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Digital Engineering: A Short Overview

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ABSTRACT

The digital transformation is being embraced by companies around the world with the expectation of improving product development. Digitalization has changed engineering fundamentally. Digital engineering is the construction of digital models that represent every characteristic of a system that is to be developed. Digital engineering practices are helping to improve product development processes. Digital engineering is a key evolving technology for both experts and users to understand. It will dramatically transform how humans interact with intelligent systems. It is changing the ways we work today. It constitutes the first step towards a digital future in the engineering, architecture, and construction industry. This paper provides a simple introduction to digital engineering and its various applications.

KEYWORDS: *digital technologies, digital transformation, digital engineering, digital engineers*

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INTRODUCTION

Digital technology has transformed analog processes, making complicated tasks easier, faster, and even automatic. Digital product engineering is an evolving process, a future-state that organizations need to achieve to make the world a safer, more secure place. Digital technology has enabled businesses to use computers to automate shipping systems, supply systems, and warehouse systems. It will distinguish the winners from the rest.

The field of engineering has also been transformed. Digital transformation has created a networked, intelligent, and connected economy. The way engineers design, manufacture, deliver, and consume will never be the same.

Digital engineering is an initiative of the US Department of Defense (DoD) that will transform the way the DoD designs develops, delivers, operates, and sustains systems. DoD requires robust engineering practices to develop the weapon systems the nation needs to maintain superiority. Today's military operations are dynamic and need modernizing our defense systems. Secretary of Defense, General James Mattis well said, "Success does not go to the country that develops a new technology first, but rather, to the one that better integrates it and more swiftly adapts its way of fighting." Without sustained investment to restore readiness and modernize, we will rapidly lose our military advantage. One way to achieve this is by incorporating the use of digital computing, digital engineering, and new technologies to conduct engineering designs. Digital engineering requires new techniques, processes, and tools, which will change the way the engineering community operates.

WHAT IS DIGITAL ENGINEERING?

Digital engineering is the art of creating, capturing, and integrating data using a digital skillset. It leverages data and technology to produce improvements to applications or entirely new solutions. It uses models and digital/computer resources to implement engineering tasks such as design, analysis, prototyping, and experimentation.

Figure 1 shows some components of digital engineering [1].

Digital engineering is a holistic, data-first approach to the end-to-end design of complex systems. It may be regarded as an offshoot of the traditional model-based systems engineering (MBSE), which is illustrated in Figure 2 [2]. In MBSE, the model and its artifacts replace documents to define electrical, electronic, mechanical, and software implementation.

The main goal of digital engineering is to accelerate the development of complex products and systems (such as modern aircraft, satellites, guidance systems, etc.) by overcoming the established engineering disciplines. The most promising top digital engineering companies include Indium Software, Cognizant, Hakuna Matata, Accenture, Cisco Systems, Brillio, eMudhra, Kelton Tech, Happiest Minds, and Proviti [3]. Digital engineering services companies bring core digital skills and expertise across industries. They include EPAM, Endava, Infostretch, Global Logic, and Globant.

DIGITAL ENGINEERING STRATEGY

The most consequential force behind creation and widespread adoption of digital engineering is the US Department of Defense (DoD), which announced its Digital Engineering Strategy in 2018. The main objective of the strategy is to modernize how DoD conceives, builds, tests, fields, and sustains national defense systems. In other words, the strategy is expected to guide the planning, development, and implementation of the digital engineering transformation across the Department. It is intended to modernize how DoD designs, develops, delivers, operates, and sustains systems. The Department's five strategic goals for digital engineering are [4]:

- *Formalize* the development, integration, and use of models to inform enterprise and program decision-making
- *Provide* an enduring, authoritative source of truth
- *Incorporate* technological innovation to improve the engineering practice
- *Establish* a supporting infrastructure and environment to perform activities, collaborate, and communicate across stakeholders
- *Transform* the culture and workforce to adopt and support digital engineering across the lifecycle

The Digital Engineering Strategy is displayed in Figure 3 [5]. It has become a game-changer for the DoD and each branch of the military – Army, Air Force, Navy, Marines, Space Force, and Coast Guard, as well as DoD development partners. It has accelerated development, increased efficiency, and improved quality of all acquisition activities. Any subcontractor who works with the DoD must incorporate digital engineering into the development of its products and systems (military, industrial, or commercial). The DoD has stipulated in their strategy that any company working with them must use digital engineering processes to ensure transparency, safety and accountability for their systems.

