BCG AÉRO MONTRÉAL

IN COLLABORATION WITH

Développement économique Canada pour les régions du Québec
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Aerospace and AI

Bringing together Montreal's distinctive strengths

Foreword

Boston Consulting Group (BCG) is a global strategy consulting firm that works in Montreal and around the globe with multinational companies to solve complex challenges.

Aéro Montréal asked BCG to assess the potential opportunity for artificial intelligence in Montreal's aerospace industry. In this report, we use data collected through industry interviews and proprietary surveys to understand how Montreal's aerospace industry is currently approaching artificial intelligence and to identify the hurdles to more widespread adoption. We also assess the potential impact that artificial intelligence will have on the sector. In the last section of the report, we lay out specific company-level and industry-level action plan.

Executive Summary

Artificial Intelligence, which has already profoundly changed many industries, is poised to transform aerospace next. In retail, early AI adopters gained significant competitive advantage, changed customer expectations and transformed how the industry operates. In automotive, the development of autonomous vehicles and mobility-as-a-service is proving a major disruptive force. Aerospace companies are relatively late in adopting AI, but the shift has begun and some companies have started launching AI initiatives. We anticipate a much larger wave of AI-driven innovation is on the way.

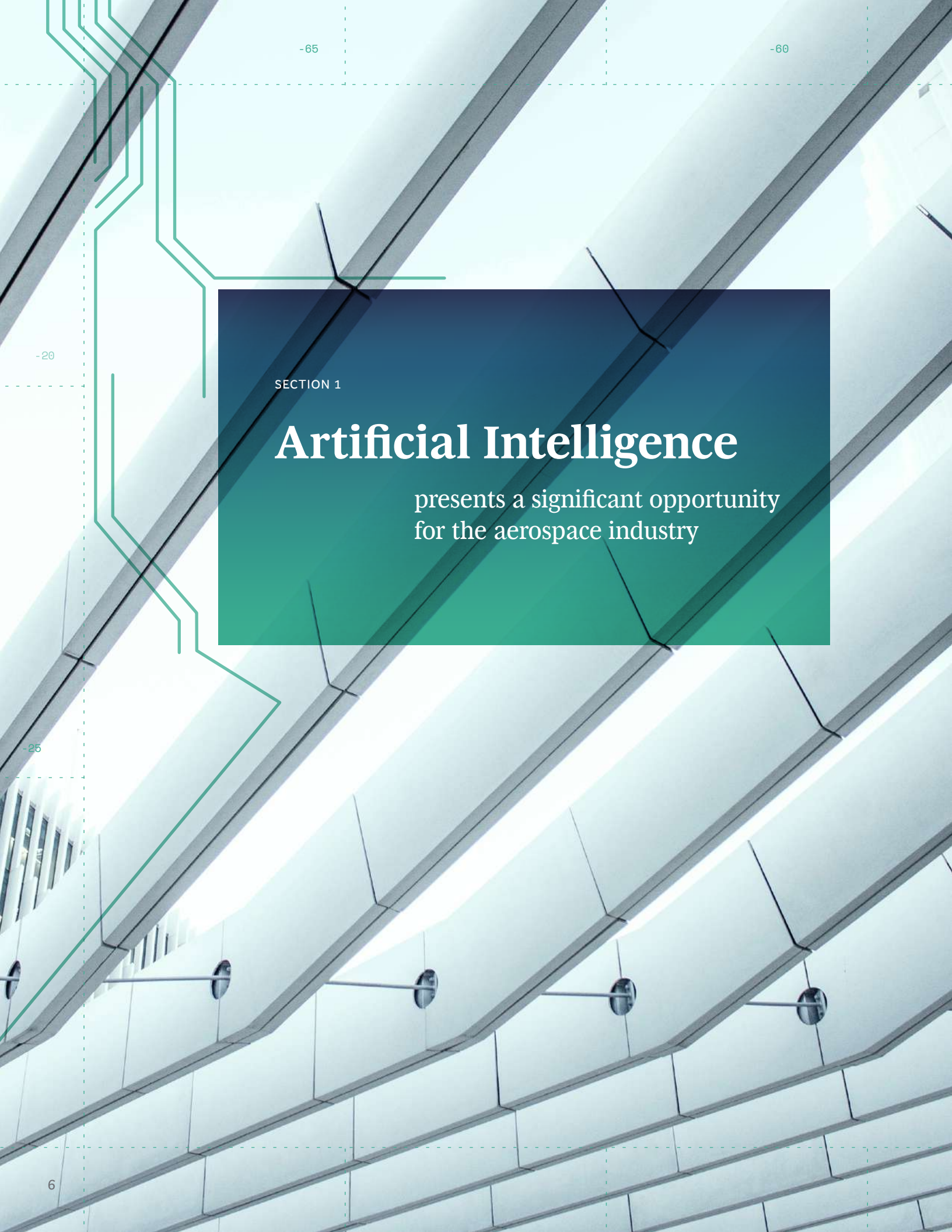
Montreal is well positioned to become a global leader in this emerging space. We estimate there is an opportunity to create $3-4B in total industrial value over the next five years by developing AI for aerospace in Montreal. The city is the world's third largest aerospace hub and home to world-class AI research labs in fundamental and applied research of both machine learning and optimization. Yet other than some individual industrial projects and a handful of partnerships and pilot programs to bring together Montreal's aerospace and AI sectors, the metropolis' potential has been largely untapped.

To live up to this potential, Montreal stakeholders need to do much more. Aerospace companies that have already started to experiment with AI need to pick up the pace and get ready to scale up. Companies that have not yet started to explore AI need to mobilize, digitize, and develop the right capabilities to adopt AI.

AI-focused companies in Montreal can tap into significant, local industrial demand for AI by devoting more resources to prototyping and commercialization efforts for aerospace applications. The aerospace and AI communities need to come together to help SMEs scale-up, share best practices with one another, and nurture talent to create a world-class hotbed for AI and aerospace innovation.

Artificial Intelligence will transform the aerospace industry. Given Montreal's strengths in aerospace and AI, the metropolis is well positioned to be a global leader of this transformation. But in order to do so, Montreal's aerospace and artificial intelligence sectors must mobilize and work together.

Contents



SECTION 1

Artificial Intelligence

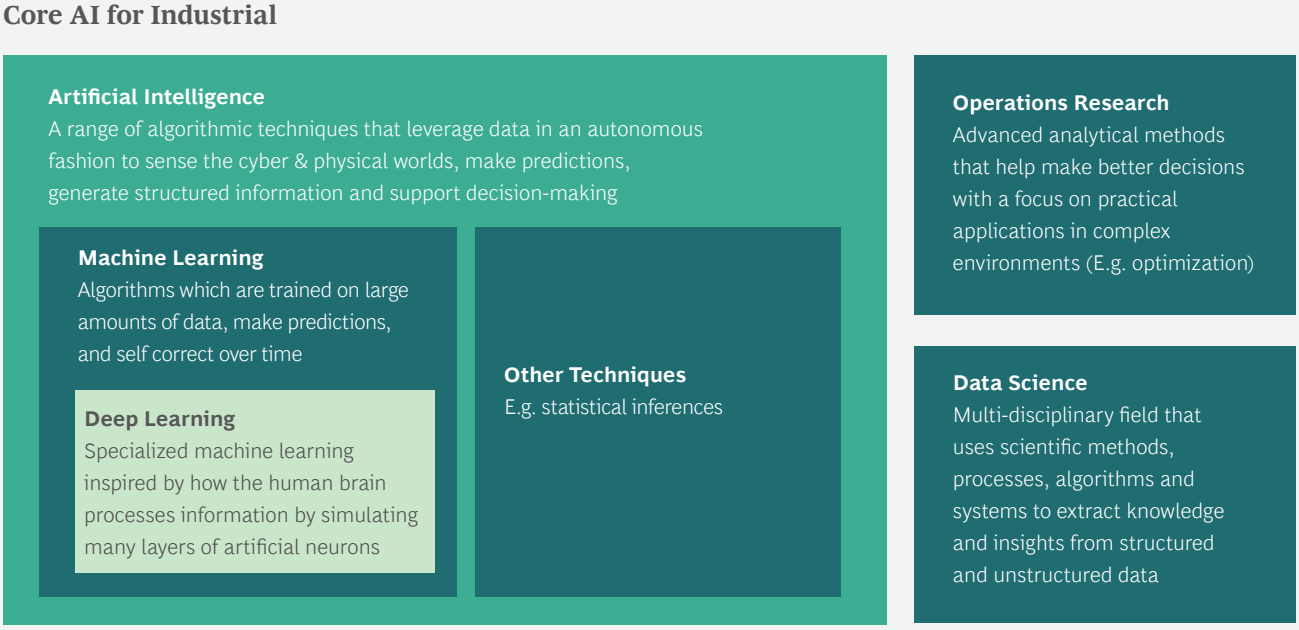
presents a significant opportunity for the aerospace industry

There's a lot of exaggerated hype around artificial intelligence (AI), but there is also no denying that AI is revolutionizing the way companies do business. In recent years, we have seen a proliferation of technological breakthroughs in AI that has led to disruption across many industries.

Broadly speaking, AI is a range of mathematical and computer science techniques that simulate cognitive processes like learning, reasoning, and problem solving. There are many ways to define AI ranging from broad power (narrow, super, etc.), to functionality (reactive, theory of mind, etc.), to the underlying techniques (statistical inference, symbolic, machine learning, etc.).

Machine learning is the dominant form of AI technique today. It's being applied successfully in a number of use cases, from natural language processing to computer vision to making predictions and recommendations. Machine learning is frequently combined with other advanced analytics disciplines such as operations research and data science in industrial applications, as figure 1 illustrates.

FIGURE 1 | **AI and Advanced Analytics for Industrial applications**



Though much of the foundational mathematical science behind AI was developed decades ago, AI applications are gaining traction now as the volume of data has mushroomed. AI requires massive amounts of data that have only become available in the last decade or so. Storage capacity and processing power have increased exponentially while their costs have dropped. High-speed internet has become faster and more affordable, enabling widespread adoption of cloud-based applications, including AI solutions. The creation of flat structure data lakes further supported operational applications of AI, while the development of deep learning, notably for image recognition, has opened up new, practical applications for AI.

AI is also becoming more and more accessible, thanks to open source APIs and platforms. It is increasingly easy for committed companies to access and adopt AI. The most complicated applications still need expert developers, but tools such as coding libraries and data handling make it possible for companies and individuals to implement AI without having to start from scratch. This democratization allows more people and companies to leverage AI, accelerating its growth.

AI adoption varies across industries

Companies in all industries are now adopting AI, though adoption rates vary depending on the sector. Some, such as retail and financial services, have already been using AI for a while, whereas others, such as aerospace, are in early stages. There are four main factors that affect the rate of adoption.

