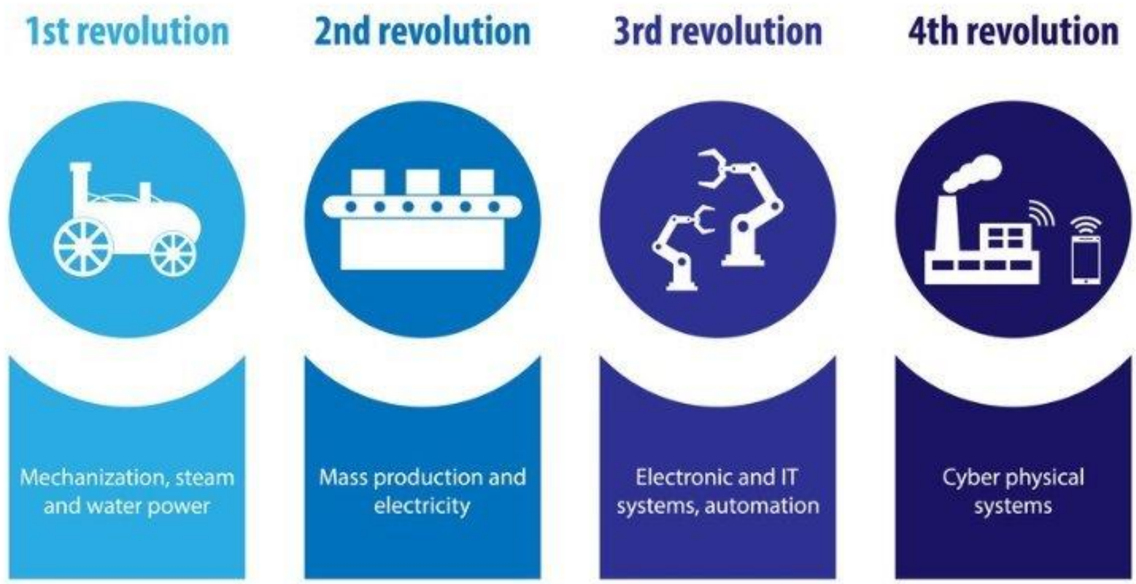
INDUSTRY 4.0 / SMART MANUFACTURING OVERVIEW

As a result of developments in the modern world, manufacturing is changing. This document is designed as a tool to help create a common understanding and nomenclature for community colleges, students, and industry employers to have conversations regarding these new developments. This document defines Industry 4.0, gives real world examples of its application, and explains associated concepts such as Cloud Computing, Smart Factory, Internet of Things (IoT), Cybersecurity, etc.

The third revolution of manufacturing in the 20th century brought us continued innovation in technology such as robots, IT, etc. Its systems have helped revolutionize productivity. Today, these types of systems are commonly known as “traditional manufacturing”. The 21st century has brought continued technological improvements to move advanced manufacturing towards integrating Industry 4.0.



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Industry 4.0 / Smart Automation - The 4th Industrial revolution is about digitally interconnecting all components on a factory floor including, sensors, software, and data analytics. The application of “machines talking to machines”. Within smart factories, cyber-physical systems monitor physical processes using a virtual copy of the physical world to make decentralized decisions. Over the Industrial Internet of Things (IIOT), these cyber-physical systems communicate and cooperate with each other, while at the same time humans must also monitor and make decisions across organizations.

Example from the field: A pilot facility, developed by The German Research Centre for Artificial Intelligence (DFKI) in Kaiserslautern, Germany, is demonstrating how a "smart" factory can operate. This pilot facility uses soap bottles to show how products and manufacturing machines can communicate with one another.[ii] Empty soap bottles have RFID tags attached to them, and these tags inform machines whether the bottles should be given a black or a white cap. A product that is in the process of being manufactured carries a digital product memory with it from the beginning and can communicate with its environment via radio signals. This product becomes a cyber-physical system that enables the real world and the virtual world to merge.

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Industry 4.0 has been driven primarily by 4 phenomena:

1) a rise in the volume of data readily available;
2) computational power and connectivity;
3) emergence of analytics and business intelligence capabilities – e.g. new forms of human-machine interaction such as touch interfaces and augmented-reality systems, and
4) improvements in transferring digital instructions to the physical world.

Industry 4.0 – Why should you care about this?

With the use of computers, automation and cloud technology, factories are becoming increasingly efficient and "smart". Industry 4.0 is the latest phase for the manufacturing sector which has come about because of the Internet of Things and the accessibility of data. Factories that are known as "Smart Factories" are becoming more prominent, particularly in Europe and the U.S. The terms "Smart Factory," "Smart Manufacturing," "Intelligent Factory" and "Factory of the Future" all describe a vision of what more intelligent, flexible and dynamic industrial production will look like in the future. Manufacturing processes will be organized differently, with entire production chains – from suppliers to logistics to the life cycle management of a product – closely connected across corporate boundaries. Individual production steps will be seamlessly connected. These changes to production design will impact almost all aspects of the company such as, factory and production planning, product development and design, logistics, enterprise resource planning (ERP), manufacturing execution systems (MES), control technologies, and parts procurement. In a Smart Factory, machinery and equipment will have the ability to improve processes through self-optimization and autonomous decision-making. This is in stark contrast to running fixed program operations, as is the case today with traditional manufacturing.

