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Accelerating Industry 4.0 with Digital Twin

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A grayscale image of an industrial robotic arm, overlaid with various digital data visualizations such as line graphs, bar charts, and circular progress indicators, representing the concept of a digital twin.

**“A digital twin takes transparency
to a whole new level.”**

*– Habib Modabber, Director of Business Development,
Bosch Sicherheitssysteme*



Manufacturing is on the verge of explosive growth in the use of digital twins, or a digital replica of a physical system, process or product. This technology, which allows users to experiment with a digital file before making changes in a physical environment, is already in use today in life sciences, aerospace, automotive, defense, mobility, manufacturing, energy and utilities. And the possibilities are only as limited as our imaginations.

A manufacturer, for example, can create a digital model of their assembly process that incorporates key elements including staffing levels, equipment efficiency and inventory counts. This model can then be used to test proposed changes to that process before making the changes to physical process to ensure that the most optimal change is made. Surgeons can now study the human heart by creating a digital twin of the heart before performing the surgery thereby increasing successful outcomes. In the automotive industry, companies are using these simulations to gage performance of vehicles and recognize areas of failure and maintenance.

The adoption of digital twins has huge implications for manufacturers. A manufacturer's workforce needs to acquire significant training and adopt new ways of thinking to operate in the world of the digital twin. Processes need to be integrated to optimize the use of digital twins, yet many manufacturer's processes are fragmented. Digital twin technologies are rapidly evolving, and manufacturers need to stay abreast of new products to make good software purchasing decisions.

The best way to understand these implications is to view them in the context of a manufacturer's people, processes and technology over time horizons of one-to-two, three-to-five and five-plus years.

People

Now (1-2 years)

The next one-to-two years will likely be the most tumultuous period for the implementation of digital twin technologies, as it's set to be a \$35.8 billion market by 2025. While most large innovative manufacturers on the cutting edge of technology adoption are already down the path of implementing

digital twins, many pursuing its adoption will be in the infancy stages of implementation. This will create a host of challenges.

The new skills needed to accommodate digital twin implementation is likely to significantly challenge human resource and training departments. First, the technology

teams building digital twins will need to possess a combination of very unique skills in order to create good representative models. They will need to understand the digital twin software and the manufacturer's operational processes to ensure that the digital twins they build adequately reflect these processes. In the near term, the combined skill set that is needed will come from a combination of process experts and simulation software experts collaborating, resulting in those people becoming more experienced in both areas. Companies will also need to learn to incorporate time and availability on the shop floor for validating the changes recommended through the use of simulation software.

A variety of new skills will also be needed by those across the organization who are the end users of the digital twin. The manufacturer's leaders will need to understand the business value of the digital twin so they can identify areas of its application and optimizations within their business. Finance teams will need to learn how to cost justify the implementation of the digital twin and determine its return on investment. Lastly, engineers, managers, etc., will need to understand how to evaluate the performance data provided by the digital twin. Therefore, people who are experienced in, and comprehend the context of, large operational data sets will be an asset to digital twin implementation (Adsit, 2020).

Near (3-5 years)

Digital twin adoption is expected to exponentially grow over the next 3-5 years. The manufacturers who today are already adopting digital twins will develop even more sophisticated models. Those who start adoption in the next year or two will have some experience on which to build. Meanwhile, a plethora of companies yet to adopt the technologies will likely be scrambling to enter the arena due to competitive pressures. The Industrial Data Corporation forecasts that during this time period, 70% of manufacturers will use digital twins to conduct simulations (Immerman, D. 2019).

The manufacturing companies that begin adopting digital twins today will, by this time, have a better

understanding of the skills their technology teams need to build digital models. Fortunately, new generations of recruits for these positions will be better prepared to work with the technology than their predecessors. They will have grown up in a more technologically advanced world filled with a multitude of connected and smart devices. They will also benefit as universities expand their software engineering programs and training providers offer more certificates on digital twin software, IoT integration and machine learning.