- **Frequency of customer interaction:** industries that interact more frequently with their customers tend to generate more data, creating more opportunities for AI. Repeat interactions also offer more opportunities to use AI-generated insights to influence customer behavior.
- **Value of uncertainty:** every industry faces uncertainty, but companies that face serious, material impact from being wrong (e.g. insurance) benefit most from using AI to analyze risk, trends, demand, or consumer preferences in order to make predictions.
- **Speed of decision:** industries that are accustomed to having to make quick decisions in order to seize an opportunity are more likely to benefit from automating these decisions using AI. AI adds value by making these decisions more informed.
- **Structural flexibility:** companies need to be flexible in order to test, implement, and scale up AI applications. Some structural factors that affect how flexible a company can be include: how adaptable the supply chain is; the typical timeframe for critical business decisions (days, months, years or decades); how capital intensive the sector is; whether or not there are significant regulatory or safety constraints.

The retail industry, which has been an early AI adopter, scores high on all four of these factors. Retail companies have frequent customer interactions, giving them opportunity to amass and monetize customer-related data, such as number of transactions or internet search history. Retail companies also need to make a lot of quick decisions (e.g. demand forecasting at stock keeping unit level) that could, if wrong, materially harm the company's profitability. Using AI to make these decisions creates a considerable competitive advantage. Finally, the retail industry has a high structural flexibility, with a relatively simple supply chain and low capital intensity compared to other industries. The automotive industry is showing traction on AI adoption but at a slower pace.

The automotive supply chain is more complex and capital intensive and the industry is more regulated, leading to lower structural flexibility. Incumbent automakers also do not have as many interactions with their customers and therefore have fewer data points and opportunities to monetize this data.

The aerospace industry is still further behind on AI adoption for similar reasons. Aerospace companies are generally more distant from the individual customer and interact less frequently with them, with the noticeable exception of airlines. This translates into smaller datasets, making it difficult to train machine learning algorithms. Aerospace companies generally don't face many few split-second decisions and don't need to use AI to make informed material decisions.

Where aerospace industries really score low compared to the retail and automotive industries is on structural flexibility. The aerospace industry faces significant regulatory and safety constraints, a complex supply chain, heavy capital expenditure requirements, and long business cycles. All these elements tend to slow AI adoption. That being said, certain sub-sectors of the industry, namely airlines and airports, have similar attributes to the retail industry making them better candidates for faster AI adoption.

Slow AI adoption in aerospace does not mean that the potential isn't there. Despite these obstacles, several leading aerospace companies have started experimenting with AI, especially in the aftermarket.

FIGURE 2 | **AI use case maturity across industries**

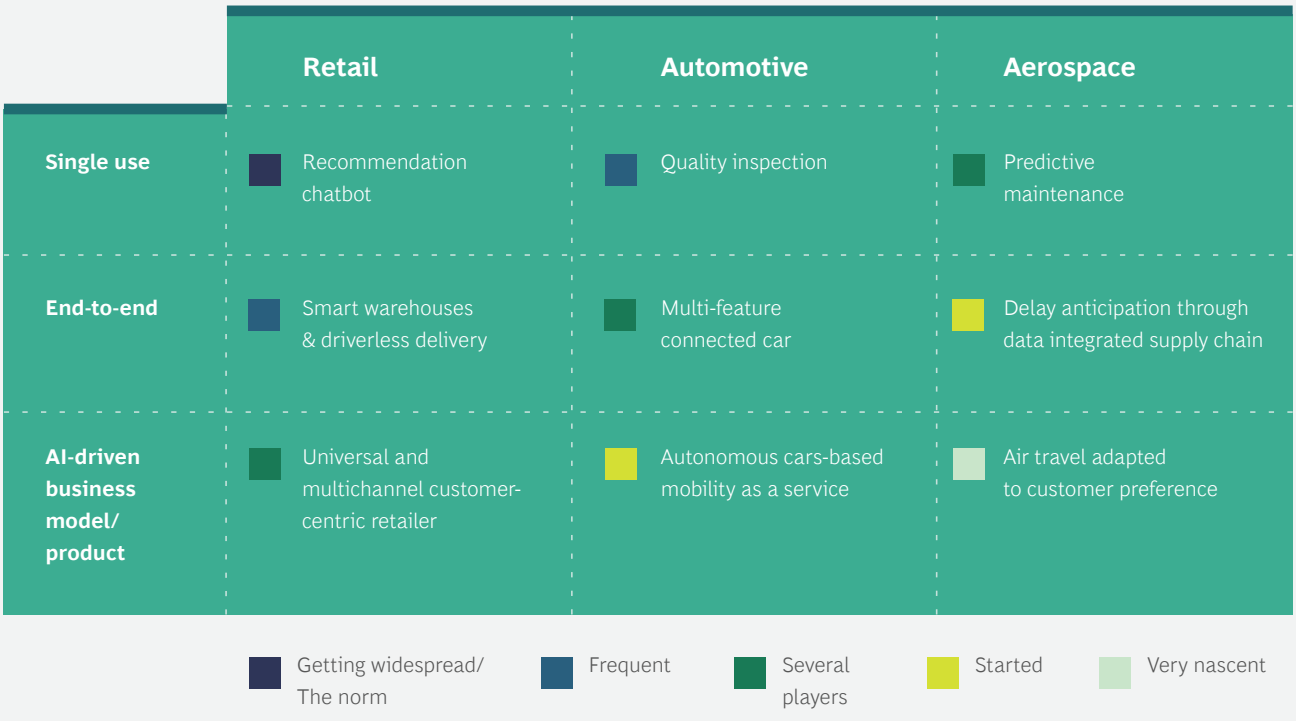


Figure 2 shows several illustrative examples of the path to AI adoption taken by incumbent companies.

Industries generally start their path to AI adoption with single use applications (e.g., predictive maintenance), as shown in figure 2. As those applications proliferate, companies move into more complex end-to-end applications that span different parts of the value chain. An example of this would be an application that links a predictive maintenance algorithm to a program that orders parts, manages inventory or suggests design improvements.

At the other end of the spectrum are AI-driven business models. Because these often require a complete re-design of process and value chains, AI-driven business models are usually developed by startups or new entrants and can be very disruptive to the industry. Incumbent companies can also develop new AI-driven business models. By understanding how other industries have adopted AI, we can predict how AI will develop in aerospace.

Fast AI penetration in retail

In the retail industry, both new entrants and incumbents have been driving AI adoption. AI-enabled newcomers such as Amazon forced the industry towards customer centricity. In parallel, incumbents have adopted AI in several areas of their value chain to adapt to market disruptions and remain competitive.

FIGURE 3 | **AI use cases in Retail**[1]

Amazon rapidly built scale using online as a new fulfillment model. It thereby established an individualized relationship with its customers through its website and application, and deepened this relationship by using AI. Amazon's AI-driven recommendation engine has been key to tailoring the shopping experience for each customer. Amazon also uses AI to make data-driven decisions more efficient. For instance, using AI to track and deploy inventory throughout their complex supply chain.

Amazon's success forced the entire industry to become more customer-centric and shift away from the traditional category-centric approach. Incumbents are now using AI to better understand their customers. Burberry, for example, is using data analytics to help sales assistants in the stores deliver more personalized advice to customers based on their history of in-store and online purchases.

Amazon's success also pushed incumbent retailers to use more data analysis in their decision-making processes—what to sell, how to price, how to promote or where to deploy inventory. Zara is using AI to analyze sales data, forecast demand, and fine-tune production.

The AI revolution enabled faster, more personalized service in the retail sector, influencing customer habits in the process. Many consumers now expect this kind of personalization for all their purchases, even outside of the retail industry. Companies that don't meet these expectations risk becoming irrelevant.

Automotive industry in the midst of transformation

New entrants are often the ones to kick-start AI adoption, but incumbents can also hasten change, typically through smaller-scale applications. In the automotive industry, incumbents are using AI to increase operational efficiencies as they face disruption on several fronts.

New companies such as Uber or Lyft are shifting the value pool to mobility-as-a-service, forcing incumbents to reconsider their value proposition and adopt similar approaches (i.e. car2go). At the same time, tech companies such as Tesla and Apple are disrupting the value proposition of traditional carmakers, changing the way cars are being designed, built, sold, maintained, and operated and are disrupting the product oriented business model of traditional OEMs.

AI penetration in the industry is paving the way for a completely new business model: fleets of autonomous vehicles that offer mobility-as-a-service, potentially eliminating the need for car ownership. The new business model shifts value away from physical vehicles in favor of mobility and software that enables autonomous driving and fleet management.

Incumbent car manufacturers face the threat of becoming the providers of commoditized hardware in a shrinking market with narrowing margins. The shifting landscape is pushing established players to reconsider their value proposition and embrace a new business strategy, fueled by data and AI.