DIGITAL ENGINEERS

Digital engineers help defense, civil, and commercial clients deliver and integrate advanced surface, air, and space solutions to meet their mission. They assess each client's needs, goals, and unique situation to ensure the fastest results with the highest value, efficiency, and cost-effectiveness, while driving digital integration. They embed digital engineering within an agile framework, thereby increasing return on investment while helping organizations manage complexity and transform faster with reduced risk. Using simulation packages and 3D models, engineers are increasingly working with advanced technologies to capture data and design in a digitized environment. Engineers must validate vendor designs before incurring the massive costs associated with building prototypes.

APPLICATIONS

Digital engineering is applied in many areas such as construction engineering, manufacturing, connected enterprise, digital twins, digital threads, software-driven business, building information modelling, software product engineering, and defense systems. Some of these are discussed next.

- Software Product Engineering: Software is the most critical component of the product engineering across industries today. The number of lines of codes in a typical product such as an automotive or aircraft has increased significantly [6]. Software product engineering (SPE) is the result of applying digital engineering principles to software development. SPE involves all stages of product creation: design, development, testing, and deploying. With SPE, design, and engineering teams work together to improve business outcomes.
- *Digital Twins:* The concept of the digital twin gained popularity in 2017 within aerospace engineering. This is an important form of modeling and simulation application in the digital age. The ultimate goal of digital

engineering is to produce digital twins, which are digital replicas of real and potential physical assets (i.e. "physical twins"). This involves creating virtual replicas to enable faster system development and upgrades with less risk. One can create a digital twin of a machine in the form of a 3D model. A digital twin can unite your CAD and controls to help create better industrial automation systems. Digital engineering and their associated digital twins intend to revolutionize how we architect and design future systems-of-systems. Artificial intelligence and machine learning are complementary technologies that will play a critical role in digital twin technology evolution. Digital twin has been widely used in intelligent manufacturing, factories, buildings, smart cities, etc. [7]. Figure 4 shows digital twins in digital engineering technology architecture framework [8]. Military applications of a digital twin to training could enable decision-makers to have a better understanding of war fighters' capabilities, previous training, and skills.

- *Digital Thread:* Digital thread is a unique communication framework that enables a connected data flow. It offers easy access to data previously stored in silos. This can provide users with a logic path for tracking information throughout the systems' lifecycle. By pulling on the digital thread, engineering teams can better understand the impact of design changes, as well as manage requirements, design, implementation, and verification. This capability is vital for accurately managing regulatory and compliance requirements, reporting development status and responding quickly to product recalls and quality issues. In terms of digital engineering, a digital thread represents a significant role in connecting engineering data to related processes and people. But a digital thread is not plug and play; it is a process that must be designed from the ground up.
- *Manufacturing:* Digital technologies are reshaping the manufacturing landscape. The digital engineering space is witnessing a wide adoption of various technologies in the manufacturing industry. Figure 5 shows the split of manufacturing organizations by country as of 2018 [9]. Digital technologies are used by manufacturing companies to help drive productivity. In managing production in a plant, digital engineering can help your product reach the market at record speeds, reduce your risk, and redefine productivity. An example of connected manufacturing is displayed in Figure 6 [10].
- *Defense Systems:* These are characterized by their demanding missions and also by the detailed documentation that must be created, managed, and interpreted throughout a system's life cycle. The document-heavy approach of traditional systems engineering seems out of step with our modern age.