As these manufacturing leaders begin to understand the power of digital twins—through results in increased throughput, efficiency and decreased downtime—more end users of the technologies will emerge within their organizations.

Increasingly, engineers will use them to test changes in assembly processes, facilities teams will use them to design more optimal factory floor layouts and workers at higher safety risks will train on them before performing in real situations. Company technicians will also use digital twins of equipment to perform predictive maintenance. The IDC forecasts that by 2022, those manufacturers using digital twins will be in a position to reduce equipment failures by 30% (Immerman, D. 2019). Beyond this, advancements in augmented and virtual reality will increase product development teams' use of digital twins to redesign and test products. This increased use of digital twins will require workers at all levels to learn more about the technology and how modeling can improve their decision making.





Far (+ 5 years)

This time period is expected to produce a plethora of intriguing and exciting opportunities to capitalize on digital twin adoption. Digital twins are expected to proliferate in a multitude of arenas including mobility, aerospace, automotive, manufacturing and health care. Manufacturers that adopt digital twins in the next several years will, by this time, have taken their digital twin adoption to entirely new levels.

The digital twin software is likely to evolve more rapidly than in the past. Yet-to-be-invented software will need to be quickly absorbed by the technology teams responsible for their implementation. These teams will also need to stay abreast of the advances in synergistic

technologies that will further drive, and integrate with, digital twin software including those in the areas of IoT, cloud computing, Big Data, artificial intelligence and machine learning.

A digital twin's inter-connectivity to these synergistic technologies will also present a multitude of new data security challenges in the form of data leaks, malicious viruses, malware and cyberattacks. Digital twins are expected to be valuable targets of digital predators due to the vast amounts of company sensitive data they will contain (Markets and Markets, 2019). As a result, technology teams will also need to understand how to overcome these challenges. Because the technology will be evolving so rapidly, companies are very likely to experience a

paradigm shift in their efforts to recruit technology team members who can build effective models. More emphasis will be placed on identifying candidates who are nimble and can quickly learn yet-to-be-invented software and less on candidates with specific software expertise.

The end users of digital twins within organizations that adopt the technology within the next several years will, by this time, be well on their way to rethinking how they approach their work. Digital twins will have provided these leaders, supervisors and front-line workers with a valuable tool to improve their decisions with less emphasis on gut and experimentation and more emphasis on data and analysis.



Process

Now (1-2 years)

Manufacturers implementing digital twins for the first time are facing a variety of process challenges. First, they will need to understand which processes within their operations best lend themselves to modeling. Having realized the power of digital twins, some may gravitate toward using them to solve their biggest problems by applying them to their most complicated processes. This is a common mistake. Modeling a complex process with a lot of variation can be tedious, time-consuming and discouraging. It can actually impede a manufacturer's ability to adopt digital twin modeling. Manufacturers will most likely learn that the best approach is to capture their organization's low hanging fruit by modeling targeted simple processes that, if streamlined, have some financial impact. This allows them to learn how to create a model and understand its impacts before proceeding to solve larger operational issues that involve more complex processes.

Second, as manufacturers learn and start to use digital twins to tackle their more complex problems, they are likely to experience the sobering realization that digital twins are most impactful when the organization's processes are integrated. This not only saves time creating effective

models, but it also enhances the information provided by the models leading to more optimal decisions. Most manufacturers will find that their processes are not integrated to the degree necessary to maximize the impact of digital twin adoption. They will therefore be challenged to re-evaluate their processes and integrate them where possible.

Near (3-5 years)

As more teams within an organization start to use digital twins to tackle their specific challenges, leaders will start to integrate processes across multiple teams within their organizations to further capitalize on the benefits of digital twins. For example, a digital twin of a piece of assembly line equipment that collects real-time data will provide more than just scheduling information to the assembly line supervisor. It will also provide the purchasing team with forecasts of part needs to expedite ordering and assist the finance team in developing improved forecasts of machine replacement costs. Digital twins also recognize machine downtime trends, aiding in predictive maintenance. In turn, this increases uptime and throughput resulting in better production numbers.