[1] Sources: companies websites and press releases

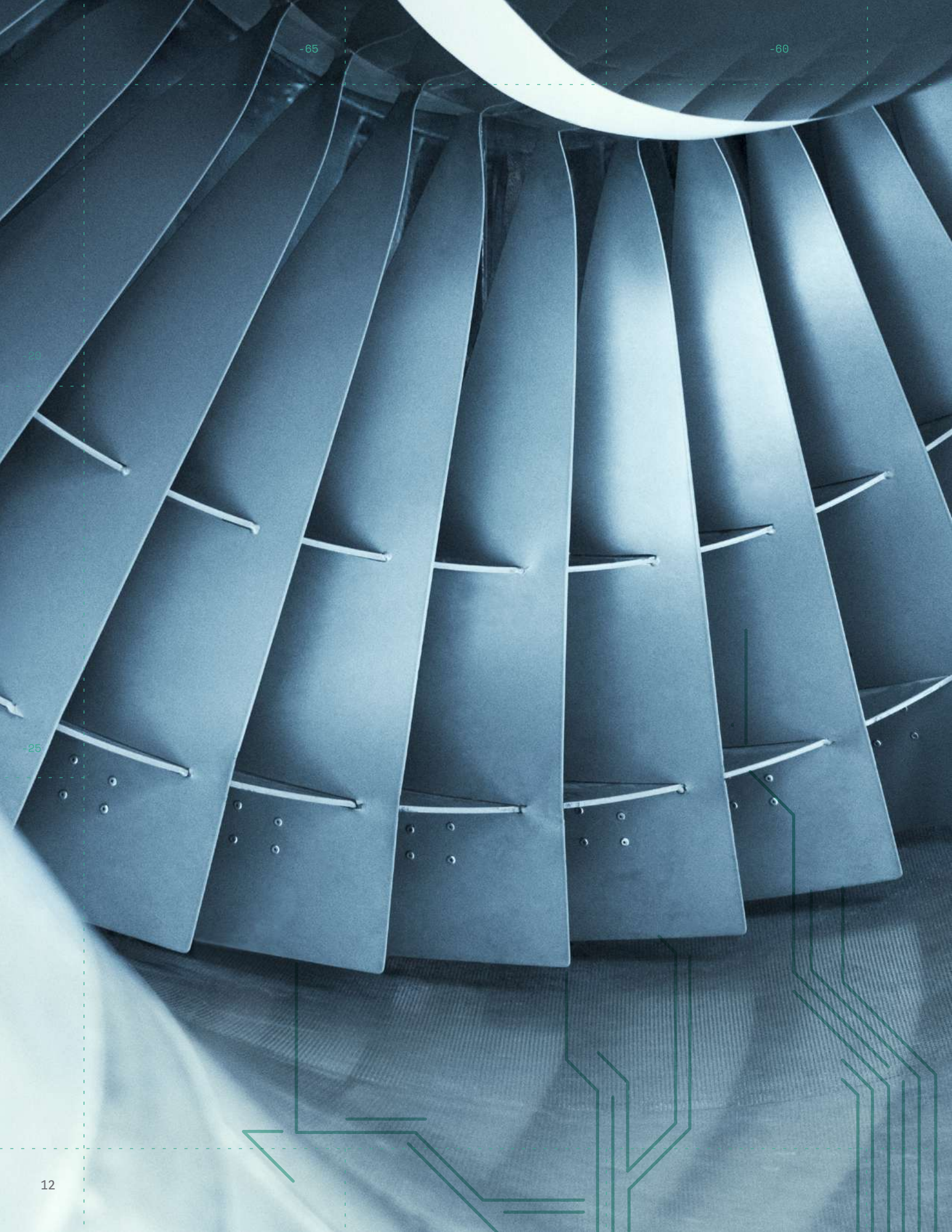
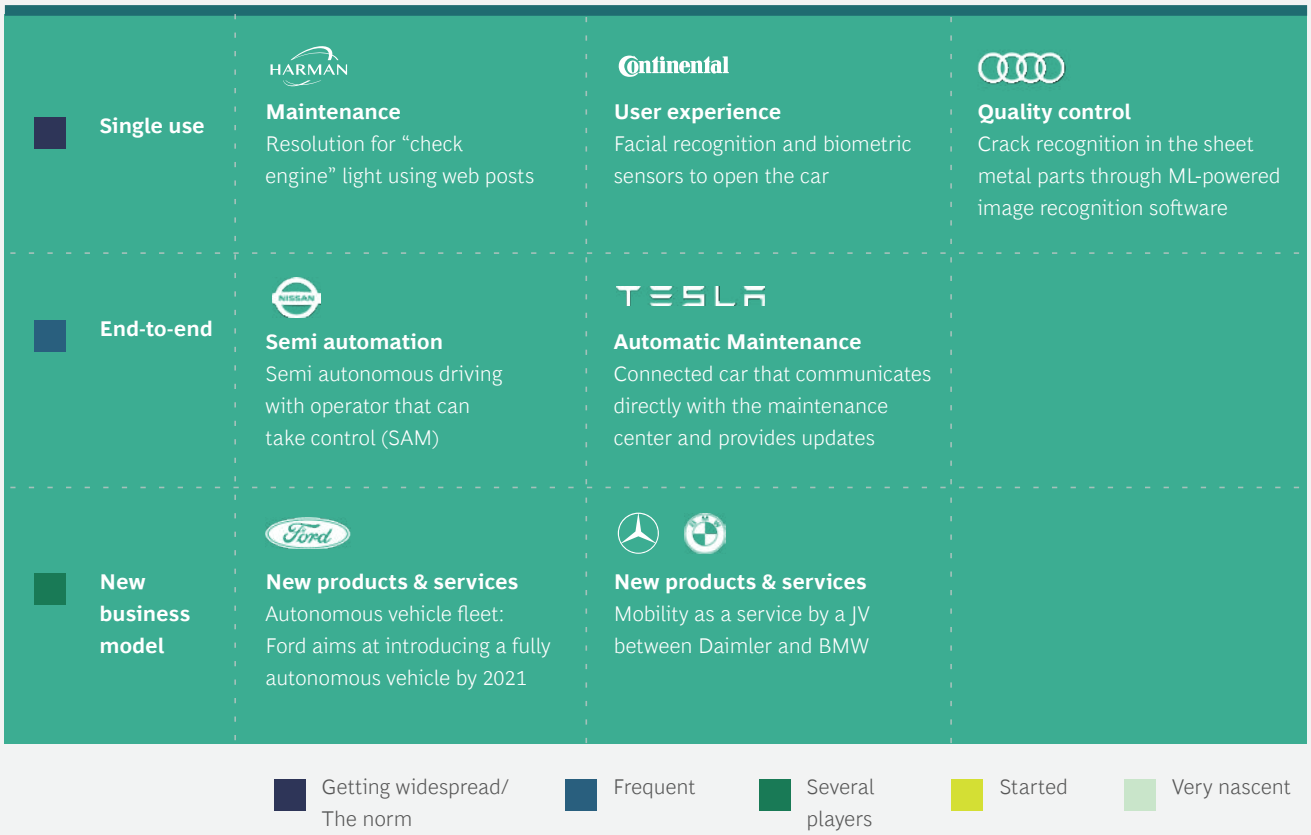


FIGURE 4 | **AI use cases in Automotive**[2]



In the new automotive industry landscape, companies will have to differentiate themselves with their software and service offerings. Incumbents are reinventing themselves to maintain profitability and remain relevant. Toyota and some other carmakers are shifting to a services-focused growth strategy, embracing a model pioneered by Tesla in which a car acts as a platform with which to sell additional services, thus viewing hardware and software as separate entities.

Aerospace: awakening to AI's potential

The aerospace industry is in the early stages of AI adoption. There is a growing number of single use applications and a handful of end-to-end applications, but more disruptive business models are yet to be seen.

[2] Source: Financial Times - 2019-02-22 - BMW and Daimler to invest €1bn in mobility joint-venture; Green Car Congress - 2018-10-16 - Audi using machine learning to optimize quality inspections in the press shop; companies websites and press releases

FIGURE 5 | **Examples of single-use applications across the aerospace value chain**[3]

	Use Case Examples	Implemented Examples
Product	• Image recognition for drone direction • Advanced weather analysis in aircraft • Autonomous aircraft tarmac taxiing	Iris Automation Detecting drone collisions
R&D	• In-service feedback automatization • Automated test means • Root cause analysis improvement	AUTODESK. AIRBUS Designing innovative structures
Supply Chain	• Advanced demand forecasting • Network optimization • Real time inventory management	neewee AIRBUS Detecting issues in the supply chain
Production	• Remain-to-do task optimization • Dynamic workforce planning • Defect inspection	BOEING Increasing machine productivity
After Market	• Automated claim management • Maintenance schedule optimization • Pilot training recommendations	UPTAKE ROLLS ROYCE Improving engine availability
Customer Relations	• Delays/ missed connections mgmt • Personalized In-flight entertainment • Chatbot to inform cust. on flight status	DELTA Speeding up boarding

The potential is great. Just as we've seen in other industries, early AI adopters gain valuable experience, positioning themselves to grab efficiency gains. Companies that do not adopt AI risk falling behind and underperforming competitors that use AI to optimize their processes.

Aerospace players are starting to launch single-use applications

Several aerospace players have launched initiatives that improve upon different parts of the value chain, often through partnerships with tech companies (Figure 5).

- **Product:** Iris Automation developed an AI software for drones, aimed at detecting potential collisions and avoiding them. Its software analyzes a video feed from the drone camera and directs the drone to make the necessary actions.
- **Research & Development:** Airbus has partnered with Autodesk to design and build stronger cabin parts that are just half the weight. Using machine learning algorithms, Autodesk able to develop a generative design technology that can design innovative new structures.
- **Supply Chain:** Neewee, an Airbus incubated startup, leverages its analytics platform, Athena, to detect, diagnose and forecast problems with industrial assets within the supply chain. It makes extensive use of IoT for data gathering as well as AI and machine learning for data analysis.
- **Production:** Boeing introduced a machine learning algorithm to increase the productivity of four skin-fastening machines in the production of the 787 aircraft. The algorithm learns by analyzing newly generated data, creating cost savings in the process.
- **After Market:** Rolls-Royce teamed up with AI specialist Uptake Technologies to improve the reliability of its aircraft engines using Uptake's predictive analytics and machine learning technology.
- **Customer Relations:** Delta Airlines is using AI-powered facial recognition to speed up boarding. Delta customers that register to use this system (CLEAR) have their own expedited line at equipped airports.

The aerospace industry is starting to develop some end-to-end use cases

While still rare, some aerospace companies are starting to launch end-to-end applications. KLM is launching several applications that they will ultimately be able to integrate in an end-to-end solution. With AI, KLM is able to:

- help load luggage smarter
- reduce delays by lowering the impact of no-show passengers and preventing disruptions
- ensure one delayed flight does not impact other flights
- create more efficient crew schedules
- use chatbots to answer basic customer questions on social media (through a partnership with DigitalGenius). This frees up KLM agents to focus on answering more complex customer questions

Another example is Airbus and Palantir, which joined forces to create Skywise, a platform that collects data from aircraft and shares that information with value chain players, from equipment manufacturers to airlines and MROs. As of end of 2018, 3,000 aircraft from 29 customers[4] were plugged into Skywise.

[3] Sources: Iris Automation, Airbus, Bizlab, Boeing, Rolls Royce & Delta websites press releases

As an end-to-end application, Skywise enables numerous single use applications. The platform has enhanced flight operations by improving zero-fuel weight computations and center of gravity baggage loading. One of the customers on the platform, Hong Kong Airlines, expects to save as much as 210 kilos[5] of fuel for an A380 plane on a single descent.

The platform has also helped improve maintenance, preventing Aircraft On Ground (AOG) through preventive maintenance. Delta, a customer on the platform, expects to reduce operational interruptions by 15%[6]. The platform can also track maintenance effectiveness over time and accelerate reporting to regulatory bodies.

All these developments are exciting for the industry, but Skywise's main value comes from enabling the creation of more end-to-end applications. The platform's enhanced root cause analysis[7] not only helps airlines improve their maintenance procedures but also helps equipment manufacturers improve equipment design and overall reliability (Figure 6).

High potential for new AI-driven business models

These developments are promising for the aerospace sector because they demonstrate that aerospace companies can create new revenue streams and transform air operations by adopting AI. We expect that new AI-enabled business models will emerge in the aerospace industry soon and that new services, rather than products, will create the most value, just as we have seen in the retail and automotive industries.

With AI, new entrants can commoditize existing air travel providers by utilizing the assets more efficiently — whether it is planes, crews, traffic schedules, connections, destinations or types of services.