BENEFITS

Traditional engineering methodologies are human intensive and offer insights from the transactional data generated at every point. The art of digital engineering enables designers to explore possibilities and develop innovative solutions in a virtual environment. Digital engineering enables integration, collaboration, automation, and mobility. It speeds creation of technical representations and enables analysis to speed decision making, model behaviors, and validate requirements. It allows people to share and view up-to-date engineering information for a project. It ensures that everyone is on a common platform, reducing confusion and providing absolute design clarity. Digital engineering is the answer when flawless, accountable production can result in life or death. It holds great promise for defense organizations.

Other benefits include [11]:

- Modernize system practices
- Improve decision making and flexibility
- Streamline processes and approaches
- Increase return on investment
- Improve performance
- Manage complexity
- Transform rapidly, with flexibility
- Spot gaps and reduce risk
- Accelerate data-driven decisions
- Accelerate timelines—and ultimately, faster mission success
- Automate generation of technical documents
- Traceability across the system architecture
- Instant updates and intuitive visualizations
- Embedded cybersecurity and assured compliance
- Multidisciplinary approach incorporating strategic planning

CHALLENGES

Digital Engineering can provide several opportunities. However, some challenges must be overcome. Engineering organizations are at a crossroads. New market forces as well as the need to continuously enhance the product functionality pose challenges and opportunities. For example, in construction engineering, labor productivity has been stagnating for decades and companies have

been slow to change, adapt, innovate, and benefit from emerging technologies. Another major challenge is finding enough people to develop digital engineering skills and produce the next generation digital products.

CONCLUSION

In the digital new era, everything including the entire world can be digitalized. Digital engineering is essentially an integrated digital approach that supports lifecycle activities from concept through disposal. Adopting digital engineering processes will help improve safety, reduce risk, minimize cost, and improve sustainability.

Digital engineering is now being offered a course in many colleges of engineering. The course is designed to prepare students for rapidly changing digital technology and its applications. Digital engineers may consider joining the Society of Digital Engineering [12]. More information about digital engineering can be found in the books in [13-20].

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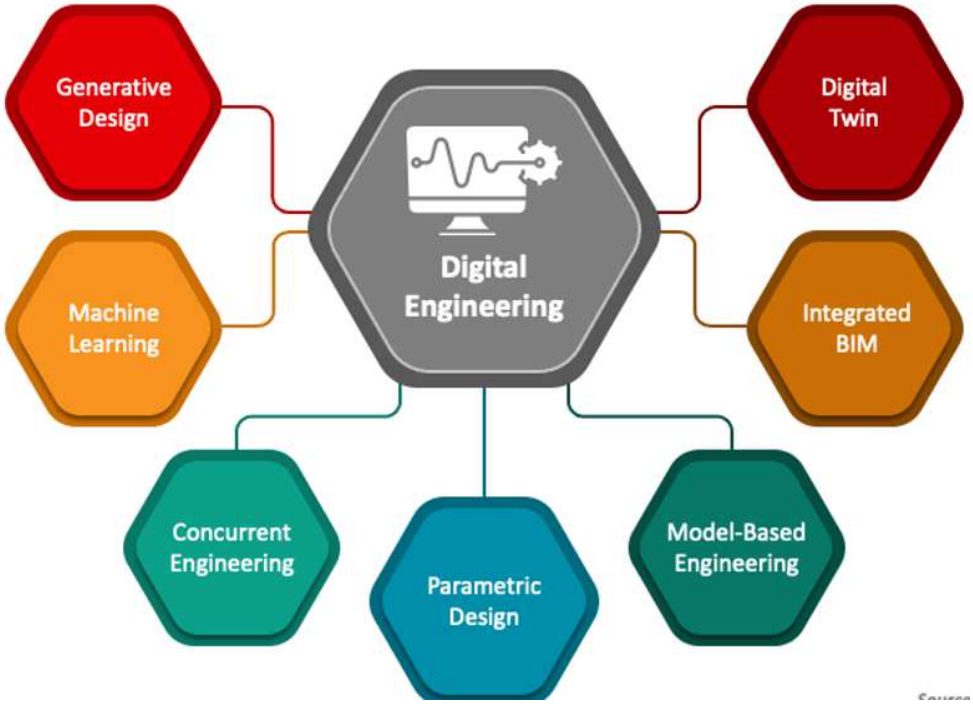

Figure 1 Components of digital engineering [1].