Similarly, retailers using digital twins of their shelving displays will not only assist their store

managers in designing product displays to maximize consumer purchases, these digital twins will also provide the company's marketing team with consumer behavior information, the warehouse team with future inventory needs and the finance team with revenue forecasting data. Integrated processes across teams will make it easier to build digital twins with these capabilities.

In the next three to five years, we will also witness more use of distributed digital twins to manage entire supply chains. This is particularly true for products provided via e-commerce. A 2019 announcement by PYMTS.com revealed that Amazon's Prime two-day delivery service will soon be serving more than 50% of American households. Consumers now want their purchases delivered quickly and expect to be continuously informed about the status of their purchase's arrival. To deliver on these increasingly high consumer expectations, more e-commerce supply chain managers are expected to develop distributed digital twins of their entire supply chain to expedite their decision making. Real time data from strategically placed IoT sensors across the supply chain will provide a supply chain manager's digital twin with information about a product's assembly, packaging, warehousing, transport and



delivery to a customer's doorstep. As issues then arise in the physical world (for example delivery truck traffic delays) the supply chain manager will use the digital twin to make quick decisions (i.e. re-direct the delivery truck) that are played out in the physical world thereby enhancing customer experiences (Elliot, C. 2017).

Far (+ 5 years)

New and exciting uses for digital twins will likely continue to proliferate over the next five years and beyond. Manufacturers will increasingly build distributed digital twins to manage entire supply chains. They will also provide more clients with smart and connected products that will supply manufacturers with valuable insights as to

how their products are being used. Automobiles, electronics equipment and appliances armed with IoT sensors will provide their manufacturers' digital twins with critical real-time information while the products are in use by the consumer. The manufacturer's digital twin will then use this information for generative design, building improved products and servicing existing products. The opportunity for connected vehicles seems endless. For example, a sensor on a consumer's vehicle that provides the manufacturer's digital twin with real-time information about the vehicle's airbag system will assist that manufacturer to build better airbag systems and detect defects more in advance leading to less injuries. This will all lead to significantly enhanced consumer

experiences on numerous levels. (Watts, B. 2018).

Other innovations in the area of digital twins will likely expand as well. In a feature aired on China Central Television, four human hosts were joined by a digital twin of themselves that used machine learning, natural language processing and computer vision (Marr, B. 2019). Imagine manufacturers building digital twins of trainers to bring new hires up to speed more cost effectively.

A recent digital twin of Singapore has helped city planners understand the efficiency of energy consumption among other critical infrastructure issues (Marr, B. 2019). Imagine the implications this will have for companies that have entire manufacturing complexes to manage.





Technology Evolution

Now (1-2 years)

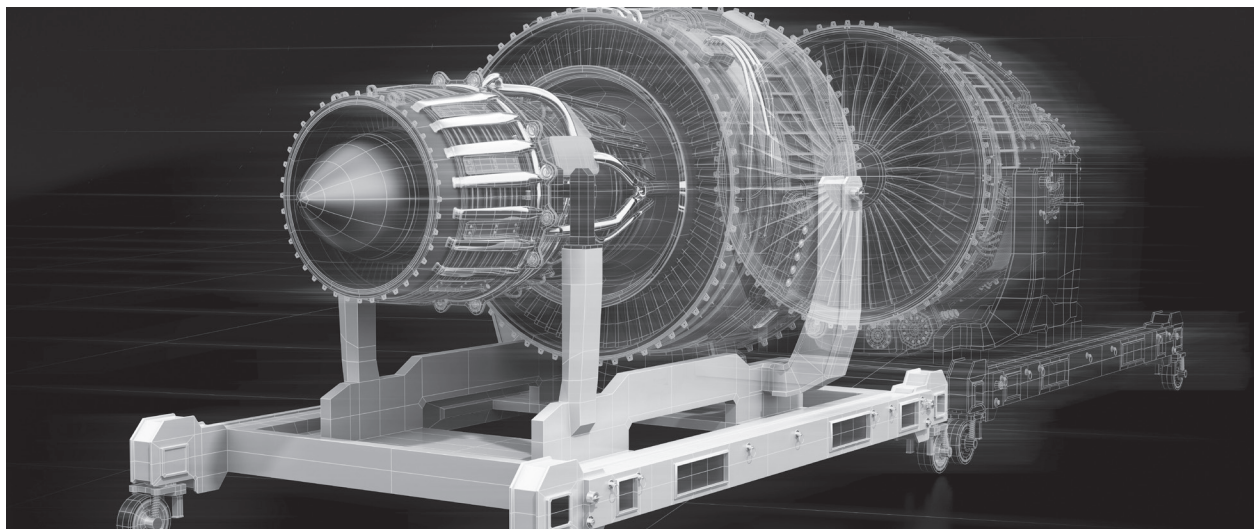
Today, the technology challenges faced by manufacturers pursuing the implementation of digital twin modeling for the first time are significant. Digital Twin may bring to surface companies with outdated ERP, MES and PLC solutions.

