Digitalization of American Aerospace SMEs

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Abstract. This study is about artificial intelligence (AI) maturity models in aerospace manufacturing. In industries ranging from aerospace to non-technology-intensive companies, artificial intelligence has become an integral part of digital transformation. Artificial intelligence (AI) is used in aerospace to develop smart systems. SMEs focused on aerospace must embrace digitalization to remain competitive, reduce operating costs, and compete with larger firms. This paper examines AI applications in American aerospace SMEs using the maturity model for artificial intelligence.

Keywords: Aerospace, SME, Maturity model, Digitalization, Manufacturing

1 Introduction

U.S. aerospace innovation and pioneering accomplishments have made it the world's aerospace leader for decades. The aerospace industry has shown resilience in the face of global pandemics, supply chain issues, inflation, and macroeconomic uncertainty. Over the years, the aerospace and defence industry has grown exponentially and has become an economic force. Aircraft and spacecraft development is the primary concern of aerospace engineering. Among its branches, aeronautical engineering and astronautical engineering are the two most prominent and overlapping. In the aerospace industry, there are strict regulations and high sustainability standards.

During the period from 2022 to 2023, the global aerospace and defence market grew 7.5% at a compound annual growth rate (CAGR). It's predicted that the aerospace & and defence market will reach $1076.56 billion by 2027 at a CAGR of 5.9% [1]. In 2010 there were 477,700 aerospace workers in the U.S., and in 2019 there were 534,3000, with a growth rate of approximately 0.72 percent. Since 2014, production and nonsupervisory employees have grown by 0.08 percent, from 271,500 in 2014 to 300,300 in 2019 [2].

The best-fit automation and digitalization solutions will enable SMEs to survive and thrive against fierce competition. A survey of manufacturing workers in the United States, Germany, France, Spain, and the United Kingdom conducted in 2021 revealed that 45% would leave their current employer for a more modern, digital environment [3].

Artificial intelligence has developed rapidly and is now being applied to many aspects of social and economic life. As a result, innovation and change have been promoted, and industrial development has been expedited [4]. Several sectors, including hospitals, military, law enforcement, energy, and education, are integrating AI into their decision-making

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processes [5]. Several research areas participate in this field, including robotics, image, language, and natural language processing, as well as expert systems [6].

AI and Machine learning (ML) allow real-time monitoring, predicting maintenance needs, and improving flight control systems. Even though artificial intelligence is not human intelligence, we can develop intelligence that can think like and even exceed human intelligence through related research and development [6]. Digital transformation is powered by technologies such as AI, IOT, and big data. Aerospace and defense are the sectors that have embraced the Industrial IoT the most and have achieved impressive results [7].

It takes a holistic set of capabilities for the entire organization to succeed with digital and AI transformation. To make significant changes to an organization's processes, ways of working, and key performance indicators, the 70/20/10 rule describes how 70 percent of people have participated in successful digital transformations. Getting the data right accounts for 20% of the work, and technology accounts for 10% of the work [8].

Markets must be won by businesses through competitive strategies [9]. Developing an appropriate culture involves implementing business processes, technology, and marketing approaches, managing risks, and managing people [10]. Business strategies have become increasingly reliant on digital technology and innovation [9].

In an age where digital transformation (DT) is sweeping across society, large corporations are well-positioned to benefit from digital solutions [11]. Due to limited resources, understanding, and implementation skills, SMEs struggle with DT, so they need both tools and methods and support to use them [11]. A few initial missteps are inevitable when implementing digital transformations. There is no quick fix for digital transformation, which involves a series of evolutionary, and occasionally disruptive, steps. In this modern era of digitalization, a company's success is not determined by how much capital it has or how long it has existed, but by how flexible it is in responding to these changes and adapting to the new environment [12]. Data, algorithms, and AI can open new possibilities in today's data-intensive and intelligent business landscape.

Digital and AI-based systems can be developed by the entire organization through a distributed technology environment and modern software engineering practices. Digital tools and data enable co-creation through innovation. As Leaders focus on building a quality digital talent bench, they ensure that engineers thrive in environments that are tailored to their interests. Those who work in data science, artificial intelligence, and digital transformation know that it is often a culture that hinders progress, not technology. A leader should create a culture and capabilities that will encourage innovation from the bottom up. The solution for changing an existing culture is to find things that the current culture will embrace to move the data culture forward. Digital transformation is described as a journey by everyone who has been involved.

