Industry 4.0 Technology Applications for Manufacturing Engineering



Abstract

The fourth industrial revolution is well underway and new technologies are changing everything we know about manufacturing and manufacturing engineering. Cloud computing, Virtual and augmented reality, machine to machine and internet of things connectivity, artificial intelligence, additive manufacturing, digital twins, and other new technologies allow manufacturing engineers to do things they never imagined with smarter designs resulting in less scrap, better products, and new market opportunities. This document explores Industry 4.0 technologies available today with a sneak peek into the potential these technologies and others will have on manufacturing engineering for decades to come.

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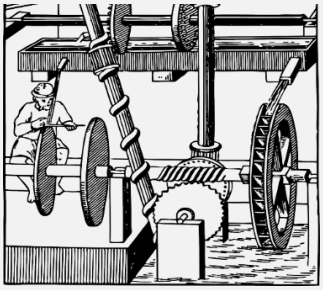
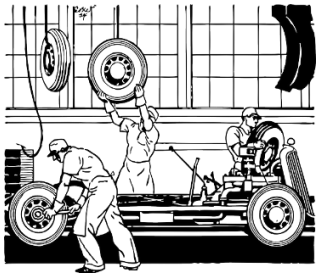
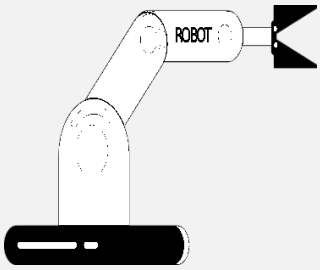
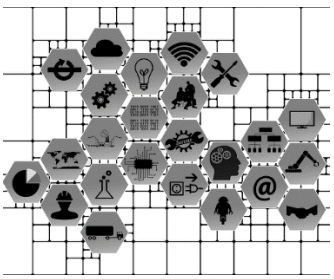
Welcome to the 4th Industrial Revolution

Manufacturing never seems to sit still ever since the industrial revolution with the introduction of steam and water power from about 1760 to 1840 AD. This period of time saw incredible advances in production using power and machines to significantly improve mankind's ability to produce better products faster and with significantly less effort. This led to the second industrial revolution sometime between 1870 and 1920 with the advent of mass production and assembly lines and new power sources including coal, petroleum, and electricity. This era marked a considerable improvement in manufacturing, impacted the age of consumerism, and paved the way for a truly global manufacturing environment. The third industrial revolution from about 1960 through the early 2000s was marked by advances in automation – primarily in the form of computing and robotics. The third industrial revolution resulted in significant improvements in manufacturing processes, data, and connectivity among the entire supply chain with systems in place to monitor and report on data throughout every phase of manufacturing including accounting, inventory, production, shipments and receipts, purchasing, sales, and more. And now a new revolution is underway disrupting everything we know about traditional manufacturing with new technologies that will elevate some manufacturers to the top leaving others behind if they don't adapt and change with the new age of modern industrialization.

Industry 1.0		**1760 to 1840**	**Steam and water power. Early mechanization of manufacturing processes.**
Industry 2.0		**1870 to 1920**	**Mass production assembly lines. Coal, petroleum, and electric power.**
Industry 3.0		**1960 to 2000**	**Computerization, robotics, automation**
Industry 4.0		**2000 - Present**	**Internet of Things, Cloud, Big Data, Machine Learning, AR/VR, Additive Manufacturing**

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Introduction to Industry 4.0

Industry 4.0 is a relatively new concept for manufacturers and engineers to comprehend. It's often difficult to understand what's happening around you when you are focused on the tasks and hand and when you have no experience with the changes occurring elsewhere in the industry. Much can be said for early manufacturers at the dawn of the very first industrial revolution. Manufacturers continued to build products by hand until they saw others building water wheels or utilizing steam power to drive production of new machines. Similarly, today's manufacturers are very much aware that the industry is changing and they may even be aware of many of the new technologies impacting the industry but few understand how deeply these technologies will transform manufacturing for the coming decades.

Industry 4.0 is open to a lot of interpretation but it is primarily comprised of 7 categories of emerging technologies – each unique in and of itself but also connected to each other. This white paper explores each component of Industry 4.0 through the lens of not just manufacturing but specifically, how these technologies relate to manufacturing engineering and design.

Industry 4.0 Technologies:

1. Cloud Computing
2. Big Data & Analytics
3. Machine to Machine (M2M) & Internet of Things (IoT)
4. Artificial Intelligence & Machine Learning
5. Simulation, Virtual & Augmented Reality
6. Additive Manufacturing (3D Printing)
7. Blockchain & Cybersecurity

Cloud Computing

Cloud computing is changing the world. One might not think that simply moving computing power and storage online would be that significant but the cloud has changed everything we know about computing and will continue to change our world as consumers and as business professionals. Cloud computing provides scalability where processes requiring more computing power can be automatically ramped up and down as needed. Further, massive amounts of data can be stored, secured, and available through protected connections to internal and external systems for improved connectivity throughout the organization and externally throughout the supply chain.

The cloud promises to eventually provide an autonomous supply chain where data from retailers is automatically shared with distribution centers and backward through the supply chain to manufacturers and their downstream suppliers keeping everyone up-to-date with supply and demand directly from in-store purchases.

The cloud is also facilitating greater collaboration across the supply chain with customers working online in real-time with manufacturing engineers and downstream component suppliers on highly custom engineered products. Further, the cloud provides access anywhere there is a secure internet connection making it extremely portable for a global workforce that is constantly on the go.

Cloud-Based PDM/PLM

The cloud is changing manufacturing engineering. While many engineers continue to work inside locally installed CAD design applications, it is becoming more and more common for elements of the design process to make their way to the cloud and it is likely that almost all CAD design will move to the cloud in the next decade. We see this happening today with a proliferation of product data management (PDM) and product lifecycle management (PLM) applications coming to market as web-native applications alongside industry giants moving their applications to the cloud.

Complacent manufacturers see the handwriting on the wall. The fabric of manufacturing and industry is being torn apart as systems, processes, and how we look at innovation is starting to change. Product Lifecycle Management (PLM) software tools are becoming central to manufacturing processes (right where they belong) across the value chain, not just the few at the top.

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But, PLM tools are broken. Dassault Systemes, IBM, SAP, and Siemens have built products that served their bottom lines more than they served the client. Over-customization on one platform makes it nearly impossible to switch to a new implementation. Interfaces mostly do just one thing and diverse user groups can barely communicate. Hydra-headed products that additional suppliers are unable to integrate with. Software that must engage hundreds of hours of consultancy and implementation to be up and running. These are common issues that remained unsolved for over three decades.

Companies today are not just looking to purchase PLM. They are on the market for solutions that effectively take care of specific business pain points for their specific industry focus. Businesses must be able to quickly acquire and deploy PLM functionality on demand, and solutions that lend them operational flexibility and improve the pace and efficiency and improve the efficiency and pace of product development, production and service. They should be able to exploit new capabilities without being required to undertake lengthy installation and customization processes. They also need to deploy and operate these new capabilities in a most cost-efficient manner. Reducing the time to deploy new PLM functionality with little of no IT support can greatly empower organizations for operational flexibility.

From a business angle, they need to achieve a quick return on their PLM investment and want to be able to grow their PLM solutions on demand without additional infrastructure or expense. They also want to have infrequently used PLM functions available on time – giving them the operational flexibility to address changing demands of the market.