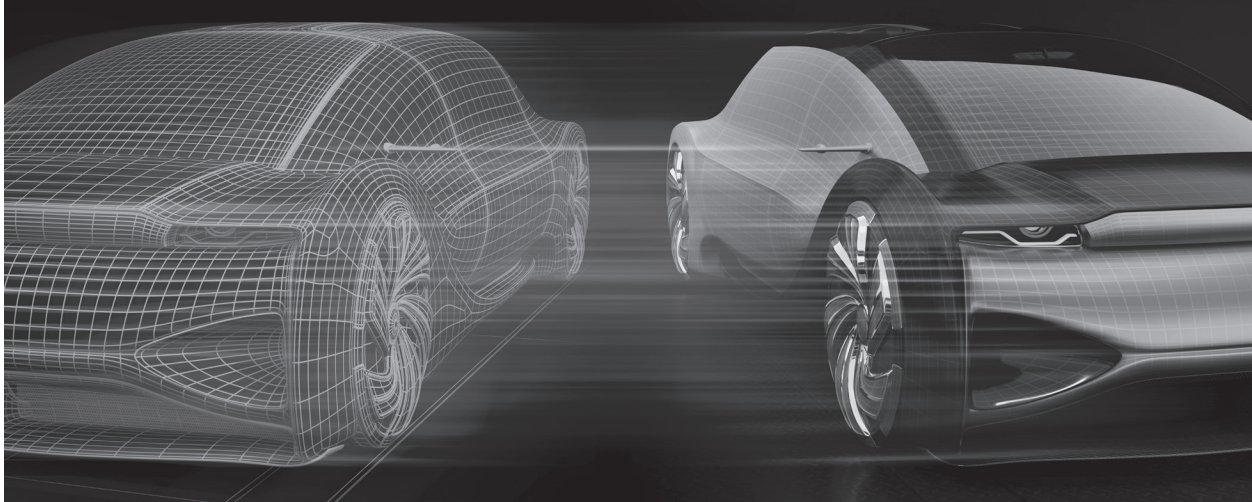
The digital twin software market is anticipated to witness a compounded annual growth rate of 35% over the forecast period 2019-2024 (Naidu, A. 2019). This growth is connected to major IoT and machine learning advancements that are further empowering digital twins. IoT sensors on plant equipment can now collect real-time data and feed it to a digital twin. The digital twin can then use machine learning to analyze the data to improve its predictive accuracy.

This has sparked a rapid deployment of digital twin software products by the industry's biggest market players including General Electric, PTC, Siemens, Dassault Systems, IBM, ANSYS, Microsoft and Oracle (Naidu, A. 2019). As a result, manufacturers seeking to adopt digital twin software will be very challenged to understand product capabilities as they make their purchase decisions. Beyond this, future technological advancements could very well render such purchase decisions obsolete shortly after they are made. Just on the horizon, virtual and augmented reality will further empower digital twin technology. Purchasers of digital twin software will need to stay abreast of these advancements and time their purchase decisions to ensure the software they purchase is capable of this integration.