Our goal is to answer these questions about maturity models in different domains.

RQ1. In the aerospace manufacturing sector, how do AI maturity models play a role?

RQ2. How do maturity models differ based on the literature?

RQ3. What are the existing maturity models for AI?

An overview of AI maturity assessments is obtained through a systematic literature review. The remaining sections of the paper are as follows: Section 2 presents the SWOT and PESTLE analysis of SMEs. The applications of AI in manufacturing are discussed in section 3. Digital strategy is discussed in section 4. Section 5 provides a literature review. The AI MM for the aerospace industry is described in section 6. Section 7 discusses future challenges. This study's conclusion can be found in section 8.

2 SWOT and PESTLE analysis for aerospace SMEs

This section describes SWOT analyses of SMEs' digitalization efforts (see Table 1).

Table 1. A SWOT analysis is used to evaluate a company's competitive position and plan its strategy.

Strength	Weakness
• Défense sales increase because of security threats	• Production-related issues, especially for aircraft engines
Opportunities	Threats
• Aircraft with higher fuel efficiency are in demand.	• Trade wars

PESTLE ANALYSIS

Businesses use pestle analysis to figure out where to launch new products (see Table 2).

Table 2. PESTLE analysis analyses a company from six different perspectives: Economic, Political, Sociocultural, Legal, Technological, and Environmental.

Political	Economical
• Aerospace industry growth continues to be driven primarily by the United States.	• The aerospace industry suffered from pandemics
Social	Technological
• The aerospace industry is facing a skilled talent shortage.	• The digital revolution is gaining traction.
Legal	Environmental
• The aerospace industry has regulatory compliance and restrictions.	• Operational impacts of manufacturing on the environment

3 Applications of AI in the aerospace manufacturing industry

AI has become a crucial tool for aerospace companies. The technology is improving fuel economy, part design, inspection processes, and maintenance, repair, and overhaul (MRO). A growing use of artificial intelligence has also allowed engineers to improve the capabilities of military, emergency response, and passenger craft.

Aerospace has benefited from additive manufacturing because it makes production faster, cheaper, and more flexible [13]. Research in additive manufacturing (AM) has increasingly turned to ML, which is a subset of AI.

- Preventative maintenance

In aerospace and defence, artificial intelligence (AI) can be used to order parts and schedule repairs before they are needed. Using IoT, predictive maintenance can help predict damage, for instance, by collecting vibration and ultrasonic data from CNC machines' spindles [14].

- Training

AI can help by providing a suitable environment.

- Factory Automation

By improving efficiency, accelerating innovation, and bringing other new technologies like 3D printing and collaborative robotics, artificial intelligence is helping to improve productivity.

- Increased safety & compliance

In addition to reducing human error, AI can improve safety.

- Generative AI and coding

It saves time and resources for teams to use AI applications for coding purposes instead of hiring high-demand talent for embedded software development.

- Quality assurance

Manufacturing and quality control processes in aerospace have become more efficient and precise thanks to artificial intelligence.

4 Digital Strategy

The Internet, big data, cloud computing, and artificial intelligence are changing as we enter a new round of industrial transformation and scientific revolution [15]. Michael Porter proposed three generic strategies: leadership, differentiation, and focus. Businesses of all sizes can use these strategies. Culture, infrastructure, and capabilities are key to digitalization. Getting there takes a step-by-step process and tailored measures.

A company's strategy serves a variety of purposes, including exploiting new opportunities and gaining an edge over its competitors, as well as developing its resources and competences [16]. In a post-pandemic economy, digitalization is an essential strategy to sustain business and growth. As part of its digital strategy, an organization uses digital technologies to create new differentiation capabilities. In recent years, digital technology (e.g., personal computers, mobile phones, AI, robotics), as well as looking into the future (e.g., human-like robots, self-driving cars, 5G, and the Internet of things), has changed the way things are done [9]. Companies must radically rethink their business models to avoid being left behind [9].

Porter’s five forces:

As the digital transformation continues, competition will become more stringent; and Porter's forces can provide useful insights to organizations throughout this period. Despite today's digital diversity, even the strongest companies will face fierce competitors (see Figure 1).

- New competitors are a threat.