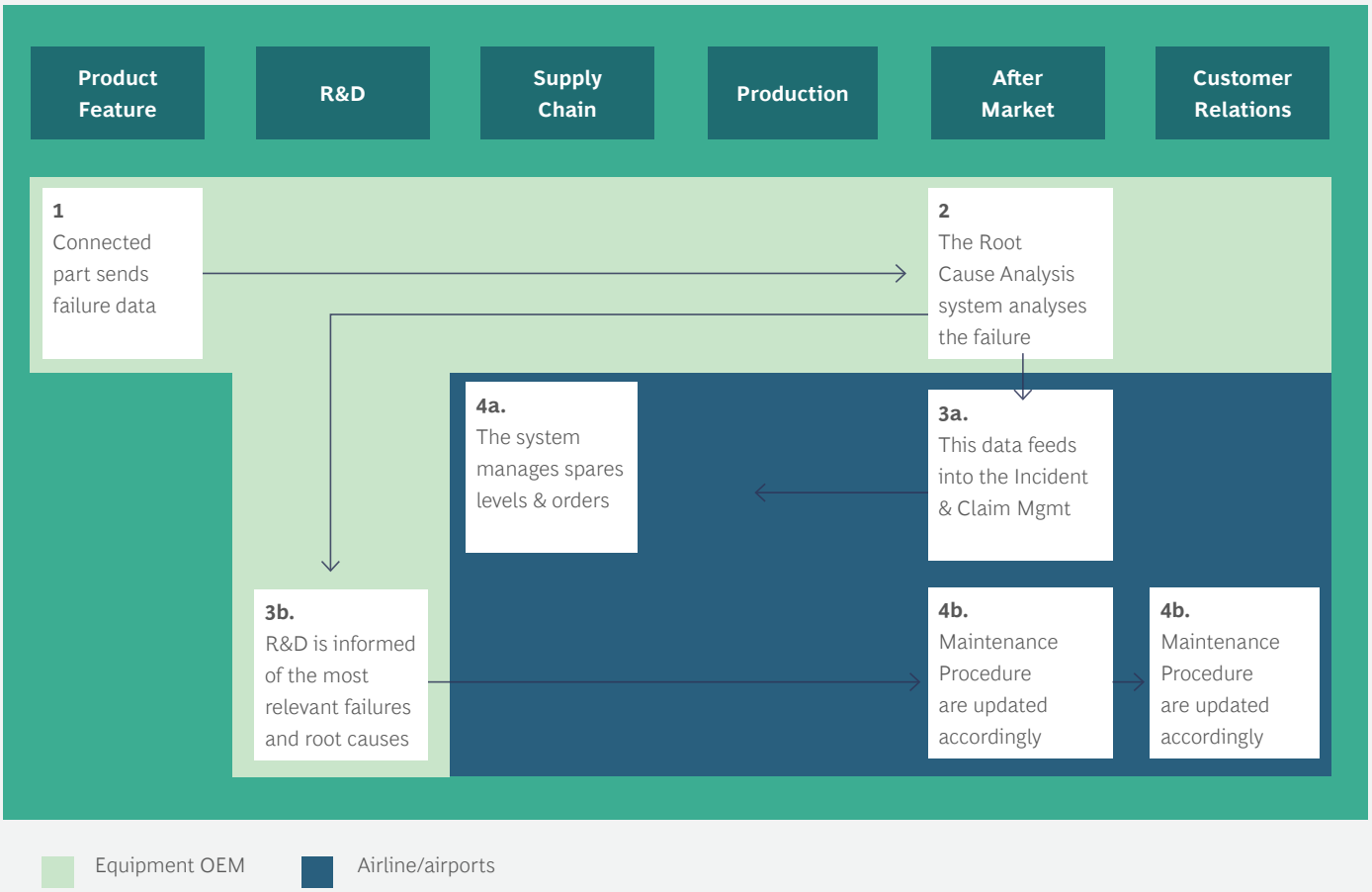
Out of the many potential new AI-driven business models that could impact the aerospace sector, we expect that models that enable more personalization and improve efficiency will be the most disruptive.

Aerospace companies can, like retail companies, use AI to become more customer-centric, creating new revenue streams in the process. With AI, airlines will be able to better track and analyze their customers' needs and wants and offer tailored transportation services that increase sales and command premium pricing. Airlines could offer tailored entertainment suggestions or other services by capturing and using data from in-flight entertainment systems or personal devices. AI can also help airlines gather and analyze customer preferences so flight attendants know customer drink preferences, or how often they want to be bothered during a flight. AI could also help business aircraft operators tailor the travel experience, giving clients the option to pay extra for personalized cabin arrangements, preferred drinks, and so forth.

In addition to new services, the aerospace industry can gain new efficiencies from integrating AI in products. Aircraft that seamlessly connect ground, space and airspace communications will enable much greater data flow to and from aircraft, setting the stage for new AI-enabled applications that can optimize the aircraft performance including flight planning, fuel consumption, and more. Other benefits include more accurate, real-time weather and turbulence information to reduce delays and missed connections.The industry also has a lot to gain from increased autonomy from departure to arrival (e.g. cockpit with single or no pilot, air traffic management, autonomous cruise, autonomous taxiing).

Aerospace companies will likely face a lot of disruption in the near future. Some companies are even working on urban air taxis with projects such as Airbus' Vahana and the Bell and Uber's flying taxis.

FIGURE 6 | **Illustration of Skywise root cause analysis**



[4] Source: Journal de l'aviation – 2018-10-10 – Philippe Mhun, Airbus: The goal is to have 100 airlines and 10000 planes connected to Skywise by the end of 2019

[5] Source: Wings Magazine – 2017-09-12 – Airbus' Skywise data platform enhances safety, efficiencies

[6] Source: Euronews – 2018-07-19 – Airbus Skywise: A revolution in the clouds

[7] Source: Liebherr press release – 2018-07-18 – Liebherr Partners with Airbus on Skywise Open Data Platform

SECTION 2

Montreal

has the potential to become a worldwide leader of AI in aerospace

Montreal has all the elements to become a leader of AI in aerospace. The city is a leading aerospace hub; home to the third largest commercial aircraft manufacturer in the world and the second largest number of aerospace jobs per capita globally. It is also a vibrant AI hub, a pioneer of deep learning and home to a flourishing ecosystem of research centers, universities, startups, incubators, venture capital, technology providers and more.

For Montreal to become a hotbed of AI in aerospace, it will need to capitalize on its strengths in aerospace and AI. Despite the city's many resources, its full potential has not been tapped. Local research centers and companies have not yet come up with a unicorn in AI. Nor have there been many coordinated efforts to commercialize ideas developed by Montreal's large research base.

In recent years, government, VC and corporates have been allocating more funding to AI research and implementation. There have also been a handful of partnerships between AI and aerospace companies. Despite these promising signs, more engagement and collaboration is needed for Montreal to become a leader in this promising space.

Montreal: a complete aerospace ecosystem

Montreal has a thriving aerospace industry. It is the world's third largest aerospace hub, after Seattle and Toulouse. Bombardier, the world's third largest commercial aircraft manufacturer, has its global headquarters in the city. It is the only major aerospace hub in the world that is also home to a major national carrier, Air Canada. The headquarters of the International Civil Aviation Organization (ICAO) and International Air Transport Association (IATA) are all in Montreal.

Montreal is one of the few urban areas in the world where an entire aircraft can be designed and assembled from locally manufactured parts. This provides a unique opportunity to drive end-to-end innovation and create a fully optimized local aerospace supply chain.

FIGURE 7 | **Montreal aerospace ecosystem**

Not a complete list

More than 70% of Canadian aerospace research and development is performed in the greater Montreal region. The area has abundant world-class expertise in a variety of fields such as engineering & development, business jet landing gear, aircraft certification and flight-testing. The city also has several world-renowned universities with highly ranked aerospace programs (McGill University, Concordia University, Polytechnique Montréal), ensuring a steady flow of top talent to meet the demands of the market.

Montreal has five OEMs: Bombardier, CAE, Bell, Pratt & Whitney, and Airbus. It also has 17 tier one partners, equipment manufacturers and MRO companies. In addition, there are more than 175 SMEs and specialized suppliers that form a heterogeneous supply base. Some of the larger SMEs have a diversified base of customers that include international customers. On the other end of the spectrum are some of Montreal's specialized suppliers —small scale assembly suppliers, fabricated metal parts companies—that are heavily dependent on the local market to sell their production.

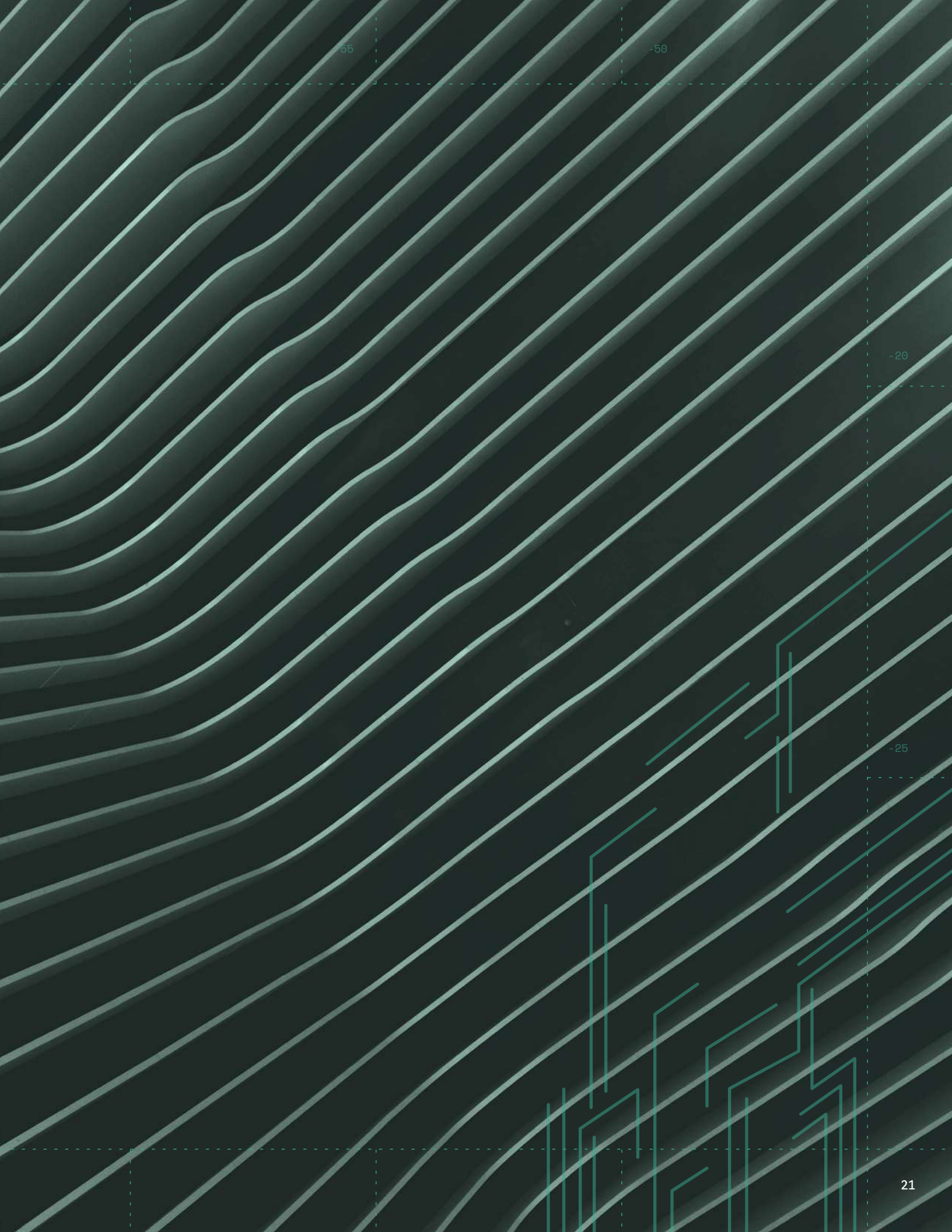

55
50
20
25

FIGURE 8 | **How Montreal compares to other aerospace hubs**[8]

	Seattle	Toulouse	Montreal	Hamburg	Sao Paulo
Number of aerospace jobs	136,000	97,000	41,000	36,000	19,000
Number of aerospace companies	1400	1200	200	300	90
Airline HQ / hub	Alaska Airlines (HQ) Horizon Air (HQ) Delta (Hub)	Volotea (Hub)	Air Canada (HQ) Air Transat (Hub)	Lufthansa (Hub) Eurowings (Hub)	Azul Airlines (HQ) LATAM (Hub)
Top aerospace employers	Boeing 64,000	Airbus 27,000	Bombardier 16,000	Airbus 15,000	Embraer 16,000

Lastly, Montreal is home to important industry organizations like CARIC (Consortium en Aérospatial pour la Recherche et l'Innovation au Canada) and CRIAQ (Consortium de Recherche et d'Innovation en Aérospatiale au Québec) which are spearheading aerospace research collaborations among aerospace companies, research institutes and universities. These organizations provide examples of successful collaboration that can be a source of inspiration for similar initiatives for AI in aerospace.