Traditional PLM solutions were delivered on several in-house servers and networks (those managed via the Internet and browser-based user interfaces are now quite common). Solutions were configured for each firm's needs and then some degree of IT administration was required to support the PLM environment.

The inclusion of new functionality meant companies needed to obtain required licenses and then configure all additional functional modules to work within their tailored environment. This was effective, but required plenty of time and offered less flexible access to new and vital PLM functionality.

With this approach, IT has been a natural speed check, especially in deploying highly customized PLM applications. CIOs (chief information officers) have remained committed to lowering IT complexities by harmonizing and rationalizing applications and establishing corporate IT standards. Yet, within the field of PLM, this continues to present as a thorny issue.

To make matters worse, the expertise needed to implement and operate comprehensive PLM applications is a significant mismatch with the capacities and abilities of the majority of IT departments.

In addition, where IT is already outsourced, the conflict between the outsourcers yearning for predictable, stable and low cost and low effort environments is in direct opposition to the customer's demand for flexible and agile environments giving room for business changes such as flexible organization, and divestitures.

Benefits of Cloud PLM & Design

Companies are starting to recognize the need to have simple PLM solutions and reduce significantly, even eliminate the customizations that have long impacted PLM implementations. They are also seeking PLM environments fitted with more industry-specific best practices embedded within them. This is another key factor in eliminating customizations. The functions and features of PLM applications are the strict purview of the PLM solution vendors. They are combining those capabilities to offer custom, ready-to-use solutions for the bulk of their customers. Every advantage of a customization should be carefully compared with the disadvantage of losing flexibility and increased costs for support. Industrial companies seek to improve the simplicity of their PLM implementations to gain flexibility and the ability to rapidly modify the solution to meet evolving business needs. This required and noticeable trend of simplicity is the foundations for the second component, cloud computing.

Cloud-based computing offers new, highly flexible delivery paradigms that address many issues with traditional PLM delivery. Cloud-based PLM solutions relies on the following:

- the cloud's ubiquitous "anywhere" access
- infinite computing resources, and
- unlimited scalability

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All three of these elements provide organizations a highly flexible workspace within which personnel in multiple organizations (internally and externally) can collaborate using workflows that span the full partner enterprise and organizational structures.

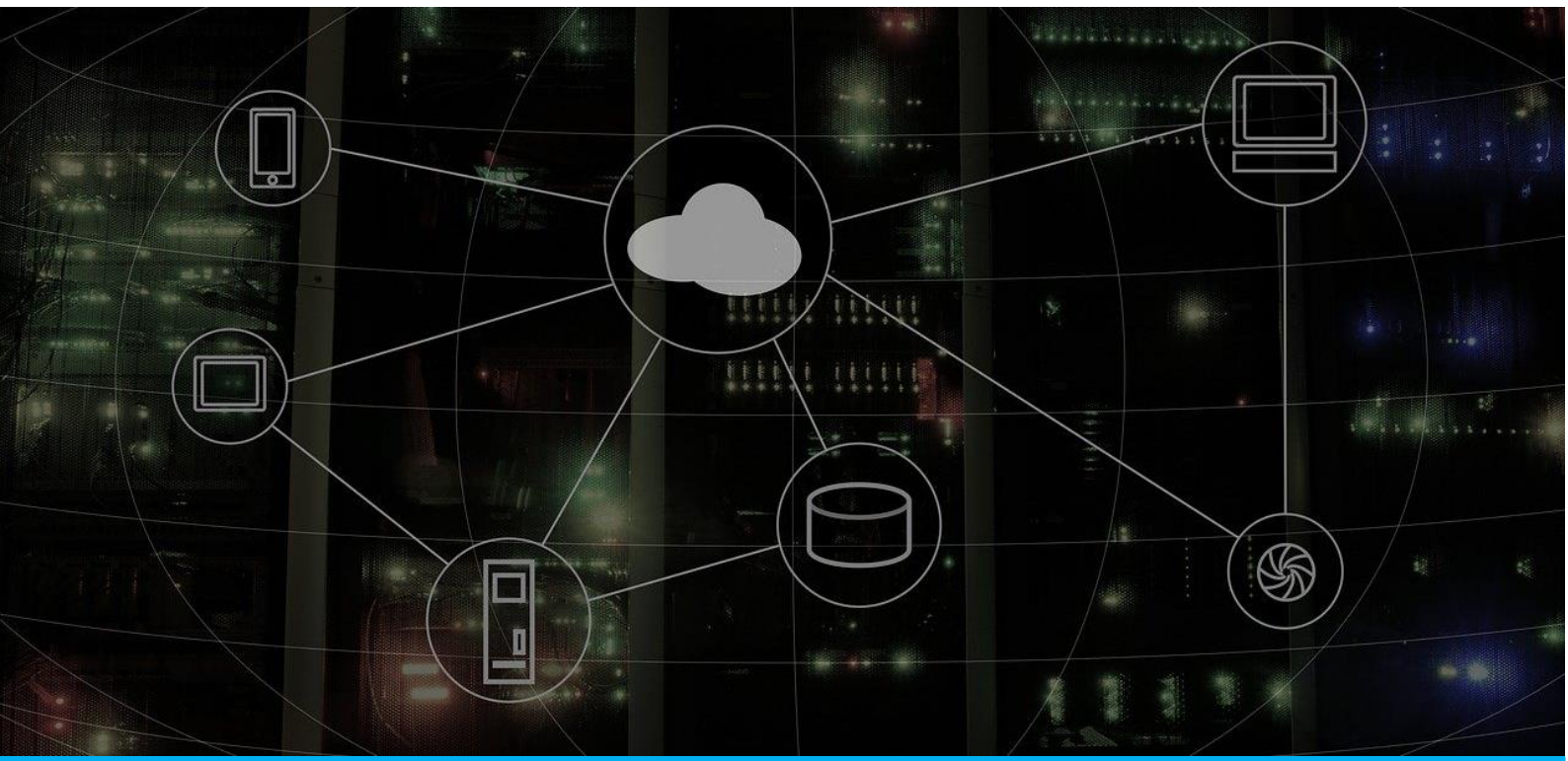
The core benefits of using cloud-based PLM software are:

1. To deliver managed services at controlled costs without a customer needing to own the supporting IT infrastructure.
2. On-demand access to computing resources and applications, lower upfront and continuing costs.
3. Flexibility of resources, allowing the company scale to match their needs.
4. Deployment speed.
5. Packaged services, available out of the box and managed by the cloud solution provider.
6. Consumers have access to more information to make decisions, and organizations positioned to best meet demand for newer, better, and trending products are most likely to succeed.
7. Innovation is easier to drive forward as moving parts can integrate better and supply chains can become less specialized.

Challenges in Migrating to the Cloud

Businesses investing in cloud solutions should be aware of the challenges that also underlie demand for the benefits of cloud solutions:

- IT management of on-premise solutions and fake clouds can weaken a manufacturer's ability to be nimble, weigh them down, and distract them from being more return on investment (ROI)-centered on their core business.
- Dissemination of critical data – intellectual property (IP), CAD files, and bills of materials (BOM), for instance – across an increasingly convoluted network raises the risk of security breaches, product errors, and delayed time to market.
- Portable and mobile devices require a solution architecture that can be served at world-class service levels.
- A level global playing field where balance sheet, technology, or geographical borders do not exist – a flat world, in essence – improves the need for solutions that can scale efficiently to give manufacturers the ability to take advantage of global market opportunities.
- A supply chain workforce that is globally distributed impacts people, processes, and overarching business goals in terms of proper alignment. This can increase the potential of breakdown in communication, product revision coordination, and control issues.