As the industry is capital-intensive, new entrants are not likely to enter. The barriers to entry play a crucial role in determining whether new entrants pose a threat [9].

- Threat of substitute

End users must buy product that matches requirements and the criteria outlined by government and aviation administrators.

- Bargaining power of the buyer

Quality assurance is required hence medium bargaining power.

- Bargaining power of supplier

Supplier technical competency and adaptability are important hence medium.

- Competitive rivalry

Moderate suppliers are usually long-term.

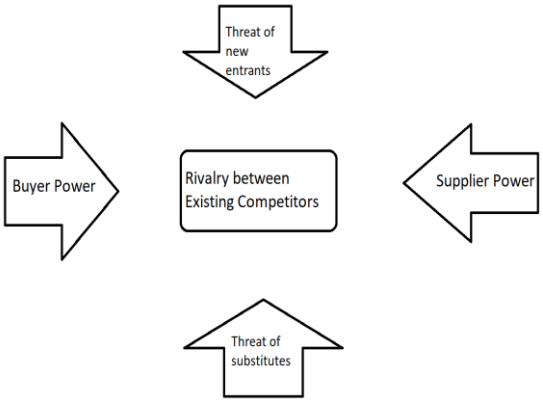

Figure 1. Porter's forces can provide useful insights to organizations. Strongest companies will face fierce competitors due to digital diversity.

A value chain analysis is part of Porter's Value Chain model. By disaggregating a company's strategic activities, Porter's value chain can help identify the sources of competitive advantage, i.e., cost-cutting or price-raising steps. Companies use Porter's Value Chain model to analyse each of their processes for profitability using a customer relationship-cantered approach. Here, A primary activity is one that generates revenue directly, while a support activity is one that enables primary activities to occur (see Figure 2).

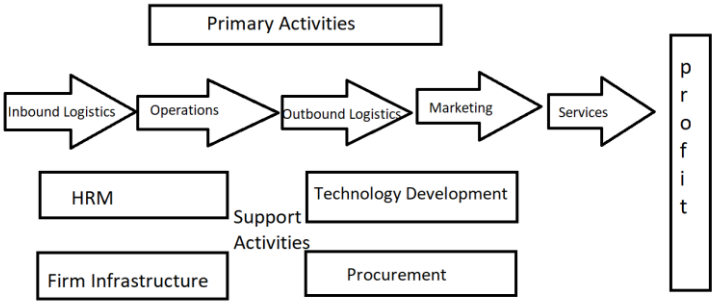

Figure 2 Competitive advantage can be identified with Porter's value chain.

How companies create value is being impacted by digital transformation. It's the inversion of a company that's most valuable in digital transformation. When companies orchestrate value with other companies, this becomes possible. Businesses that invert create partnerships with users, developers, and merchants (see Figure 3). Inverted firms have high market capitalization not because they automate or shift labor to capital, but because they coordinate external value creation. Increasing digital transformation value comes from a firm inversion or changing from creating value by itself to orchestrating it [17].

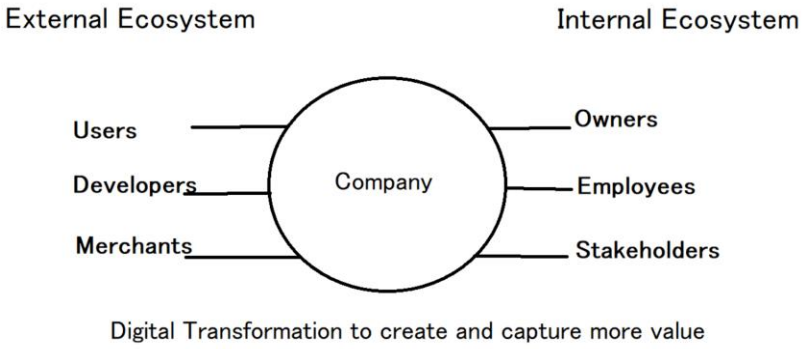

Figure 3 Firm Inversion through partnering with external ecosystem.

5 Literature review

There are over 30 million SMEs of fewer than five hundred employees in the United States, which represents 99.9% of all businesses. Over 80% of small American businesses don't use digital tools well [18]. AI maturity models can be used to evaluate the progress of an organization and gain a better competitive edge with higher productivity and efficiency by understanding the requirements for change. Maturity models can help organizations assess their effectiveness and plan next steps. An evaluation of the available maturity models is conducted through a literature review.