Montreal is a vibrant AI hub

Montreal has a vibrant AI ecosystem. With its abundance of world-class AI research capabilities, the city has what it takes to create leading aerospace-focused AI solutions that that combine the predictive power of machine learning with the prescriptive power of optimization.

Montreal is recognized worldwide for its AI research thanks to the contributions of Yoshua Bengio, a renowned computer scientist at the University of

[8] Sources: Choose Washington, new midmarket airplane council website; Technologist - 2017-07-01 - Spotlight on Toulouse; Aéro Montréal website; Aerospace Brazil aerospace cluster website; Hamburg university of technology website; Embraer annual report 2017; Hamburg aviation website

[9] Sources: The Economist – 2017-11-04 – How Canada's unique research culture has aided artificial intelligence; Wired – 2018-10-11 – Montreal has reinvented itself as the world's AI startup powerhouse; Newcities – 2018-05-07 – Why Montréal Is Winning the AI Race; Financial Post – 2018-10-17 – Canada to host G7 conference on artificial intelligence in Montreal in December; Forbes – 2018-11-06 – Why Montreal has emerged as an artificial intelligence powerhouse; Les Échos – 2018/05/25 – Montréal, cerveau de l'intelligence artificielle; CBC – 2017-12-17 – Montreal seeks to be world leader in responsible artificial intelligence research

FIGURE 9 | **Press on Montreal as an AI hub**

Montreal who, together with Geoffrey Hinton and Yann LeCun, are known as the fathers of deep learning. The three were recently awarded the prestigious Turing Award for their pioneering work in this field. The city also has a community of world-famous professors and researchers as well as international researchers.

Montreal has several world-renowned institutes focused on operations research and other data sciences. One of them is IVADO, also known as the Institute for Data Valorization, which is a federation of research labs with a combined 1,000 researchers, including many world-class thought leaders in machine learning and optimization. Another is MILA, or the Institut Québécois d’Intelligence Artificielle, a fundamental research institute at the forefront of AI research that was founded by Yoshua Bengio. Montreal’s strengths go beyond scientific research. Top universities ensure an abundance of locally-trained talent while lucrative job opportunities in the city help to keep recent graduates and attract more talent. Montreal is vibrant with innovative companies, including multinational tech giants and startups. Facebook, Google, Microsoft and several other players including Morgan Stanley, RBC, and Samsung, have opened or are opening AI labs in the city. There are also more than 120 AI-focused startups in Montreal and the number keeps rising.


-65
-60
-20

FIGURE 10 | **Montreal AI ecosystem**

Not a complete list

Both the federal and provincial governments have been investing heavily in Montreal's AI scene. Government agencies pledged $470M between 2016 and 2018 for the development of AI within Quebec. However, international competition is fierce: the German government pledged to invest €3B euros in AI R&D by 2025 while the French government pledged €1.5B within 5 years and the Chinese government is funding a US$2B AI park to house up to 400 companies as part of its Next Generation AI Plan.

Montreal's academia and AI research punches above its weight in terms research quality, averaging 11 forward citations per publication, on par with other leading AI hubs like Beijing and only slightly behind San Francisco.

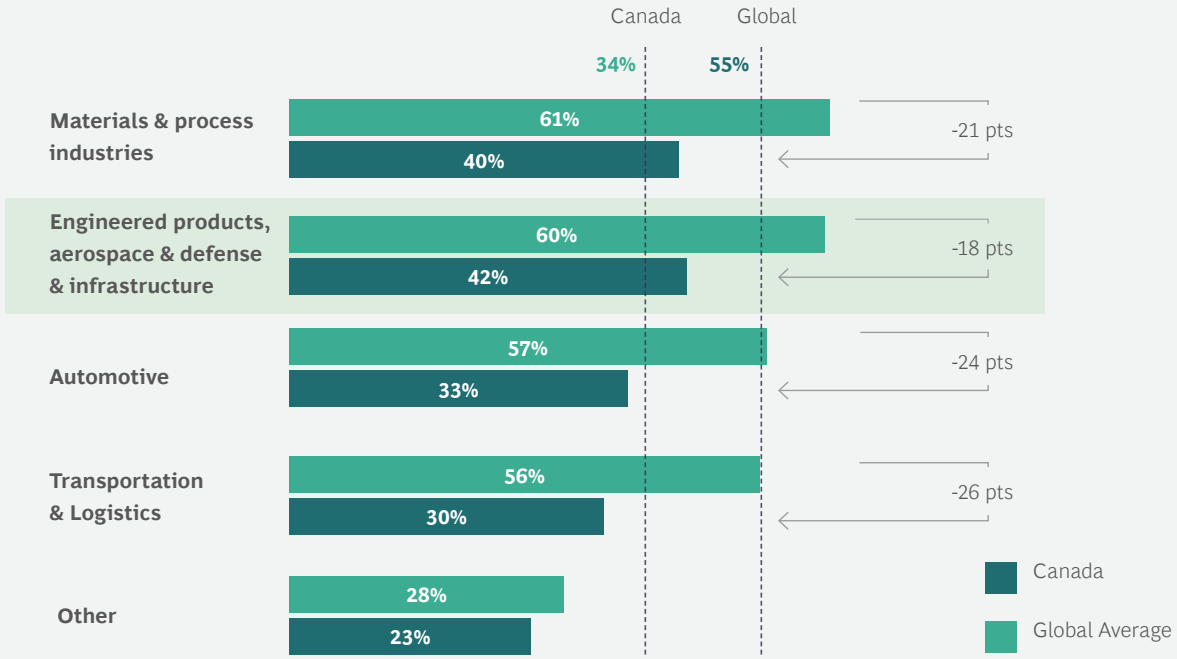
Despite its tremendous potential, Montreal's AI ecosystem still has significant gaps. Montreal companies are behind when it comes to commercialization of research. Toronto has issued four times more AI-related patents than Montreal since 2014 . Montreal's startup scene

[10] Source: Reuters - 2018-11-13 - Germany plans 3 billion in AI investment: government paper

[11] Source: CIFAR report – 2018-12-06 - Building an AI world

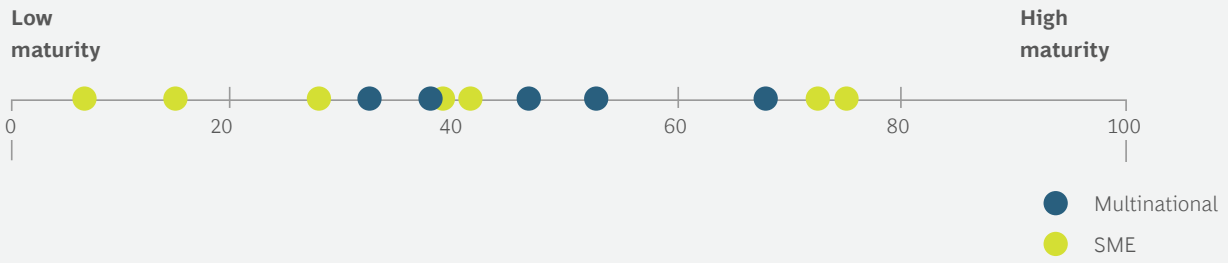
[12] Source: BCG analysis

FIGURE 11 | **Share of companies active in AI by industrial sector (BCG study[11])**



Note: The survey defines Active Players as those companies who are already moving to adopt AI into existing processes or currently running pilot initiatives, and whose efforts thus far are reported to have generally been successful.

FIGURE 12 | **AI maturity score of 12 Montreal aerospace players (BCG survey)**



has similarly yielded few significant scale-ups. There have been some lab spin-offs that scaled up, such as Expretio in revenue management for rail transport, but these are few and far between.

Similarly, Montreal's startup scene has not yielded many significant scale-ups. There have been a few lab spin-offs that scaled up, such as Expretio in revenue management for rail transport, but these are few and far between.

Montreal's unique position as an AI and aerospace hub make it ideally positioned to be at the forefront of the development AI in aerospace. However, aerospace companies in Montreal have not yet fully embraced the potential of AI. Canadian companies in all industries have lagged behind their international peers in AI adoption. On average, Canadian companies have about 20-25% fewer active players in AI than the global average (see Figure 11). This is consistent across all industries, including aerospace.

AI adoption in the Montreal's aerospace industry has room to improve

A survey[14] of Montreal aerospace companies, including multinationals and SMEs, revealed that companies in Montreal's aerospace industry vary in their AI maturity levels. In general, companies can be grouped into two categories:

- **Industry leaders:** companies that are further along the adoption journey and that have successfully piloted one or several use cases
- **Industry followers:** companies that have not yet piloted AI use cases

Company size is not necessarily a predictor of how likely a company is to be considered a leader in AI adoption. Several SMEs (software and hardware providers) surveyed were further along in AI adoption than large multinationals (Figure 12).

While some SMEs have started the path to AI adoption, many others are lagging. Only a quarter of the Montreal aerospace SMEs we contacted for the survey about AI responded, indicating a general lack of engagement around the topic.

Some of the attributes that really separated the industry followers from the leaders were:

1. **Business strategy driven by AI:** followers are very clearly behind the leaders in understanding how AI can affect overall company strategy
2. **Make or buy:** followers do not have a robust process to decide how to approach external AI contractors or compare their offerings to internal capabilities
3. **People and Organization:** followers do not have the right skills or governance within the organization, hindering the company's ability to move into new opportunities.
4. **Data management:** followers struggle with data governance, data strategy and algorithm training.

Some attributes seem to be equally difficult for leaders and followers:

1. **Data infrastructure:** all companies, even leaders, revealed some difficulty with data infrastructure
2. **AI integrated at the core:** leaders and followers alike are struggling to integrate AI within the organization's internal processes

[13] Survey from BCG perspective - 2018-12-05 - Mind the AI Gap – One of the goals of the survey was to evaluate which companies are active leaders in adopting or piloting AI. BCG surveyed more than 2700 managers from a broad and representative range of industries (incl. consumer, energy, financial services, health care, industrial, technology, media, telecom, public sector, etc.) and countries (focused on Austria, China, Germany, France, Japan, Switzerland and the United States, but also spanning Canada and others). The participating companies ranged from small SMEs (under 250 employees) to large corporates of 50,000 or more employees. BCG accepted responses only from managers with at least a basic understanding of AI and its potential.