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While a growing number of manufacturers are embracing the cloud to maximize their IT investment and ROI, many product lifecycle management (PLM) providers still consider the cloud to be an unclear virtual concept. That's far from true! On-premise cloud virtualization gives up cloud-based economics, forces the manufacturer to embrace business risks, and weakens scalability.

As more companies discover the benefits of the cloud, a growing number of fake cloud providers have shown up on the horizon with the first goal to exploit naive company executives. Multi-tenant cloud PLM solutions have the real promise of:

1. cost savings due to removal of IT expenses
2. simplifying implementation
3. scalability
4. increasing security, and
5. providing a faster trajectory. to return on investment.

One of the foremost benefits of cloud is to enable mobility and accessibility. With cloud applications, supply chain teams are able to access documents, e-mail, and BOMs (bills of materials from any part of the world over a secure Internet connection.

Because employees, contractors, and partners have remote mobile access to information beyond the traditional firewall, and can reach for it at will, efficiency is added to make for streamlined processes than on-premise solutions can promise. Streamlined processes and tasks in turn, give companies room to be deliberate about innovating and developing new products.

Cloud computing presents no upfront capital costs needed for servers, hardware, and data centers, as is what obtains with on-premise solutions. A cloud service provider would typically charge a lot less for energy than a business would spend on their own data center. There are statistics to support this: on a general note, only 15% of on-premise servers are ever used. Operations alone are responsible for 30% of total data center costs. Then there are power and cooling costs for 30% of costs.

Cloud provides customers with a unique security advantage over on-premise solutions and irresponsible cloud solutions. True, cloud was once considered a security liability, but with security patches, updates, backup, upgrades, handled by focused experts, it has become a superior security option relative to many on-premise solutions.

Now armed with the information to consider investing in a cloud solution, businesses can forgo the expensive infrastructure and resources required to maintain on-premise PLM software. This removes the opportunity cost of managing an on-premise solution, granting the company's personnel to focus on critical core business activities such as designing new products.

PLM in the cloud is fast becoming a more viable and accepted form of delivering PLM solutions. Companies are interested in deploying cloud-based solutions to tackle infrastructure and software issues and requirements. Yet, it is necessary to differentiate the infrastructure as a Service (IaaS) approach from the Software as a Service (SaaS) approach.

IaaS substitutes physical hardware (on-premise and hosted) with virtual hardware. The advantage is the flexibility of the infrastructure and the rental model. IaaS is an IT issue, leaving the complexity of implementing and operating the application to the customer.

SaaS is a major paradigm shift in software use and management. With SaaS, a vendor assumes full responsibility for the PLM solution and the working environment. They also assume responsibility for the PLM solution and the working environment as well as services and implementation. SaaS means the vendor also supplies a ready-to-use configuration – this is the point where present limitations exist. Full SaaS for high end PLM implementations (for large, complex enterprises) is not available off-the-shelf. At present, existing SaaS configurations being offered still need customer-specific adoption. User licenses in most cases are not included. This is because PLM software vendors do not usually support that model.

Continuous pressures to enhance productivity, lower costs, eliminate delivery times, and enhance product quality are some of manufacturers' biggest challenges. Companies need dynamic, flexible Product Lifecycle Management environments that scale quickly to match peculiar business needs.

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They must be able to include functionality and users on the fly – as new projects and product programs demand. What companies really desire is a PLM solution that provides fast, simple, low-cost deployment and the flexibility to scale in functionality and size.

Using the cloud and cloud-based computing tools and resources will help companies better develop innovative products. Cloud-based PLM has the ability to deliver the fast deployment, flexibility of solution, and reduced IT cost that companies need to establish and maintain their competitive advantage.

The ideal cloud PLM service should show resilience in meeting complex and demanding requirements. It should combine the core merits of cloud computing – flexibility, readiness, cross-platform integration, business model – with the power of on-premise implementations – individualization.

Organizations desiring new ways to maximize their PLM investment while improving their flexibility to respond quickly to business and market demands have several cloud PLM options on the market that are worth considering.

Big Data & Analytics

As mentioned previously, there is more and more data available and much of it is on the cloud where powerful computers can analyze data faster than ever before providing faster analysis and a deeper understanding of what's happening throughout the manufacturing engineering process all the way through the production process and the entire supply chain.

Big data coupled with other Industry 4.0 technologies like the Internet of Things (IoT) and artificial intelligence and machine learning promise to provide insights that manufacturers and manufacturing engineers could only dream about just a few years ago. Imagine utilizing big data to determine the right design to prevent product failures or to leverage data and computers to determine the optimum design for an item and any of its components to minimize production waste taking into account machine and tooling constraints.

Further, big data and analytics coupled with additive manufacturing enables manufacturing engineers with the complex configuration of designing parts that are optimized for nesting (layout) in a three-dimensional, print job where there is minimal scrap and maximum product produced from each expensive 3D printer.

Big data is a reality. We see it everywhere but only the largest manufacturers and manufacturing engineers at those companies are just starting to experience it firsthand. Everything is trackable, manageable, easily accessible, and shareable through every computerized device we own. The information is accurate, easily attainable, and reliable with the capacity for us to share information with co-workers and business partners outside of your company firewall in a safe and secure environment.

In a world of fierce competition, it is important the data you have collected will be used to its utmost capability. Big data and analytics are now being applied throughout manufacturing engineering including CAD data management and into PDM and PLM applications.

CAD data management coupled with big data is vital in managing product design and helps with the downstream processes like collaboration, reviews and releasing to production in time to meet deadlines. Managing these processes are key components in increasing a high level of productivity and efficiency in launching them quickly.

CAD data management includes:

- Knowing where a part belongs and how it is used at any time or at any location
- Designers are kept up to date, empowering them to access the data they need in seconds
- Preventing accidental overwrite of CAD data
- Complete control over who works with the data

CAD data contains CAD models like drawings and bills of materials. It encompasses other CAD information like specifications, calculations, production notes (NC programs), routings, and assembly information.

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CAD data management is just that, managing data. The same as your devices at home, you can track information seamlessly, quickly, and effortlessly throughout the company. It integrates easily with existing applications which allow the company to control data across the entire enterprise. Anyone who needs it can access it through any terminal or device including mobile, at any of the company locations.

CAD data management is a structured storage system and is used in an organized and controlled manner. The system streamlines the processes a company takes to introduce a new high-quality product. Big data is making data management easier with the ability to slice and dice and analyze the information manually or even to have the computer analyze the data automatically with alerts provided on an exception basis when there appears to be data that's out of the norm.

There is more data involved in CAD today than ever before. There is more data provided from the manufacturing floor that is important to the manufacturing engineer. And there is more data available from suppliers relating to material attributes that must be taken into account in the initial and on-going design process.

Businesses can make better decisions about product development, management, design, and production with greater visibility. Personnel can collaborate on projects with anyone from anywhere within the company no matter the location including easily sharing information with business partners outside the company.

