraft component repair will be defined by the ability of component repair to adapt to rapidly evolving operational demands through strategic technology adoption. As the industry faces an aging workforce, increasing aircraft complexity, and unprecedented fleet growth, component repair shops must implement solutions that enable scale, precision, and agility. Automation, predictive analytics, digital workflows, and supply chain resilience are no longer optional—they are fundamental to sustaining operational performance and regulatory compliance in a high-pressure environment. Each of these capabilities not only addresses immediate challenges but also builds a foundation for long-term competitiveness and service excellence.

By embracing a forward-looking operations strategy, repair shops can transform traditional pain points into opportunities for differentiation and growth. Predictive tools enhance planning and customer engagement; automation offsets labor shortages and drives efficiency; paperless systems improve traceability and compliance; and resilient supply chains ensure continuity in a volatile global market. Together, these changes create a more intelligent, responsive, and sustainable repair ecosystem. Organizations that invest in these technologies today will be best positioned to lead tomorrow, supporting airlines as trusted partners while delivering faster, safer, and more cost-effective maintenance solutions.

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