AI provides customers with deeper insights and improves the user experience. Indirectly, mass individualization is enhanced by providing AI support for customers [19]. To promote prosperity economically and make technology safer and more secure, a need exists to cultivate a culture of innovation [20]. According to a McKinsey study, 70% of manufacturers are currently using or plan to use artificial intelligence in their production processes. Many manufacturers see AI's value in production and want to integrate it into their processes [21]. The use of artificial intelligence in production has led to a reduction in accidents, a reduction in energy consumption, and a reduction in breakdowns.

The goal of a literature review is to identify and select relevant studies [22]. Systematic reviews involve many stages, like identifying search sources and search strategies, picking primary studies, downloading data, monitoring, and synthesizing the results. This study followed the steps of identification, screening, eligibility, and inclusion for a comprehensive and systematic search. Identifying relevant records started with a title and subject search in multiple academic databases, like ACM Digital Library, Springer, ScienceDirect, IEEE, ABI/Inform Global, and ProQuest. A manual search was also done using Google, and Google Scholar. Journal papers, conference proceedings, book chapters, and technology reports were found using these key resources.

Several search terms were combined in this paper to identify keywords that addressed the research questions such as "Maturity Model", "Manufacturing", "SME", "Artificial Intelligence", and "Artificial Intelligence Maturity Model". Search strategies usually involve extracting terms from the research question and then performing advanced searches using Boolean "ORs" and "ANDs" [23].

The search string is (‘‘model’’ OR ‘‘maturity’’ OR ‘‘maturity model’’) AND ("Aerospace" OR "Aeronautical") AND (‘‘manufactur*’’ OR ‘‘SME*’’ OR ‘‘producti*’’) AND (‘‘Industr* 4.0’’ OR ‘‘Digital* Transformation’’) AND (‘‘artificial intelligence’’ OR ‘‘AI’’). Models developed by academics and practitioners for AI and manufacturing from 2010 to 2023 were included in this study. The papers selected must focus on Artificial Intelligence or Manufacturing maturity models. In the study, only content relevant to answering the RQs is included. In the review, we looked at 50 papers and finally, 10 papers were selected based on RQs. The available maturity models from journal articles were systematically reviewed. Based on the classification of the MM dimensions, the following six classifications were identified: Production, Organizational Strategy, Leadership, Consumer, Institutional Culture, and Technology. A comparison of AI Dimension is shown below to identify gaps and directions within the MM (see Table 3).

Table 3. Overall comparative analysis AI dimension based on Production, Strategy etc. and whether SME organization.

Author	Production	Organization Strategy	Leadership	Consumer	Institutional Culture	Technology	SME
[24]	X	X			X	X	Yes
[25]		X	X		X	X	No

[26]	X	X	X	X		X	No
[27]	X	X	X	X	X	X	No
[28]		X			X	X	No
[29]	X	X				X	No
[30]	X	X		X		X	No
[31]		X	X	X	X	X	No
[32]		X		X		X	No
[33]		X		X	X		No
[34]	X		X				No

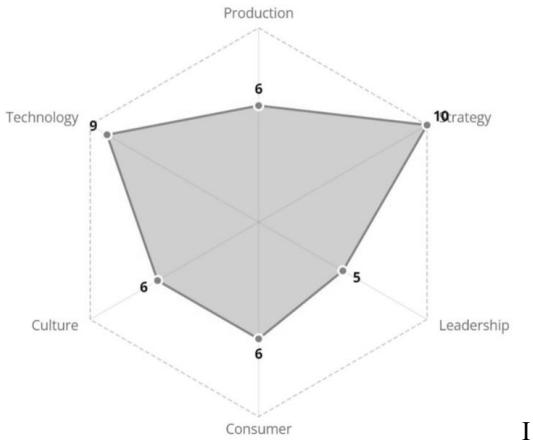

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Figure 4 Dimensions of AI based on the above calculation.

Using this comparative analysis as a guide, AI maturity models could be developed to address existing MM flaws (see Figure 4). Involvement in research, assessments, and criteria for implementation are more intensive for SMEs as these have lagged other sectors in digitization efforts. An AI maturity model that meets SMEs' requirements will help in assessing AI maturity levels in SMEs.