Tomorrow's manufacturing engineers will have a lot more information available with computers assisting them with designs using vast amounts of data to create products that could never have been designed before – products that are stronger, more adaptive, and engineered perfectly for fit and function.



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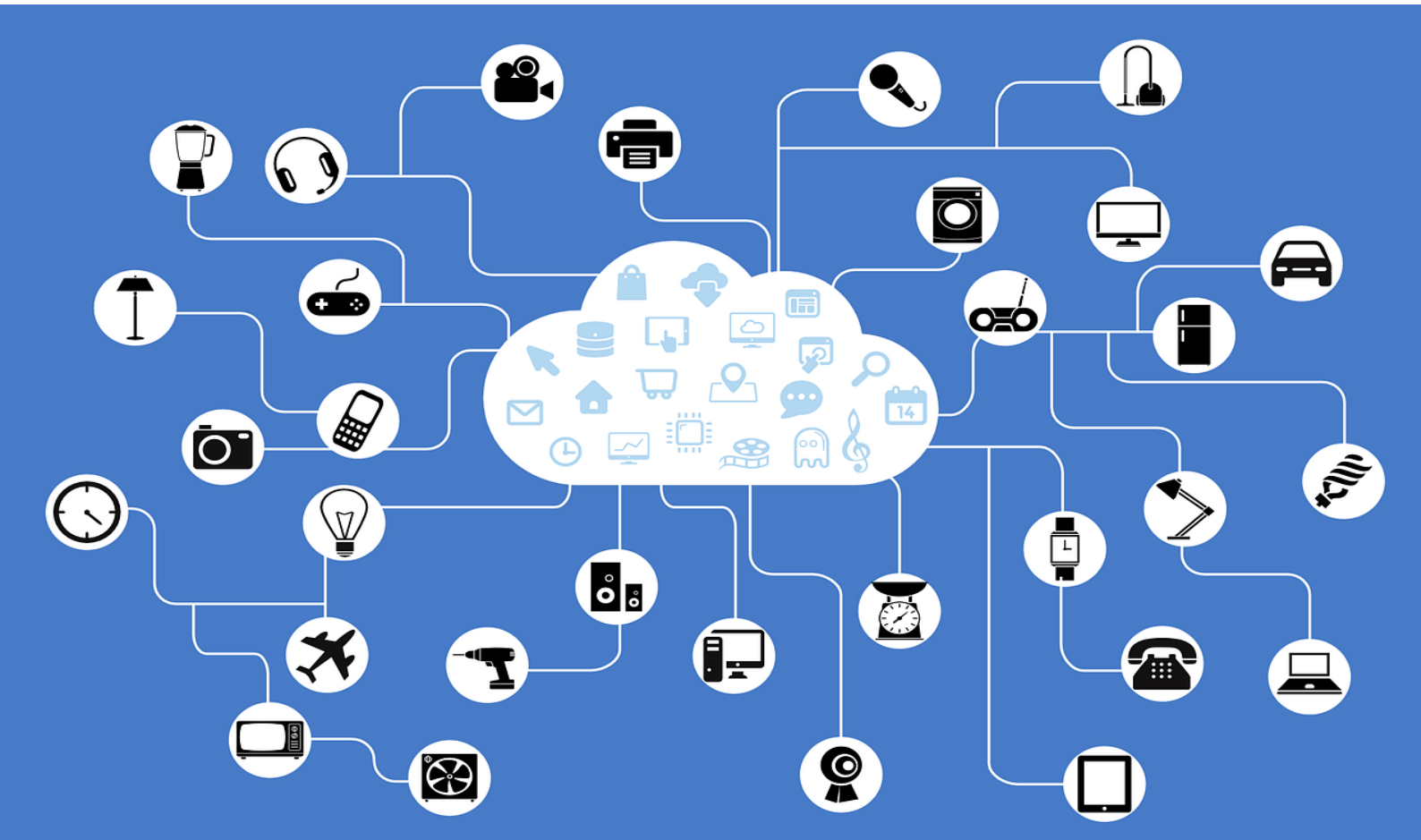
M2M & IoT Connectivity

Machine to machine (M2M) connectivity has been around for decades but the technology is advancing rapidly providing machines with access to more data with the ability to make better decisions without human intervention. Many production and assembly lines are now operated autonomously with any issue up or downstream shutting down all related processes simultaneously. Machines communicate with robotics to signal replenishment from robotic forklifts or for put-away when production has been completed. And M2M technologies allow technologies to work asynchronously to ensure the highest possible product quality. Case in point is how ovens on a pizza assembly line or hockey tape production line can communicate with the conveyor system or roll slitting and ovens respectively to slow down or speed up the throughput of product depending on room temperature, moisture content in the raw materials, and other factors.

M2M coupled with robotics have eliminated thousands upon thousands of mundane, manually intensive jobs. Love it or hate it – M2M is here to stay and has proven to be cost-effective in the long-run for the vast majority of manufacturing operations – and it's getting better every day.

Internet of Things (IoT) – also called the Industrial Internet of Things (IIoT) is the connectivity of almost anything in the physical world with the digital world and it's having a major impact – especially in manufacturing. IoT enabled with radio frequency devices (RFID) technologies can capture moisture content in perishable inventory warehouses, temperatures on shipments for temperature-sensitive raw materials, and even bacteria counts for food, beverage, or chemicals. This data is captured and stored inside massive big data applications and can now be linked to machines and systems providing more information and insight than ever before to improve quality and eliminate waste.

IoT has a lot of application inside manufacturing engineering and design. Consider how RFID technologies monitoring complex machinery can provide predictive maintenance alerts as an example. The more the machine or machine tool is used, the more likely a part is to wear out. IoT will get to the point where this failure data will be captured and provided back to manufacturing engineers so they can redesign parts that will experience less wear, longer production lives, and parts with faster change-overs.



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Leading CAD, PDM, PLM, CAM, and CAE vendors are producing the next wave in manufacturing design tools with augmented reality, generative design, and simulations using digital twins to build better products and often times these software applications are using data collected from IoT-enabled devices.

Engineers now have to take into account not only instructions and specifications coming from customers, vendors, chemists, and manufacturing – but also data coming directly from their raw materials and existing products deployed in the field for continuous improvements in design.

Some manufacturers are further utilizing RFID and IoT to automate the manufacturing process. This requires manufacturing engineers to build IoT devices into their design processes whereby assemblies in process armed with IoT can trigger automatic data capture and operations during the production process. Consider how IoT can trigger a robot to move assemblies throughout the production process when they are completed in real-time. The engineer's placement and usage of the IoT device will have a dramatic impact on the success of the communication from the product with the robot and system to move it to the next operation and future operations through to completion of the finished good.