[14] Survey realized by BCG for this report, aiming at understanding the level of maturity in Artificial intelligence of the aerospace players in Montreal along several dimensions. 13 companies answered, both from large multinational groups and SMEs.

FIGURE 13 | **Detailed AI maturity survey results**

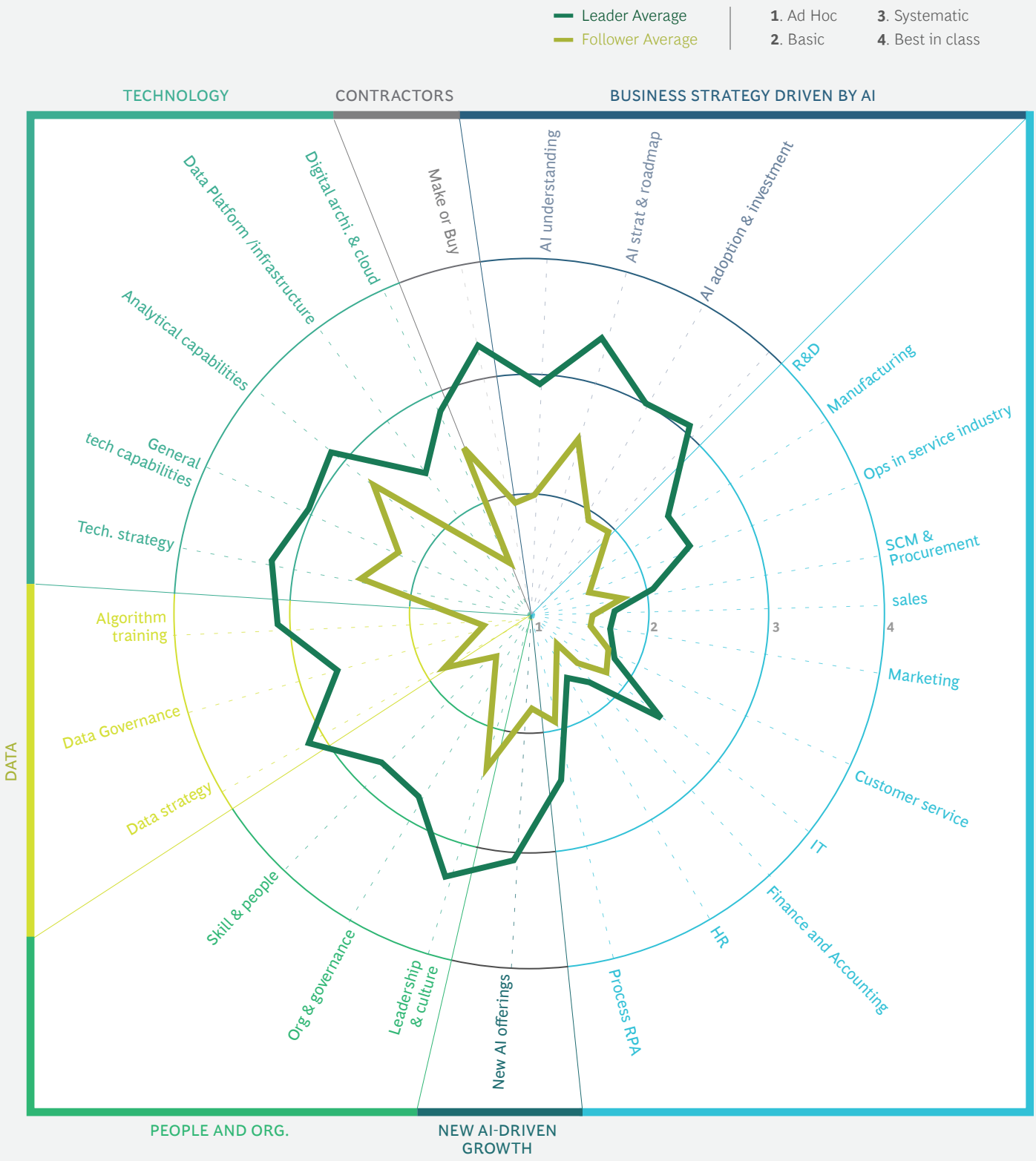
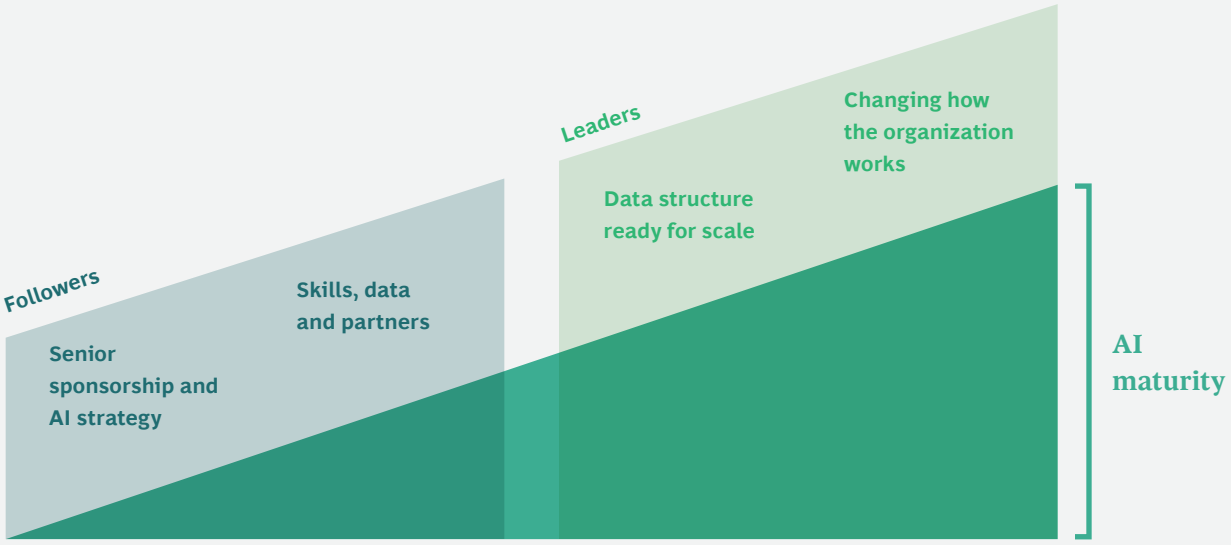


FIGURE 14 | **Key challenges for AI adoption**



The survey and interviews also revealed that followers face several hurdles that prevent them from starting their AI journey:

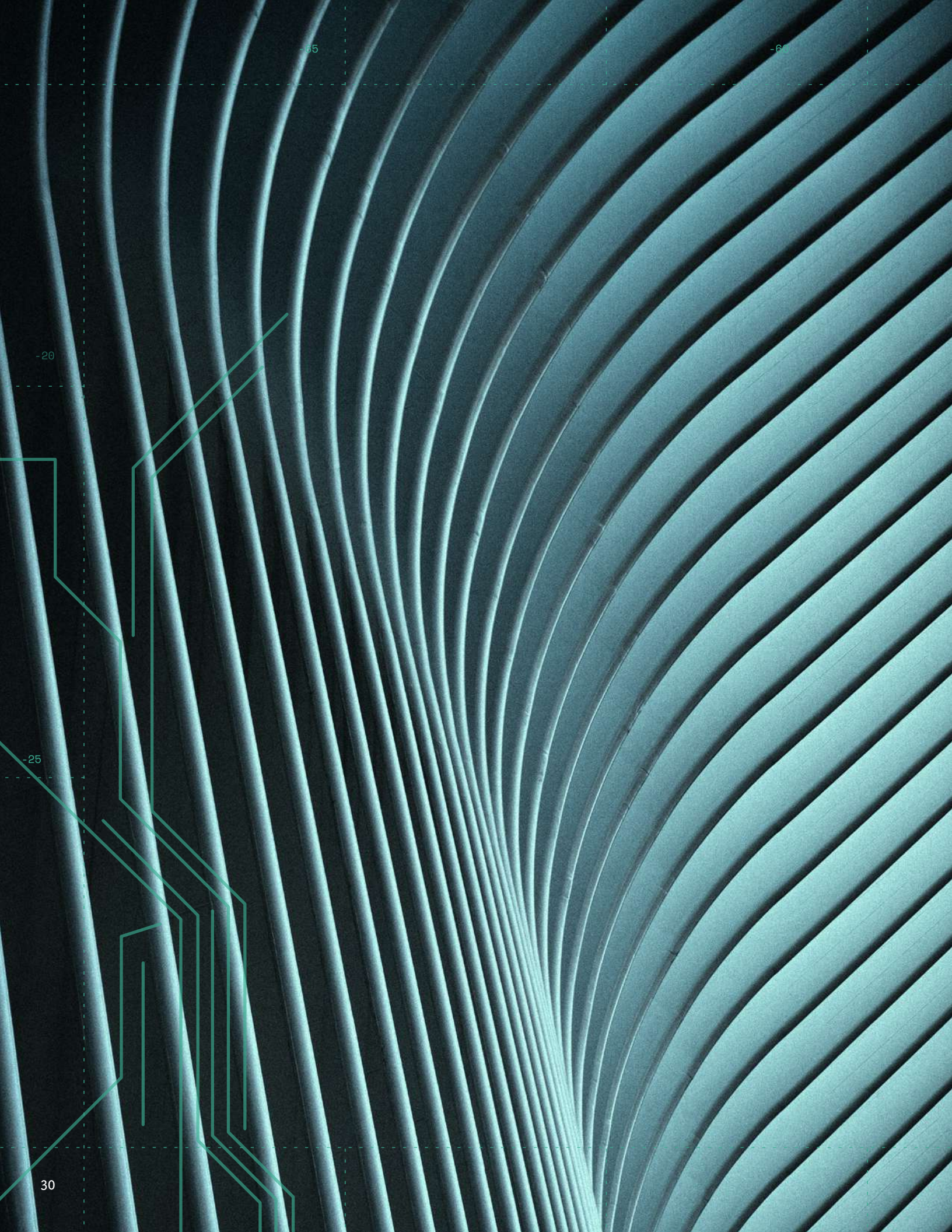
Lack of senior management sponsorship and AI strategy.
For management at these companies, AI may not be a priority and the benefits are unclear. Companies might launch an AI project, but there is no sustained involvement or interest from leadership after the project launches. Moreover, determining who is in charge of AI projects, whether IT, operations, or otherwise, might be a challenge.

Lack of skills, data and partners
Hiring skilled AI talent is very difficult, especially in a competitive market. Companies struggle to find managers with enough of an understanding of AI to hire an AI specialist. This lack of understanding about AI makes it hard for companies to identify use cases, hire specialists and vendors, or to buy solutions for AI projects. Another challenge is that companies may not have processes in place to collect or acquire good quality data or do not know which technology partner to choose to start collecting it. Finally, aerospace companies that have gone to the effort to collect the right data tend to be reluctant to share it with third parties.