Near (3-5 years)

Several technology trends that enhance the capability of digital twins are expected to further proliferate their adoption during this period. IoT sensors will likely continue to decline in cost and increase in variety. This will lower the cost of, and increase the ability to, capture and transmit real-time operational data used to feed the digital twin. Advancements in cloud computing, Big Data and machine learning will increase a digital twin's ability to analyze large volumes of real-time data thereby improving its simulations and the accuracy of its predictions. Developments in human-computer interfaces in the form of improved speech recognition, virtual assistants and augmented reality will enhance the ability of workers to interact with a digital twin (Mussomeli, A., Meeker, B., Shepley, S., Schatsky, D. 2018).





As more manufacturers attempt to build digital twins that integrate processes across multiple teams, there will be an increased need for digital twin technologies to integrate with enterprise-wide systems across the company, including those providing customer relations management, enterprise resource planning and product lifecycle management. Digital twins will likely continue to be offered as an embedded feature of newer enterprise applications or acquired separately and added as an enhancement to older enterprise applications. Many manufacturers will probably combine both approaches (Lheureux, B. 2019).

While many technology providers offer IoT-specific development and tools to produce digital twins, some manufacturers may find that a better option will be to outsource the development of digital twins to external IoT service providers who may be more capable of addressing these challenges. IoT service pro-

viders like Accenture, Hitachi and Infosys are expected to continue to offer IT assistance with the design and development of digital twins as part of the project services they offer to customers implementing IoT. (Lheureux, B. 2019).

Far (+ 5 years)

The demand for digital twin software will continue to grow during this period as users of digital twins identify new and exciting opportunities to implement them across their operations and supply chains particularly in the industries of mobility, aerospace, automotive, health care and manufacturing. New software features will be required which will likely lead to significant innovation within the marketplace.

This will result in a stream of new digital twin software products and intensified competition in the marketplace. Large software providers will most likely acquire

smaller providers with niche products that can enhance their offerings. Partnerships among providers will likely grow in order to quickly respond to the needs of the marketplace. As the race for market share continues, software providers will need to be very mindful that their products address, to the extent possible, the multitude of data security challenges.

Furthermore, the numerous technological trends that are empowering the digital twin will likely continue. The explosive growth of IoT sensors will provide even more access to real-time data. The ability to store and analyze huge amounts of data will grow due to even more advancements in the cloud, artificial intelligence and machine learning. Advancements in augmented and virtual reality technologies will facilitate virtual digital twins of entire factories for the purposes of training, practicing emergency procedures or providing tours (Adsit, 2020).

Examples of Digital Twin Industry Applications:

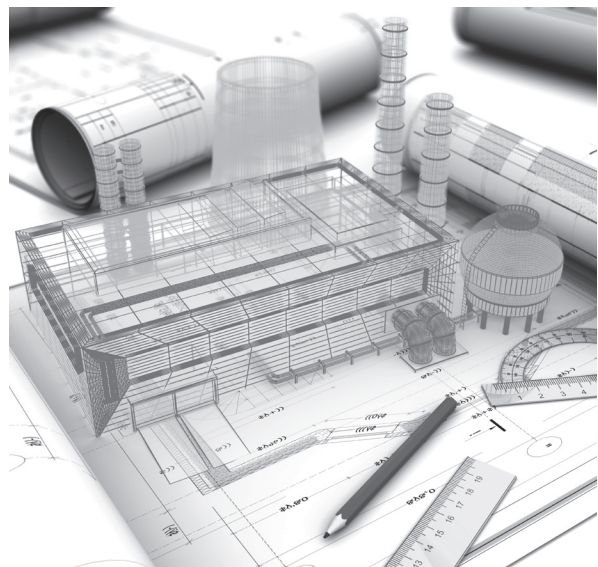
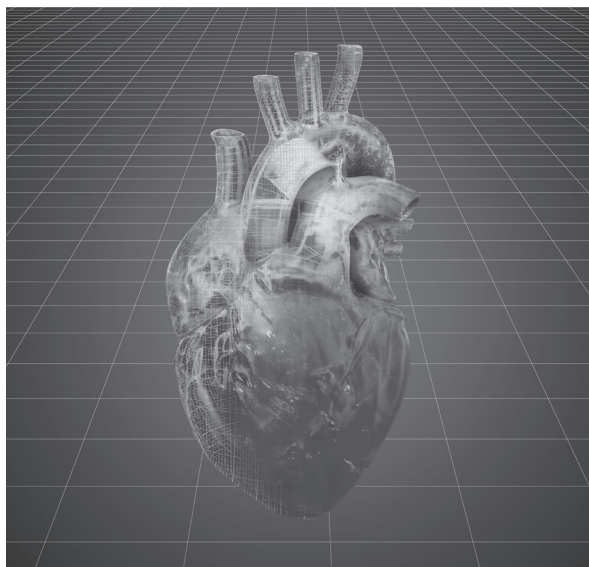
General Electric (GE) Aviation has reported creating digital twins of each of the engines it manufactures in its Lafayette, Indiana plant. The actual engine is equipped with sensors that capture massive amounts of data surrounding the engine's performance during flight. This data is downloaded during flight or when the aircraft pulls up to the gate to the engine's digital twin. This keeps the digital twin up to date with the actual engine in the field allowing for remote monitoring critical to identifying maintenance issues in advance, leading to improved service and reduced costs (Veleta, K. 2017).

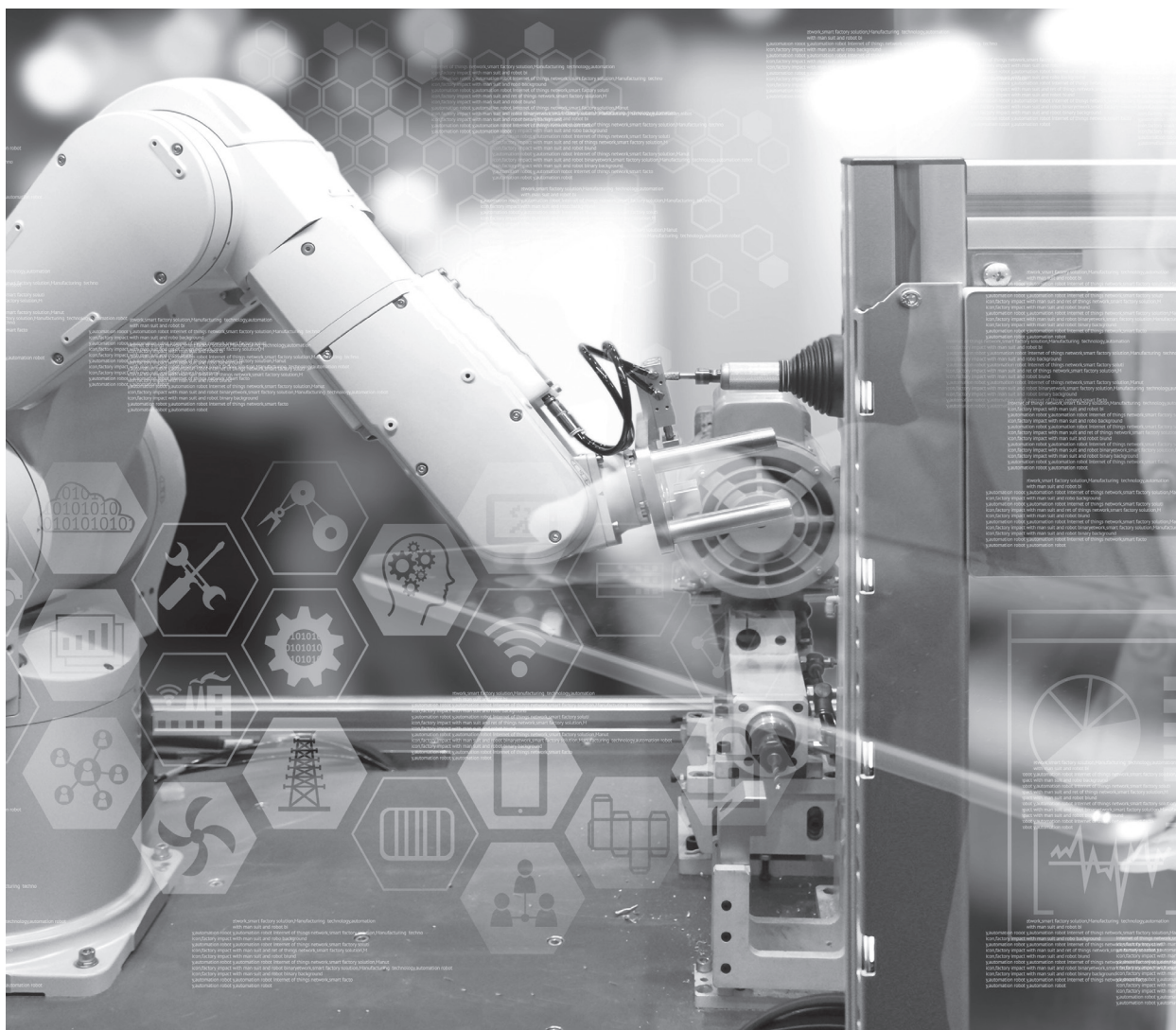
Philips recently proposed the use of digital twins to enhance personalized health care. Using all of the data available from a patient's medical record, a digital