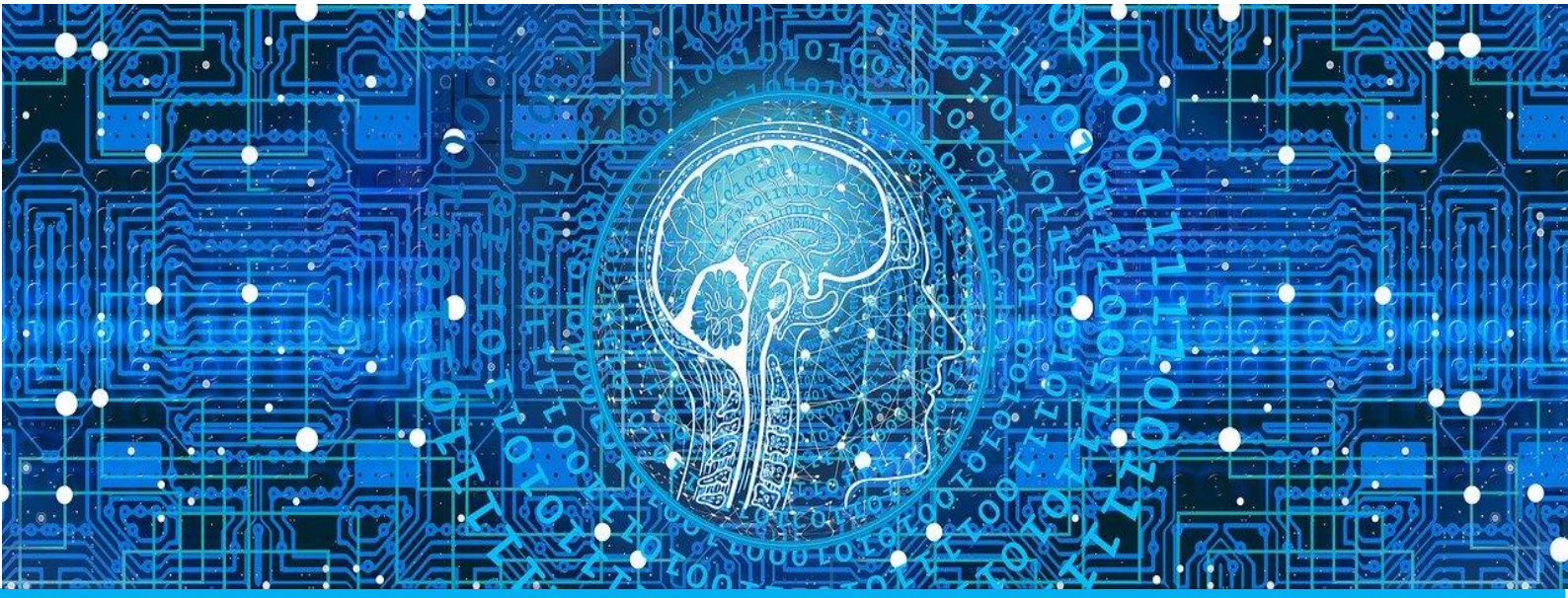
The use cases for M2M and IIoT are almost endless and the technologies are becoming faster, more reliable, more functional, and much more affordable lending them to true innovations in almost all areas of manufacturing. And all of this is and will continue to impact manufacturing engineering and design.

Artificial Intelligence & Machine Learning

According to IDC, by 2021, 20% of leading manufacturers will rely on embedded intelligence such as AI and IoT to automate processes and increase execution times by up to 25%. Further, a Deloitte study recently found that machine learning can improve product quality up to 35% in discrete manufacturing industries. Lastly, a McKinsey study shows that 50% of companies that embrace AI can expect to double their cash flow in the next five to seven years. And these are just a few of the statistics and predictions among hundreds around AI in manufacturing that are getting a lot of attention these days.

Artificial intelligence and machine learning has been around for many years but is now proliferating throughout the industry as the technology becomes more practical for smaller manufactures due to functionality and lower costs. AI in the consumer market is growing rapidly due to the explosion of personal assistant products like Google Home and Amazon Alexa. AI is now making its way into the professional and manufacturing environment and it's a whole lot more than just asking for information and getting an answer.

AI has thousands of use cases in manufacturing – from what to do with out of spec product received from a vendor to how to prioritize production schedules based on product demand mix and current and future machine and labor resource availability. AI can also be applied equally as well to manufacturing engineering.



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AI today is powering generative design in manufacturing engineering. Generative design is something relatively new from most major CAD vendors where you design a part or detail a set of parameters for a part and the system (using AI) provides alternative designs for you to consider. The great part of generative design is that some of the systems can provide options for both traditional manufacturing as well as newer additive manufacturing providing a lot more design options than ever before and some of these simply could never have been produced without today's 3D printing technologies.

Another of the many examples of AI in manufacturing engineering is data manipulation. IT staff or engineers used to have to re-key bills of material, items, and manufacturing routings into their enterprise resources planning (ERP) systems every time they designed a new product or revised existing products. But AI-powered integration tools like CADTALK can transform the data from CAD, PDM, PLM, and other applications directly into ERP data in a matter of minutes without manual data entry. Further, this type of AI automation is now being leveraged in other integrations such as configure price quote (CPQ) applications that can be converted into CAD models or where AI powers data transformation between layout nesting applications and the ERP business application.

Machine learning is still relatively new for most manufacturers but will change the way all business applications function. Manufacturing systems with machine learning will be able to correct themselves or learn from human intervention to change the way they work. Machine learning is a key component of iterative design and has many other applications in manufacturing engineering – many of which have yet to be fully explored.

Simulation, Virtual & Augmented Reality

The modern-day technology has led to the revolution in the various aspects of the virtual reality to conceptualize the various aspect of designs and manufacturing. There has been a great revolution in the modern-day Virtual reality (VR) technology. The modern VR like the Oculus that was invented in 2012 is promising more software and hardware functionalities that have made to the recent acquisitions in the Tech industries. We see giants like Facebook having a wide interest in the VR market with the latest being Facebook CEO Mark Zuckerberg announcing the possible acquisition of Oculus in 2014 (Jerald, 2016). This was a deal that as estimated at 2-Billion US dollars. This is an indication that the tech giants are seeing a possible success in the VR market and the entry-level companies have a vast advantage. VR technology that has a vast market in the gaming industry also has other applications in the manufacturing industry.

The manufacturing industry is a dynamic industry that has so many variables that need to be constantly checked. This calls for the uses of technology and VR has been on the forefront in this area. VR, for instance, has been factory-based manufacturing simulations. The simulations would mean that the reduction of the manufacturing process is greatly reduced due to the shorter duration that is used for the design and the actual concept. This means that the CAD designs that are done can be greatly visualized for the 3D designs and the designer can interact with the various stakeholders so as to cut down on the production time. This means that the approvals of the designs can be greatly reduced and this can lead to increased production of the various components that are to be designed in the process. In the manufacturing process where the production cost is a huge factor on the overall profitability of the product. The reductions in the production costs will have a huge toll on the profit margins.

VR is promising huge advantages that are already been realized for the current user and even more with the concepts to be adopted, despite the huge success during the roil out, there are various proportions of VR that would see still need to be addressed. The first one is the issue of adoption of the technology that would need to the taught across the numerous users in the manufacturing industry. The sensitization and the education are both costly and time consuming. The roll out by the major player has been hit by some of the costs that would be required to train those that would be required to adopt the technology (Dai, 1998). Since for most of VR kits the data is shared virtually the data is prone to being accessed illegally through intrusion of systems, this would need the employment of security layers and also access control for the database. This means that the programming for this system would be suited in away that the data takes would have to have the proper clearance that would be required for that level data access.

The other challenge with VR unlike the convectional prints for the 3D presentation is the portability of the systems. VR would be restricted in most cases to the positions that have access to power and in some cases internet access. This mean that the

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transfer of the technology in the filed purposes would be a great challenge since the various users would be in most cases restricted physically to the points of access of the data and technology. On the aspect of data intrusion extra expertise would be required for the data security and also measures to prevent data access.