Then there are challenges that almost all companies face, regardless of how far along they are in AI adoption.

Scalable data structure
Many companies have difficulty organizing their data architecture and structure to scale. Companies may lack a clear strategy to capture and store data or have difficulty finding talent that understand both AI and IT well enough to lead initiatives to create a scalable data structure. Another roadblock: difficulties identifying the right partner to scale up AI use cases implementation.

Changing workforce culture
Some companies find it difficult to implement AI within their core processes. This requires a change in the organization's way of working, which can require a significant culture shift.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Lastly, one challenge that's endemic to both leaders and followers is a tendency to underestimate the level of effort needed to get effective results from AI. AI is a powerful tool, but one that's difficult to implement successfully. Company management often have high initial expectations of AI, then that enthusiasm wanes when difficulties arise. This is particularly the case in the aerospace sector, which has many regulatory and safety concerns that can delay AI adoption. For example, creating an algorithm that can determine whether or not a part is flightworthy requires a level of explanation to engineers and regulators that AI cannot yet provide. As such, explainable AI is an important field of research of the aerospace industry.

Despite these challenges, aerospace companies are eager to apply AI on their own or through partnerships.

- In October 2017, Thales announced the creation of the Centre of Research and Technology in Artificial Intelligence eXpertise (cortAIx). Led by Thales, cortAIx, along with MILA and IVADO, plans to hire 50 AI experts to widen the use of AI at Thales. Already, the group has announced several research topics, including the ethical use of AI. Potential clients and partners include airlines, air traffic controllers, and satellite operators.
- In 2018, Bombardier, the CARIC, Digital Catpult, and the UK Science and Innovation Network launched the AI Innovation Challenge, a contest for startups to apply AI to real-world aerospace problems. Some examples included designing more aerodynamic planes and solutions to eliminate or control ice build-up on aircraft.
- In February 2019, Bombardier and IVADO established a partnership to solve complex problems using AI (e.g., non-conformity prevention in manufacturing and supply chain)
- On August 8, 2018 CAE announced that it will invest C$1 billion over 2019-2024 to support innovation and to stay at the forefront of the training industry. One of the main objectives of the investment is to fund Project Digital Intelligence, a digital transformation project to develop the next generation training solutions for aviation, defence & security, and healthcare. Project Digital Intelligence will transform CAE's products and services to leverage digital technologies—including big data, artificial intelligence, cloud-computing, cybersecurity, and augmented/virtual reality—while making use of its training network and data ecosystem
- CAE and AirAsia together launched CAE RISE, a data-driven training system. It is currently available for military and defense organizations. CAE RISE leverages big data analytics to reduce subjectivity in pilot assessment by using live data during training sessions, and allows instructors to focus most of their energy on teaching. The solution provides deep analytical insights and a new source of data to create more efficient and effective pilot training programs.

In addition, a few AI research projects in Montreal are focused on aerospace. For example, the IRT St-Exupéry in Toulouse, IVADO and CRIAQ entered a partnership to create the DEEL project (Dependable and Explainable Learning), aiming at reaching a maturity level in explainable AI/ML allowing the algorithms to be embedded in aircraft systems. As mentioned earlier, to ability to explain AI decisions is a critical factor to be able to use AI in aerospace products. This initiative will contribute to putting Montreal on the world map for AI in aerospace.

All the building blocks for Montreal to become a success in aerospace AI are in place, with some organizations and business leaders working to capitalize on the city's strengths. However, more is needed at the individual enterprise level and industry level to unlock full value from AI in aerospace.

SECTION 3

Vision & Action Plan

for Montreal

Vision

Make Montreal a globally-recognized hub for AI innovation and adoption in aerospace by fostering the development of a thriving ecosystem that brings together and augments Montreal's top industrial and technological strengths.

Desired Outcome

Create sustainable economic and social value in the Montreal metropolitan area and contribute to the long-term prosperity of Canada's aerospace sector.

Pillars

The vision is articulated around three complementary pillars which, together, support the development of a thriving ecosystem of innovation.

Adoption

- Senior leadership at all aerospace companies make AI a top priority
- Most aerospace companies, large and small, have adopted AI in their core business, gaining significant competitive advantages in the process
- AI adopters are increasingly mature in their approach to implementation and are scaling up the use of AI
- Local research & development and industrial AI implementation are attracting international capital

Commercialization

- Applied AI research is focused on concrete and relevant aerospace use cases
- The generation and monetization of strong commercial IP is an ongoing objective of the ecosystem's innovation activities
- The go-to-market of leading edge industrial AI products is facilitated and accelerated
- Montreal is a local playing field for Canadian start-ups and scale-ups which target global markets

Talent

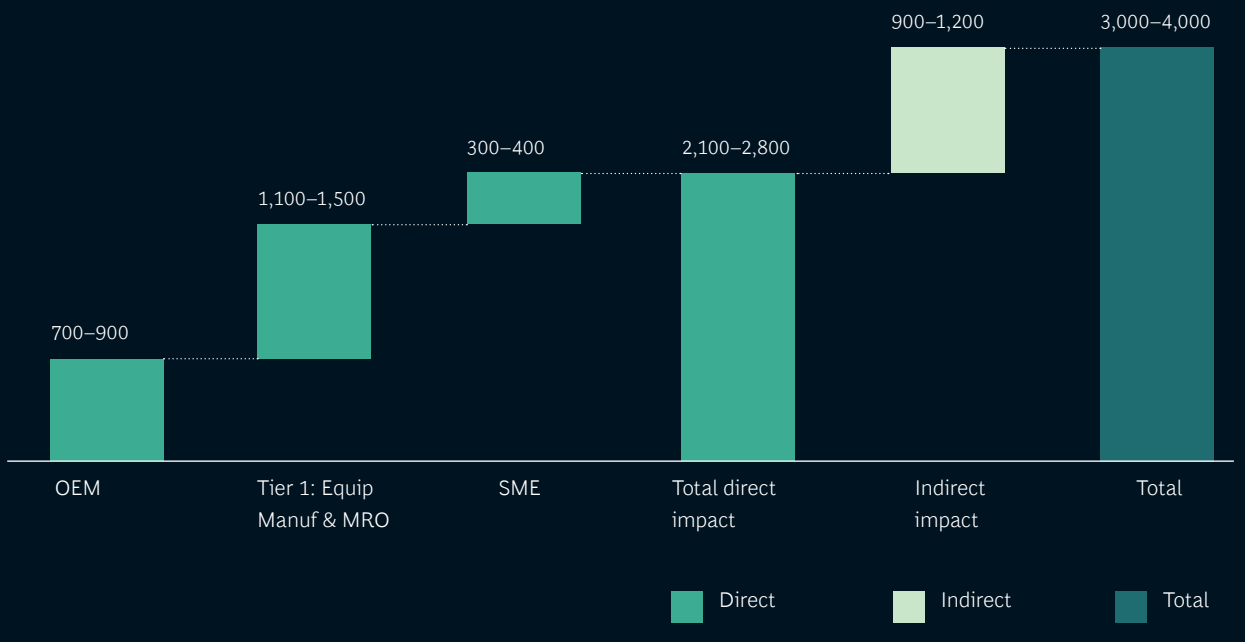
- Montreal has one of the world's largest pools of global aerospace AI experts
- The local aerospace workforce is broadly educated about AI adoption and use of AI solutions
- Montreal's universities train an increasing number of AI-capable engineers each year
- Montreal's aerospace industry is the preferred destination or top international AI talent

Quantifiable benefits

Adoption and implementation of AI will generate significant value for all aerospace stakeholders. We estimate a potential $3-4B in additional net present value (NPV) over the next 5 years for the whole industry, with $2.1-2.8B coming from improved efficiency and additional revenues from AI implementations and $0.9-1.2B from additional indirect impact (Figure 15).

To achieve this vision, key stakeholders need to act now, especially given the speed at which AI is evolving. Actions need to be taken at the company-level and industry-level.

FIGURE 15 | **Net Present Value (NPV) of additional margin potentially generated by aerospace AI in Montreal over the next 5 years ($M CAD)**



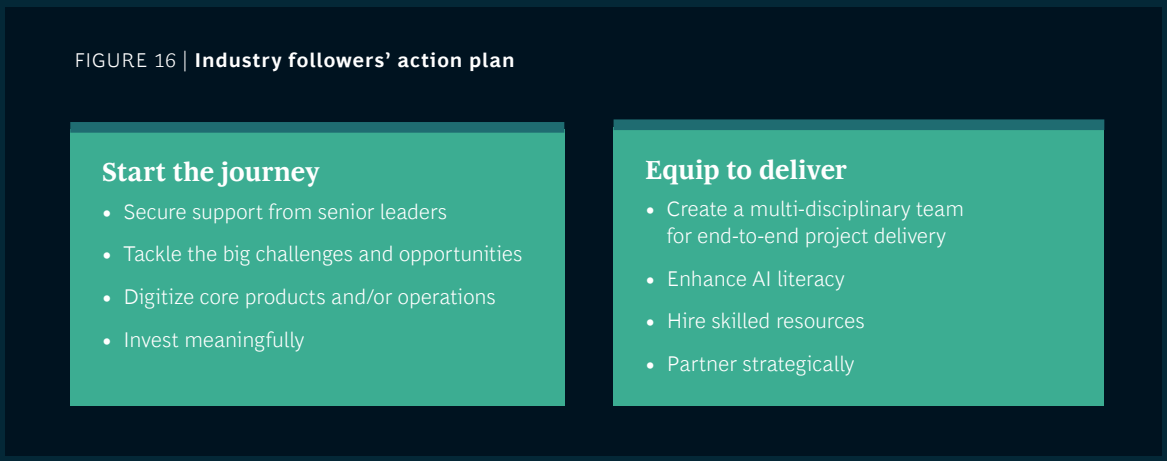
Company-level action plan

Not all aerospace companies have the same starting point. Depending on where they are along the path to AI adoption, the plan will be different. However, in order for the Montreal aerospace industry to have the scale and momentum needed to become a worldwide leader in AI adoption, it is critical that the majority of Montreal aerospace leaders embark and progress on the journey.

Industry followers: ***Mobilize***

Followers, or companies that have not started their AI adoption journey, will need to start the journey and equip to deliver.

FIGURE 16 | **Industry followers' action plan**



Start the journey

The first step in the followers' journey is for top managers to make AI a priority by spearheading AI initiatives and pushing them through. Companies need to identify the most critical challenges and opportunities in their businesses today. To get the highest rates of return, companies should focus their resources on only the most promising projects with the most impact.

Companies that haven't yet done so need to makes sure products and operational processes linked to these promising AI projects are digitized. The resulting data is needed to fuel the AI algorithms. While full digitization is the end goal, companies can start by digitizing products and processes to support the most promising projects. A data strategy clearly linked with the targeted business model needs to be defined and implemented.

Scaling up AI solutions from proof of concept to widespread implementation is costly and time-consuming. Companies need to set aside considerable budget and resources in order to pursue these projects and realize meaningful impact. This effort must be sustained. Companies typically need continue investing resources for at least 6-12 months before the return is fully materialized.