6 Aerospace SME market analysis using AI MM

A maturity model assesses an organization's readiness and pinpoints its weaknesses. These weaknesses need to be addressed to move up the assessment level. A maturity model is a powerful tool capable of analyzing the current state of a specific focus area and aiming for continuous improvement [35].

Industry 5.0 is more human-centric than Industry 4.0 [36]. The 5.0 industrial revolution is a future-looking concept that complements and extends the fourth industrial revolution but isn't classified as such [35]. For AI maturity to be human-centric, resilient, and sustainable, it needs to be assessed against Industry 5.0 (see Figure 5).

Figure 5 Industry 5.0 emphasizes human centric approach.

People are the focus of Industry 5.0 because it gives them a chance to shine, strengthens their social standing, and makes them learn for life [35]. Resilience is the ability to cope with change flexibly in globalized value chains and markets [34]. The resilience of an industry contributes significantly to society's resilience, and it makes sure production can continue, and workers can keep working [36]. By building on Industry 4.0 technologies, such as Big Data, digitization, and artificial intelligence, Industry 5.0 emphasizes technology's role in meeting new, emerging social and environmental needs [35].

Data generated and processed at the edge will account for 50% of enterprise data by 2025, up from 10% today [38]. The convergence of edge computing and 5G simplifies data access by optimizing service delivery at the network edge and reducing latency [38]. Data generated by smart tools and sensors raises important questions, including what data you are going to need to achieve real change, where should you put the data, and how should it be used. 6G can lead to low latency results with IoT. This can benefit in predictive maintenance, remote monitoring, remote maintenance, automated warehouses, etc. Sixth-generation (6G) mobile communications feature low latency, high throughput, and massive connectivity compared to previous generations [39]. The Industrial Internet of Things (IIoT) will benefit greatly from these advantages, especially as edge intelligence is widely applied [40]. Data is everywhere, but how to intelligently manage it to improve operations is a challenge. The application of artificial intelligence technology to intelligent manufacturing facilitates model development, system architectures, and technology systems. The Internet of Things is powered by three vital technologies. AI, Big Data, and 5G. IoT frameworks provide the data, and AI uses the data to accomplish specific tasks. A higher industrial revolution is still in its early stages, but AI has been used in engineering and manufacturing.

7 Future challenges and opportunities

As digitalization transforms multiple aspects of business, it offers unparalleled opportunities for value creation and capture, as well as posing serious risks. Digital transformation is a

cultural challenge. A common vision must be shared by all - from the top down to the new employees. The aerospace industry is increasingly reliant on artificial intelligence (AI). Several technologies (such as AI & analytics, cloud computing, 5G, IoT, and data engineering) are converging at a rapid rate in the Factory of the Future. To prepare for future challenges, SMEs must ensure the health and resilience of their supply chains, prioritise strategies to increase the flexibility of their workforce, and modernize their manufacturing capabilities on a calculated basis.

Recently, Magnix Electric Aeroengines, based in Seattle, claimed the world's first commercial electric plane flight when it powered a modified Harbour Air seaplane with an electric engine [41]. Battery-powered flight presents major technological challenges, but it can be a game changer and disrupt the aerospace industry.

8 Conclusions

Review of current MMs and recommendations for expanding them to accommodate 6G and Industry 5.0. An assessment of the existing MMs was conducted by SLR for aerospace SMEs. A human-centered approach and technological upgrades through 6G can address an existing research gap. After 2020, the aerospace industry is slowly, but surely, recovering [14]. Collaborating and working together is essential for American aerospace SMEs. In addition to benefiting SMEs, society will also benefit from future technologies.

9 Glossary

Digital Factory: The concept of Industry 4.0 describes how digitalization is integrated with traditional industrial processes.

Digital Manufacturing: Companies can improve their operations using advanced software and digital technologies in digital manufacturing.

Digital System: A system in which information is transmitted in a series of pulses.

DIS: Data and Information System

OEM original equipment manufacturer

VAM value-added manufacturer

OJT on-the-job training

NORAD North American Aerospace Défense Command

10 Companies

Airplane manufacturer: Boeing (civilian and Défense), Lockheed Martin, Northrop Gruman

Plane engine: GE Aerospace

Best states for aerospace SMEs: California, Nevada, District of Columbia, Arizona, Utah, Washington, Massachusetts, and Colorado.

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