Virtual reality, or VR, is not integrated into everyday life quite like augmented reality (AR). For any VR experience, an HMD is required. With an HMD or goggles, VR is made possible by completely immersing you in a different environment, which is the major difference between AR and VR.

Having been around since the 1950s in its earliest form, VR's rebirth in the 2010s has it regaining the industrial', corporate, and public's attention. Now, with interest having peaked in 2016 and continuing, VR's goal is to create what appears to be a lifesize, 3D virtual environment without any rules or boundaries, similar to the ones other forms of entertainment take on, like TVs and computer screens. Both of which have screens, enclosing the environment within them. VR allows you to walk around the new environment, viewing it from all different angles and perspectives.

Its 3D designs and mathematical models create the impression of depth, which provides users with multiple points of view and perspective. This opens up so many doors for opportunity in a plethora of industries. Again, VR goes beyond gaming and entertainment. Yes, it is mind blowing to be able to view outer space and many of its complexities just from your living room; however, VR is being developed to improve efficiencies in many other realms beyond entertainment, such as medical fields, engineering industries, and more.

In terms of engineering and design, VR alters computer-aided design (CAD) processes from how we once knew them. Because of VR, engineers and designers can now preview CAD in 3D, as if it already existed in real life right in front of them. Because of this, it makes it easier to break down models into different pieces to pay closer attention to detail with increased clarity. The ability to create realistic models omits the need for excessive prototypes, which as a result, reduces overall production costs.

Beyond design, VR amplifies training capabilities. In the US military, VR is used in training systems to create simulation testing and put soldiers into seemingly real-life scenarios for practicing purposes. With such an environmental submersion that VR provides, this overtakes senses, allowing soldiers to practice and prepare how to take the proper initiatives and appropriate reactions to different situations that could appear in their military careers.



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With VR, the HMD completely blocks out any surrounding real-life environment, which allows people to interact with this new virtual environment on a 1:1 scale without any distractions. Additional accessories are also available to cater to VR experiences such as varieties of HMDs, goggles, handles, and other controls for a more hands-on experience.

Whether you're creating in CAD and the engineering industry, progressing forward with AR/VR in medical fields, or you're just a public consumer of the advancing technology, you can expect to see these alternate realities gaining power for years to come.

The future of AR and VR will be even more handheld than it is now, allowing humans to gain access to all sorts of information and visuals faster than ever before. Not only that, but when it comes to business, we will also only continue to break down walls that were once barriers, allowing us to create products in new ways and new forms in a more efficient manner.

VR is a form of a digital twin – a digital representation of a physical item. In the digital world, simulations can be performed against the item virtually to test for defects in design. Further, VR allows the designer the ability to "touch" and "move" the newly designed part before it's even created.

Skeptical that VR is impacting manufacturing engineering? Attend any of the major CAD vendor conferences and you are going to be surprised at what you find – there are so many new and exciting technologies available that are not just cool – but practical, useful, and innovative.

Additive Manufacturing

Additive Manufacturing (AM) – the industry term for 3D printing – has proven to be advantageous in almost all industry segments – especially with expansion in the capabilities of 3D printers to work with not just plastics, but metals and other materials and the decreased pricing and accuracy of these exciting machines. Additive manufacturing is cutting down lead times and improving manufacturing designs. Consider that the Royal Engineers of the United Kingdom's British Army kept a Lulzbot TAZ 6 printer on site during Operation Trenton in South Sudan. About the size of a microwave, the little printer produced brackets and plumbing parts, among other things. It was even capable of printing its own spare parts.

3D printing was invented at MIT and originally patented in 1995. Since that time, its use has pervaded business and industry due to its flexibility and portability. Technology has advanced a lot since 1995, enabling improvements to print accuracy, speed, size and cost. Companies like General Electric, Boeing and Airbus have already invested billions in AM production of aircraft replacement parts, such as cargo door brackets and jet engine leap fuel nozzles. But when it comes to national defense, AM is no longer restricted to plastic parts.

As technology and materials advance, so does the scope of the projects. At Oak Ridge National Labs in the United States, big area additive manufacturing (BAAM) has been used to create composite wind turbine blades and even Jeep-like vehicles. The material used for this application is plastic pellets about the size of coins, and the printer is able to combine them with other materials to yield composite parts. For example, chopped carbon fiber is sometimes added to thermoplastic ABS to produce stronger, more resilient components.

The results can be surprising. "They have developed coating and finishing processes that take the roughness off the layerized 3D printed parts and make them smooth," reports Professor John Hart of MIT, who was impressed with the metallic surfaces on a BAAM-produced vehicle. "[T]his has been done in collaboration with polymer and materials companies that have helped them develop that additional technology that's necessary to turn the basic [3D printed] parts into applications such as this."

Large-scale items are being produced via AM as well. Using concrete materials, the U.S. Army and Marines have produced roads, bridges and even barracks on demand. Concrete barracks are safer than tents, and being able to build a footbridge in an austere environment (where natural resources are unavailable) can really reduce delays. "We have a finite number of bridging assets in our inventory," says Capt. Matthew Friedell of Marine Corps Systems Command (MCSC). He is AM Project Officer in their Systems Engineering and Acquisition Logistics unit. "[I]f we can manufacture those on site, to custom designs, we can go further, faster."

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The potential in Additive Manufacturing continues to be boundless, for many reasons. The technology makes it possible to reproduce a wide variety of items, large and small, having simple or even complex geometries, at a dramatically lower cost than traditional methods requiring lengthy lead times.

Beyond this, the properties of newer materials used can exceed any available in the past. For example, materials manufacturing scientists in the U.S. Army Combat Capabilities Development Command (ACCDC) have developed a steel alloy powder for AM that is actually stronger than steel. Originally developed for use in bombs, they foresee additional value for replacement parts on vehicles.

“This material that we've just...developed processing parameters for is probably about 50% stronger than anything commercially available,” says Dr. Brandon McWilliams of the CCDC's Army Research Laboratory. He leads their Metals Additive Manufacturing Team, and predicts the alloy's use in AM production of replacement parts.. “A lot of our parts in ground vehicles now are steel, so this can be dropped in as a replacement, not having to worry about material properties – because you know it's going to be better.”

Another significant advantage to Additive Manufacturing is the ability to print complex designs – parts with internal cavities, delicate protrusions, or even encapsulated parts. These can be difficult or impossible to achieve with traditional methods such as injection molding or machining. “We were able to print parts with internal structures that they would not necessarily be able to create with [as] much dimensional accuracy,” reports the CCDC's Dr. Andelle Kudzal, also from the Metals Additive Manufacturing Team.

This combined with the reduced logistics of delivery can dramatically reduce the cost per part for complex items. Another factor in favor of Additive Manufacturing is the elimination of expensive equipment and machine configuration. Where traditional techniques see significant cost increases every time a design change is made, 3D printing requires no reconfiguring of machinery... no retooling of injection molds. Generally speaking, 3D printing for a complex part carries much the same cost as printing a simple one.

There are several considerations on the possibilities of using 3D printing technology to product prototypes of innovative solutions. The edge that 3D printing wields is its unique ability to produce directly relying on the CAD model. The model’s file provides the information necessary for generating the incremental control file.