Equip to deliver

Followers need to build their internal capabilities to successfully deliver these transformative AI projects. This starts with creating a multi-disciplinary team for end-to-end project delivery. The team must include business strategists who can direct the project toward the key value pools; functional experts with intimate operational knowledge who can address process-related issues; data scientists and AI engineers who can contribute to build the core solution with domain experts; and IT specialists who can vouch for the availability of quality data and manage systems, infrastructure and integration. Managing change shall also be a key area of focus for the leadership. Companies will need to consider changing internal processes, employee mindsets and work culture by creating new team structures and introducing new ways of working (agile & fail fast).

Increasing AI literacy across the organization is key. Doing so enables business owners, functional experts, and engineers to have a better grasp of the opportunities AI projects bring, the requirements to execute AI projects successfully, and the impact AI will have on existing operational or business processes.

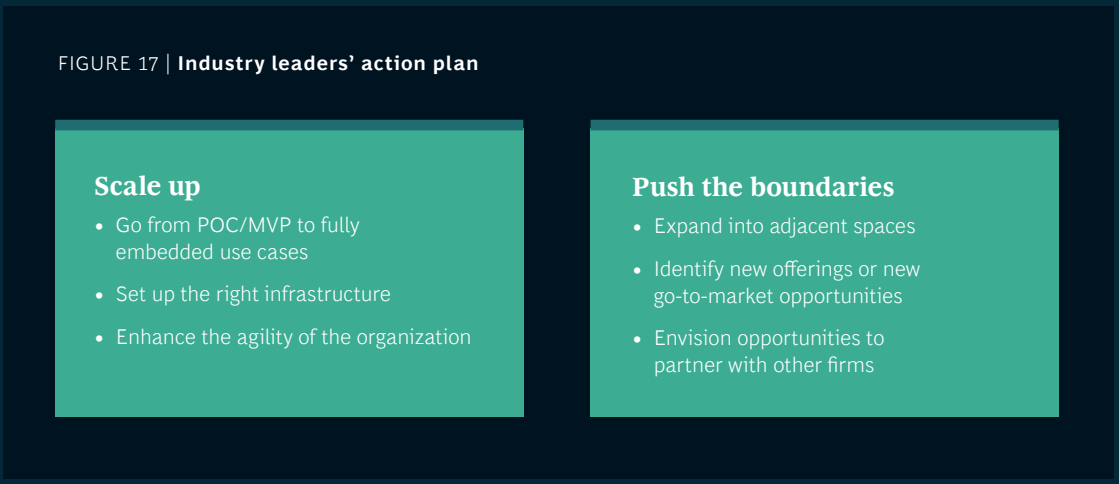
Followers should think about making strategic hires of data scientists or product, process, or operations engineers with experience in industrial AI implementation to drive projects and educate the broader workforce about AI capabilities. Top AI talent is in high demand, so companies need to be prepared with competitive hiring packages and optimal working conditions.

Followers also need to find strategic partners outside the company with complementary capabilities. Some examples include technical skills such as data science, data engineering, systems architecture, or machine learning. Companies could also look for partners in softer skills at the crossroads of business strategy, process re-engineering, and change management.

Industry leaders:
Accelerate

Industry leaders that have already implemented at least one significant AI use case need to prepare to scale up and continue their data-driven transformation. Leaders need to push the boundaries and seek more end-to-end solutions.

FIGURE 17 | **Industry leaders' action plan**



Scale up

To realize the full potential of AI, companies need to scale up from small proofs of concepts to large, transformative end-to-end projects. Survey results show that many leaders have not yet implemented AI projects with material impact on their core business.

Successfully scaling up AI projects is hard. A good rule of thumb to follow is the 10-20-70 rule: spend 10% of time and effort on the algorithms, 20% on data and IT infrastructure, and 70% on changing business processes and enabling the workforce.

Companies should not underestimate the importance of putting the right AI infrastructure into place. It is essential for leaders to define, in detail, the architecture requirements, including model structure, data access, quality requirements, and IT systems architecture. Scaling up in AI requires leaders to shift from longer, traditional R&D cycles to a faster, more agile way of working. This means building solutions quickly, testing and iterating with agility, and staying focused on the most valuable use cases.

Moving through this early stage of development is a vital step that enables companies to invest in the next wave of AI projects.

Push the boundaries

To really stand out, leaders need to push the boundaries and accelerate the pace of AI implementation. Leaders can identify use cases that push the boundaries in several ways. They can expand into related, adjacent markets or industries to develop new AI-driven services, similar to Airbus's Skywise initiative. Leaders can leverage their existing experience in AI in new markets. Toyota, for instance, is leveraging its experience in AI and robot manufacturing to provide AI-powered robot assistants in homes and hospitals[15]. Leaders can also find opportunities by partnering with companies, either in aerospace or other industries. An example of this is Volvo's partnership with Uber to build a fleet of autonomous vehicles[16].

Innovative industry leaders are crucial to the advancement of AI in the aerospace sector. Leaders, by acting as successful role models, can inspire others, share best practices and lessons learned and help to increase international visibility of the Montreal AI aerospace ecosystem.

Industry-level action plan

FIGURE 18 | **Industry-level action plan**

Building an AI aerospace ecosystem

Creating an ecosystem requires contributions from all members of a community. Aéro Montréal members need to come together to align and deliver on common priorities.

Steer the whole ecosystem

The first step is to set up a dedicated task force that can define and lead the sector's strategy and organize activities. That task force can take several forms such as board, working group, strategic pillar, and committee. Thus, Aéro Montréal will need to identify the best mechanism to mobilize all stakeholders from large companies, SMEs, academia, and other key players from both the aerospace and the AI communities in Montreal.

The responsibilities of the task force would be to:

- Define the sector's vision and lead the aerospace and AI communities to action
- Guide the development of the ecosystem by setting up and encouraging partnerships and strategic initiatives
- Act as a hub for innovation and collaboration that encourages sharing best practices
- Inform and educate stakeholders regarding AI opportunities, existing capabilities, joint interest areas, etc.
- Be the point of contact for existing initiatives (CARIC, CRIAQ, IVADO, SCALE, etc.), to ensure continued collaboration and to discourage harmful competition
- Promote the ecosystem internationally, build connections, and attract investments, talent, and partnerships

Although the exact task force structure has not yet been defined, it will need to play a key role in responding to immediate needs and launching structuring initiatives. The next sections outline the potential roles this task force could play. Exact task force structure, programs, and key priorities will need to be defined by Aéro Montréal.

[15] Source: Bloomberg – 2018-12-26 – Toyota Wants to Put a Robot Friend in Every Home

[16] Source: Reuters – 2017-11-20 – Volvo Cars to supply Uber with up to 24,000 self-driving cars

Respond to immediate needs

Having a dedicated task force can make it easier for members to solve shared problems like workforce upskilling. The task force can spearhead a number of initiatives, such as setting up partnerships between companies and universities to develop leadership programs that educate corporate executives to AI initiatives. Another initiative could be workforce training programs for aerospace managers through deep-dive training or secondment at leading tech companies.

The task force should also help publicize cross-industry initiatives and create networking opportunities. Creating a forum brings visibility to these initiatives, helping members share what they've learned, and stay updated about projects that are nearing launch. The task force could also organize conferences or hackathons that bring together the aerospace and AI sectors to generate new ideas, share the latest industry news, and kick-start collaborations.

Lastly, the task force should encourage companies to share best practices for the betterment of all. For instance, the task force can help companies develop and distribute framework agreements for data sharing, IP, cybersecurity, privacy, and other areas. This will be key, especially given how companies in the aerospace industry tend to keep data to themselves. Sharing data sets would help members with AI model training for predictive maintenance, quality control, or other areas. The task force could establish and encourage the use of standard data formats, sensors and so forth for cross-company compatibility. Aerospace companies could also help one another find tech partners by establishing a pool of qualified technology providers with capabilities in aerospace. Creating a common pool of knowledge helps managers identify and implement AI projects, furthering the industry's development.

Launch structuring initiatives

By working together, the aerospace sector can foster mutually beneficial partnerships, encourage SMEs to start integrating AI, present an organized front to government and regulatory bodies, and establish a "Montreal aerospace AI" brand. The task force can plant the seeds for fruitful collaboration by launching some key initiatives.

One key initiative is establishing a physical space for the AI and aerospace sectors to interact. An example of this is the Innovation Center at the University of Illinois at Chicago, which allows companies to rent space in university buildings. This facilitates collaboration between companies and students.

Existing infrastructure in Montreal such as IVADO, Centech or Starburst accelerator could be used in this way, serving as an incubator for AI in aerospace projects. Beyond a physical space, other explicit measures, like the innovation ecosystem AeroNumeriQ, should be implemented to facilitate the collaboration between Quebec's aerospace and AI ecosystems. These measures should also encourage researchers to focus on challenges faced by the aerospace industry like explainable AI.

Generating more interaction between the aerospace and AI communities will help with another critical initiative: setting up partnerships among academia, aerospace incumbents, and AI companies to develop knowledge for AI in aerospace. Some potential corporate-academic partnerships should train future aerospace engineers about AI and about identifying new use cases. The aerospace industry should also work with universities to secure or provide funding for Ph.D. programs in AI applied to aeronautics. Emulating a successful model from Israel, companies can implement rotational programs for AI masters and PhD students to spend time at aerospace companies.

These types of cooperation will help generate knowledge and new algorithms that are directly applicable to aerospace and its specific constraints. They will also help to establish Montreal as an innovation hub for AI in aerospace. Building the "Montreal aerospace AI" brand will be critical to attract talent, capital and international partners.

The task force needs to encourage aerospace companies to partner up or work with smaller companies in order to push AI forward. Companies need to reach out to SMEs – from small scale assembly lines to metal part fabricators – to embark on projects that can modernize the aerospace supply chain and introduce future efficiencies. The task force also needs to emphasize data capture to SMEs that are new to AI and promote proven tools, in a working model similar to MACH Fab 4.0, an initiative launched by Aéro Montréal to encourage the implementation of digital technologies and advanced manufacturing techniques in aerospace SMEs.

Aerospace companies need to present an organized front to engage government and regulatory authorities on the topic of AI in aerospace. Companies need to embark local, provincial and federal levels of government on the journey to building a thriving ecosystem, and demonstrate how Montreal can have a competitive advantage in this nascent space.

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Conclusion

The application of AI in various industries has disrupted value chains and created tremendous value for early adopters. The aerospace industry, which has been relatively untouched up to now, is next. Montreal has all the building blocks to become a global powerhouse of AI in aerospace given its enviable strengths in both disciplines. But to meet this potential, companies need to band together to pool resources and create opportunities that will increase AI adoption, build new applications, create new business models, and scale up to meet global demand. Companies can meet these challenges but need to act now in order to be ahead of the curve.

Acknowledgment

Aéro Montréal would like to thank BCG and all the members of the project steering committee for their support. This work would not have been possible without the financial support of Canada Economic Development for Quebec Regions and Montréal International.


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