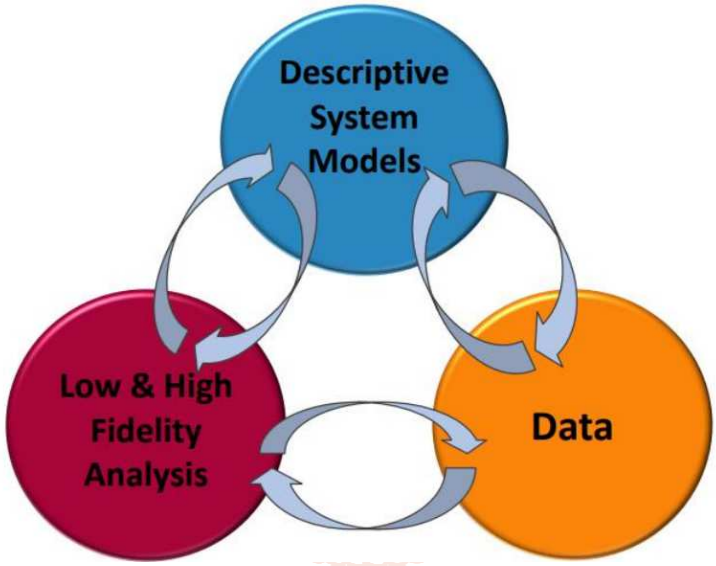

Figure 2 Model Based Systems Engineering (MBSE) [2].

Figure 3 The Digital Engineering Strategy [5].

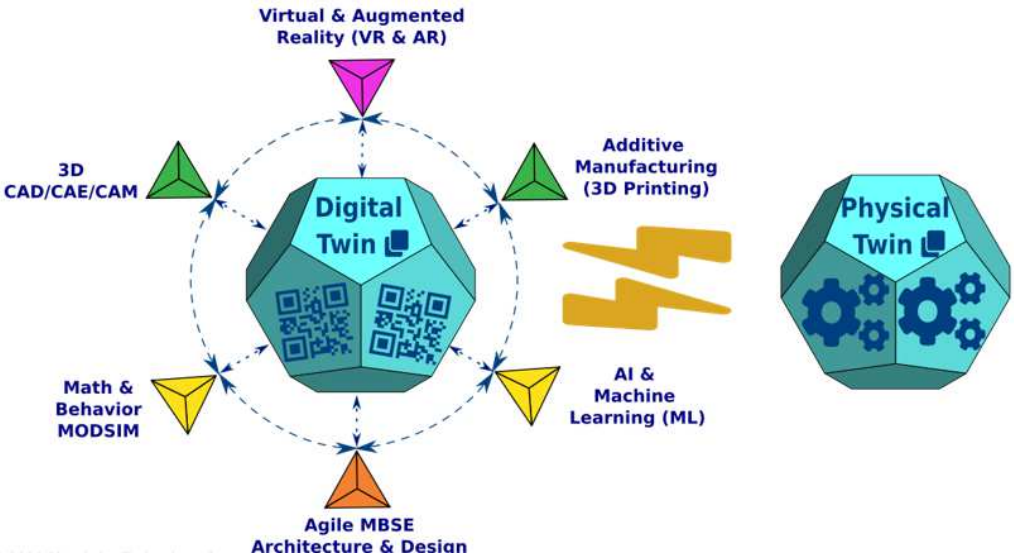

Figure 4 Digital twin in digital engineering technology architecture framework [8].