Additive manufacturing:

- is beneficial to traditional manufacturers in numerous industries
- diminishes the barriers to entry for new competitors
- is growing in capability
- is becoming increasingly affordable
- is a core competency for manufacturing success

In 2016, PriceWaterhouseCoopers reported that over half of US manufacturers now employ additive manufacturing for production. This subset also employ it in the earlier prototyping stage.

The principal phases in additive manufacturing are the design and the manufacturing process. The design work is done using a computer aided design (CAD) software suite. Common CAD software include AutoCAD, SolidWorks, CATIA, IntelliCAD, PTCCreo, OpenSCAD, and so forth. Some are free and many are premium software.

The physical production aspect, also known as 3D printing, is facilitated through exporting the CAD file (such as SLDPRT) to STL. STL is a format that 3D printers can read.

There are various major steps in both the design and manufacturing phase of additive design. Productivity is a function of how effective their design tools are, for both engineering and manufacturing teams. Such factors as their computer aided design (CAD) suite quality or the ease with which they inter-operate with parties using different CAD packages. An example is the time spent on file healing and working around the technical issues of using certain file formats (like STL) is included in time-to-

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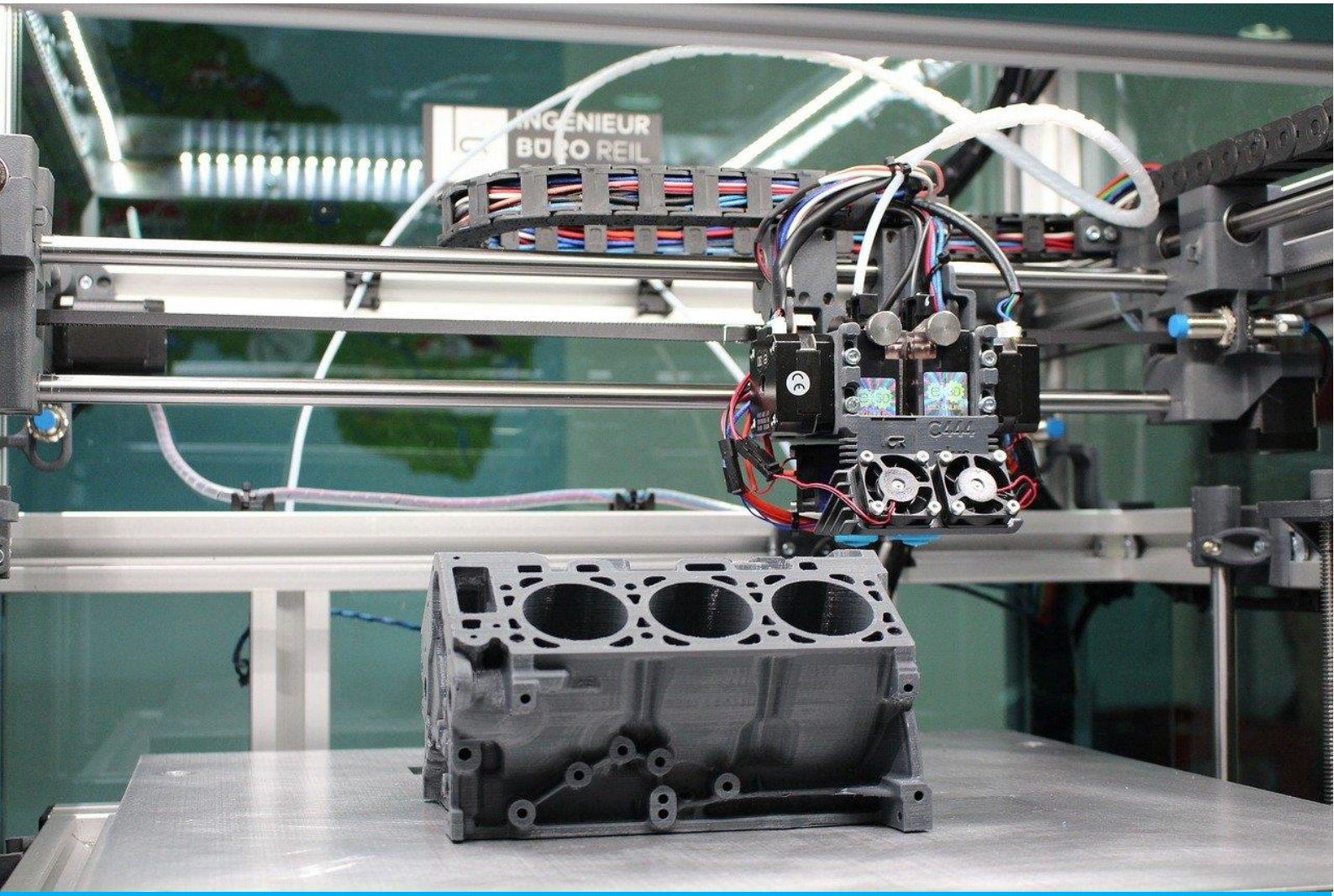
market. This piece will consider the factors in the additive manufacturing life cycle and highlight how 3D printer manufacturers and application developers may position their products as solutions.

STL is an acronym for StereoLithography or Standard Tessellation Language. Launched in 1987, its primary goal was to enable stereolithography 3D printers interpret CAD files. STL is now widely adopted across the 3D printing industry, especially as a way to enable teams with various CAD suites readily interoperate with one another as part of a wider product development project.

A CAD suite is where the action begins in a CAD suite. It is where engineering and product development workflow begins in a CAD suite. CAD users today can take advantage of a wide range of tools to design objects not only in 3D, but with the ability to incorporate a copious number of details including texture, color, and other design elements. Some CAD suites provide specialized tools to incorporate sheet metal, weldments, surfacing, and molds into the basic design workflow. As a result, the CAD design file could successfully reflect the intended product with the fullest exactness.

Many of these suites also give engineers the capability to approach design work in different flexible ways. For example, an engineer that designs on the basis of manufacturability can design, store and retrieve individual parts as SLDPRT files. Those SLDPRT files are then combined into a single SLDASM file. The ability to design CAD files with the intended real-world design also makes it possible for design teams to test and verify the design's viability before physical prototyping (that is, virtually). This includes aesthetics, colors, mechanics, surface geometries, mechanics and materials.

While the quality of analysis (including simulation and visualization) depends on the capability offered by the CAD suite, simulation enables designers to lower physical testing costs and prototyping needs through identifying and correcting design issues during the core design phase.



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To illustrate, SolidWorks' analysis tools that make use of Finite Element Analysis (FEA) method, include high-cycle fatigue simulation and time-based static linear motion in the standard package. In higher offerings, engineers are able to determine the durability of their designs, the topology and natural frequencies, and then perform several non-linear dynamic and non-linear static tests.

Modern CAD suites expect that the physical prototyping and testing stage should consume less time and financial resources. However, designers must often export the original CAD file into the STL format to allow 3D printers to interpret the original design file properly.

Converting to STL has both disadvantages and positives. First, it allows the original design CAD file to be manufactured using 3D printing. However, STL will not pick up colors, textures, and other design elements (metadata included) from the original design.

In addition, changes to the STL file will not reflect automatically in the original design file in CAD; instead, the process is one approach where changes must be made to CAD to reflect in the STL file. This adds a layer of inefficiency to the prototyping process, making the simulation and visualization work within CAD more significant.