twin of that patient can be created. It can then be used to predict the outcomes of various treatment plans to increase the likelihood of selecting the optimal plan. The digital twin can even assist doctors with decisions made during a procedure. During a procedure, an action's outcomes can be predicted by taking that action on the patient's digital twin before taking it on the patient, thereby providing real-time information critical to assessing the best next action (Philips, 2018).

Chevron Corporation is aiming to use digital twin technology to predict maintenance problems in its oil fields and refineries. By 2024, it plans to outfit its high-value equipment with sensors that can provide information critical to predicting and maintenance problems. It estimates that using this information to prevent such breakdowns could save the company millions of dollars annually (Marr, B. 2019).

Ghafari—a provider of process engineering, consulting, lean services and project management—recently created an integrated throughput, material flow and storage discrete event simulation model to meet a global food processor's requirements for optimizing production batch sizing, overall equipment effectiveness, material handling labor and equipment, and inventory storage. The robust platform determined expected system throughput, identified process bottlenecks and tested varied batch sizes. This model uncovered a 63% increase in throughput potential and identified a 40% decrease in conversion costs projected over a period of more than two years. The model serves as the food processor's mainstay in shaping a future multi-year operational roadmap with short-term tactical and long-term strategic actions for improving the plant's profitability.





Action Items

- For those just getting started, research the digital twin field and learn by modeling simple processes before trying more complex ones. Also, consider contracting with a specialist to do an assessment of your company's current state of data collection before building models (Adsit, 2020). Investigate IoT service providers, digital twin software providers and embedded features of your enterprise-wide systems when choosing how best to implement.
- If you have a couple of years of experience, identify ways to expand the use of digital twins within your organization and consider using them to integrate processes between your departments. Assess using digital twins more comprehensively across your supply chain.
- If you have more than a couple years of experience, benchmark the most recent cutting-edge applications to assess the possibilities for your organization. Ensure you are developing strategies to protect the data in your digital twins from viruses and cyberattacks.



About Automation Alley

Automation Alley is the World Economic Forum's Advanced Manufacturing Hub (AMHUB) for North America and a nonprofit Industry 4.0 knowledge center with a global outlook and a regional focus. We facilitate public-private partnerships by connecting industry, education and government to fuel Michigan's economy and accelerate innovation. Our programs give businesses a competitive advantage by helping them along every step of their digital transformation journey. We obsess over disruptive technologies like AI, the Internet of Things and automation, and work hard to make these complex concepts easier for companies to understand and implement.

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