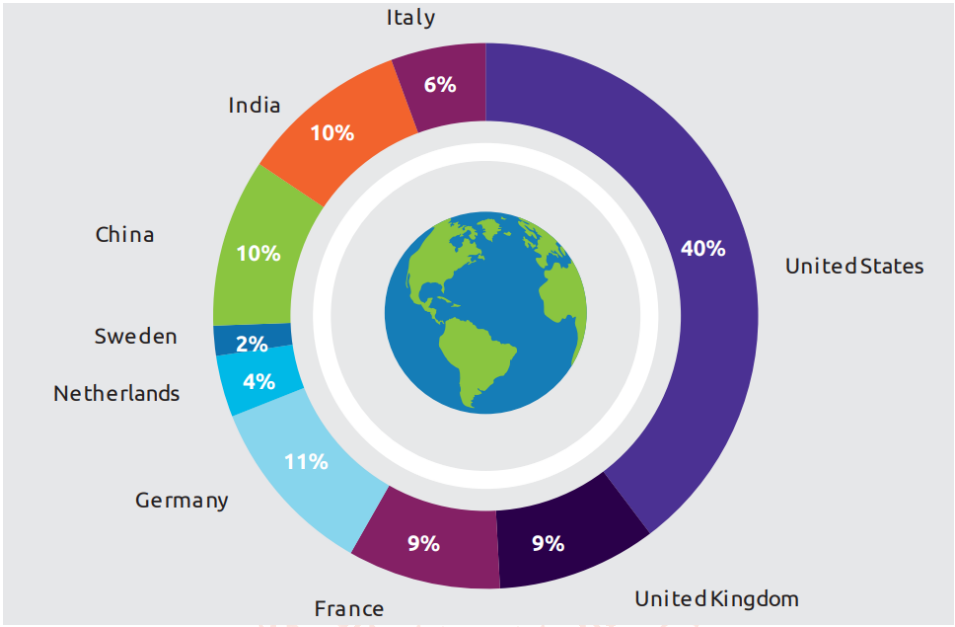

Figure 5 Split of manufacturing organizations by country [9].

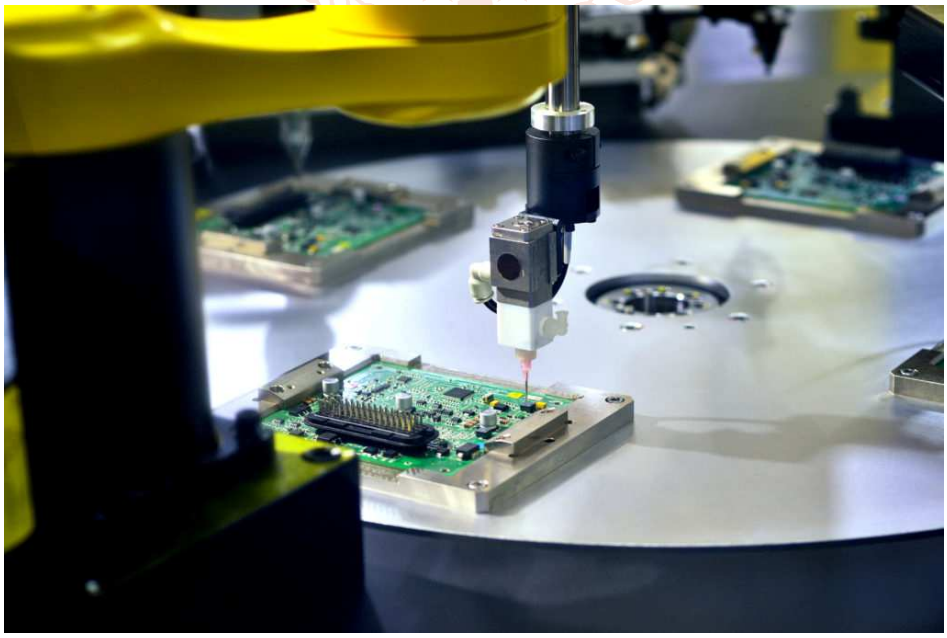

Figure 6 An example of connected manufacturing [10]