To crown it all, care must be taken with refinement done using STL files. Though the STL file could be encoded in ASCII and the user could increase the number of triangles to reduce coarseness, there is the inherent risk of drastically increasing the size of the STL file to a point where it is too large for 3D printers to read.

STL has attained wide adoption despite a stuttering start. This and robust technical maturity makes it vital for the 3D printing process.

The 3MF Consortium is a team of collaborators working to impress 3MF on the additive manufacturing industry, in place of STL. 3MF makes use of ASCII in XML to give 3D printers the ability to read CAD design files to the fullest. This means all colors, textures, and other design elements the original designer intended. 3MF is still a long-term factor, however, as STL continues to be the dominant file format used in additive manufacturing. Developers of applications and hardware for 3D printing operations must make allowance for dealing with STL.

STL is necessary to connect the design and production phases in 3D printing. It is important that end-users able to minimize time spent on file healing (that is, CAD to STL), regardless of the CAD suite involved. Interoperability is vital because not every engineering workflow uses a particular CAD tool.

Special interoperability software development kits (SDKs) are available to enable application developers with the tools to integrate interoperability into what they offer additive manufacturing companies. Whether for 3D printers or for applications meant for viewing different CAD formats, these development kits enable rapid equipping of offerings with the basic requirements of the additive manufacturing industry.

These capabilities are needed, and though they can be added, they only end up growing costs and time to market. It is important to integrate such commodity features and focus scarce business resources on product differentiation and accelerating time to market.

It is pertinent to point out that as 3D printing keeps evolving within the manufacturing sector, factory workers have spearheaded the adoption of the new technology. As the workers' skills continue to develop, the impact of 3D printing will continue to expand in every regard of the manufacturing process.

That said, 3D printing isn't quite suitable for volume manufacturing. Despite a prototype being available, prints can easily take hours or days. Unless prints are much faster, a faster production process will be preferred for products.

The low-volume, on-demand capability that additive manufacturing provides is transformative to industry in general. The ability to create and test new objects quickly and inexpensively from computer aided design (CAD) models makes it possible to innovate at a pace that is not possible with traditional processes.

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Blockchain & Cybersecurity

Many reports state that about 40% of manufacturing facilities report cyber-attacks annually and many reports show double that amount as many manufacturers either fail to report the attack or they are simply unaware the attack happened in the first place. Don't think it'll happen to you? Don't believe anyone is interested in the data inside your CAD systems? Think again. In April of 2019, a single operator pinged every computer and connected device in factories, pockets, and offices worldwide (nearly 4 billion devices). Known as the "Global Ping," it revealed over 100,000 manufacturing control systems vulnerable for attack. More disturbing is that about 13,000 of the systems could be accessed without a password.

According to Ameer Rosic of BlockGeeks.com, "A blockchain is, in the simplest of terms, a time-stamped series of immutable records of data that is managed by a cluster of computers not owned by any single entity. Each of these blocks of data (i.e. block) is secured and bound to each other using cryptographic principles (i.e. chain)." We like this definition because it's pretty straight forward.

Blockchain is of course tied tightly to cryptocurrencies like Bitcoin but the technology is virtually unbreakable and are now being adapted for use in business applications to thwart cybersecurity attacks. While the ERP market in general is not utilizing blockchain today (or at least not pervasively) – it is just a matter of time before the technology makes its way into these types of systems and to others including quality management applications, manufacturing design applications, and more.

Most manufacturing engineers aren't terribly concerned about security but those working in aerospace and defense or other highly-regulated industries certainly are concerned about the security of their data – even the data inside their CAD or PDM/PLM applications as these can contain highly-secretive information that would be detrimental to military customers if the information was leaked or stolen by foreign entities. Blockchain and cybersecurity technologies have other applications outside the obvious ones for military-type products. For example, companies who invent or discover better ways to build products may want to secure these designs to prevent competitors from copying them. In some cases, designs can be extremely difficult to reverse engineer. As such, protecting the "secret recipe" is essential to ensuring the future success of the company.

Security is also critical if you're working with other company's intellectual property. There could be nothing worse that being entrusted with a new product design from a vendor only to have it stolen from your systems by their competitors.

Security technologies are only going to get more secure and more complex in the future. This makes sense as more and more of our lives (personally and professionally) are linked to the virtual world. As mentioned previously, IoT and IIoT are growing by leaps and bounds connecting machines and objects to systems everywhere. Without security, a hacker could control your manufacturing operations. They could tamper with or delete your data. And they could steal proprietary information wreaking havoc on your business and profitability.



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Preparing for Industry 4.0

Manufacturing and design automation is at the forefront of some of the most exciting technologies ever developed – in the history of mankind! But with these new technologies comes a huge learning curve and at times, a lot of risk. But it's not going to end. In fact, it's going to get faster. Existing technologies like AI, machine learning, IoT and IIoT, additive manufacturing, virtual and augmented reality, and cloud are colliding in ways we never expected.

Tomorrow's manufacturing engineer will be very different than engineers a decade ago – or even those of today. They will be part engineer and part IT with a deep understanding of how to utilize powerful computers and systems to design new parts that are stronger, faster, smaller, and better. They will be impacted by technologies driving innovation forcing them to get better at what they do so they can stay one step ahead of the competition.

Manufacturing engineers will design and build future infrastructure and systems that our parents never imagined – from super-sonic hyperloops transporting passengers from city to city at the speed of sound to drone package delivery, self-driving cars, and autonomous supply chains. Yes, everything's changing and you need to be prepared.

So where do you start? How do you jump into Industry 4.0? Here are a few places to get started:

- **Look Online:** There are hundreds of resources available for manufacturing engineers to learn about emergine Industry 4.0 technologies online – on YouTube or professional forums and in scholarly and industry journals.
- **Vendor Conferences:** Attend user conferences for your favorite CAD, CAM, PDM, PLM, Nesting, or ERP business applications. You are sure to find many great resources available at these conferences and you can build relationships with peers and speakers at the events who are leading the charge in Industry 4.0 technologies.
- **Associations:** Join the professional industry association most applicable to you – whether this is IEEE, ASME, SME, IISE, NSPE, SAE, or others. Attend their conferences, register for webinars, attend chapter meetings, and get involved with your peers.
- **Universities:** Attend classes at colleges or universities or find an online course. There is a lot of innovation coming out of higher education today that can keep you at the top of your game while updating your resume for career opportunities well into the future.

Never stop learning. Look for opportunities to learn something new and don't be afraid to recommend pilot programs and internal tests to your organization. You never know who's ready to take the leap into Industry 4.0 and you could be the hero that helps your company make that jump at the right time.



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About CADTALK

CADTALK Software leverages powerful artificial intelligence to transform engineering CAD, PDM, and PLM bills of material into manufacturing bills of material, routings, and items in popular ERP applications streamlining the engineering to manufacturing hand-off by 80%. Additional modules and products are available to automate and transform data between ERP, engineering, configure price quote (CPQ), nesting, and other connected business applications. CADTALK offers consulting services to help IT managers evaluate, implement, and integrate business applications and processes. Contact us today for a free consultation, personalized demonstration or trial.

www.cadtalk.com

1 800 833 4CADTALK
301 Artillery Park Drive, #201
Fort Mitchell, KY 41017

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