Annaliese Kloe, Managing Director of Headland Machinery explains that "Industry 4.0 is being spoken about everywhere. In particular, it was widely reflected at EuroBLECH 2016. It will widely change the approach to the way that manufacturers work, so if you aren't looking into this now then you'll be left behind. It will revolutionize your business, so it is vital to get on board."[iv] With an increasingly digital future ahead of us, this new era for manufacturing looks set to transform businesses worldwide. It is imperative for manufacturers to consider new technologies arising and explore how they can adapt their processes to comply with the expectations of the modern world and educators ensure the workforce is prepared to meet these changing requirements.

Glossary

Industrial Internet of Things (IIoT) – The concept of connecting any device with an on and off switch to the Internet (and/or to each other)[v]. This includes everyday items from cellphones, coffee makers, washing machines, headphones, lamps, or wearable devices to components of machines, such as, a jet engine of an airplane, or the drill of an oil rig. The Industrial Internet of Things (IIOT) is a subset of IOT focusing specifically on the industrial application of IOT[vi]. IIOT opens opportunities in automation, optimization, intelligent manufacturing and smart industry, asset management, industrial control, moving towards an on-demand service model, new ways of servicing customers and the creation of new revenue models, the more mature goal of industrial transformation. IIoT is creating the potential benefit from the connection and integration of data from Information Technology (IT) systems and the data center with data from Operational Technology (OT) on the factory floor and connected devices.

Example from the field: *Predictive maintenance analytics* captures the state of industrial equipment, so you can identify potential breakdowns before they impact production. Not only can production outages cost millions of dollars but replacing broken equipment can costs tens of thousands of dollars in extra expenses. At **FANUC**, the world's largest robotics company, IIoT, organizations across the globe can continuously monitor and infer equipment status, health, and performance to detect issues in real-time.

Additive Manufacturing – is a process that uses a variety of machines that use technologies that build 3D objects by ***adding*** layer-upon-layer of material, whether the material is plastic, metal, concrete or one day…..human tissue. The advantage to additive manufacturing compared to the more traditional, subtractive manufacturing, where items are created by cutting away at excess material to form the shape needed, is that additive manufacturing allows for less waste in raw material. 3D printing is another synonym commonly used to describe additive manufacturing.[vii]

Example from the field: **Stratasys**, the leading polymer 3D printer company in the world and **EOS**, the leading metals 3D printer company in the world have many competitors as well as small, medium, and larger organizations that us these technologies in aerospace, medical, transportation, energy, and consumer products.

Cloud Computing – Cloud computing means storing and accessing data and programs over the Internet instead of your computer's hard drive[viii]. This allows for easily shared information across multiple machines. There are multiple types of applications that are used in business and access through cloud computing. For example,

Example from the field: A business chose to implement a Software-as-a-Service (SaaS) application and now utilizing cloud computing, can access it remotely and securely through the Internet.

Big Data Analytics – this principle refers to a phenomenon where companies use software analyze and organize large volumes of data in search for trends and functional information. In Industry 4.0, circulation, collection, and analysis of information is a necessity because it supports productivity growth based on a real-time decision-making process. Machines and systems connected to the production plant (as well as other operational systems) must be able to collect, exchange, and save these massive volumes of information in an autonomous and secure way and without the need of human intervention.

Example from the field: Big Data is taking the world by storm. With the huge amounts of data emanating from various digital sources the importance of analytics has tremendously grown making the companies to tap the dark data that was considered useless all these years.

[xvii] There are four types of big data BI that really aid business:

1. *Prescriptive* – This type of analysis reveals what actions should be taken. This is the most valuable kind of analysis and usually results in rules and recommendations for next steps.
2. *Predictive* – An analysis of likely scenarios of what might happen. The deliverables are usually a predictive forecast.
3. *Diagnostic* – A look at past performance to determine what happened and why. The result of the analysis is often an analytic dashboard.
4. *Descriptive* – What is happening now based on incoming data. To mine the analytics, you typically use a real-time dashboard and/or email reports.

Cybersecurity – With the increased connectivity and use of standard communications protocols that come with Industry 4.0, the need to protect critical industrial systems and manufacturing lines from cybersecurity threats increases dramatically. As a result, secure, reliable communications as well as sophisticated identity and access management of machines and users are essential. As the role of technology in corporate operations grows, security vulnerabilities—data theft, leakage of intellectual property, corporate sabotage, denial-of-service attacks—are growing.

Example from the field: The damage from cybersecurity attacks can affect a company's profits, reputation, brand, and competitive position. The damage can even affect a company's viability, as direct costs for data breaches can reach hundreds of millions of dollars.

Autonomous Robotics – Robots that perform behaviors or tasks with a high degree of autonomy. Some modern factory robots are "autonomous" within the strict confines of their direct environment.[ix] Autonomous robots, although they may not require as much hands-on operation to complete its assigned tasks, also lack varying degrees of freedom to adapt to their surrounding environment. The factory robot's workplace is challenging and can often contain chaotic, unpredicted variables that workers still need to address as the autonomous robots are not capable of making those decisions.

Example from the field: Robots designed to weld together two pieces of machinery can adjust the pieces into the correct position, move them along the line, and make slight adjustments within their programming. However, humans are still needed to set up and program the robots, and to inspect the end product to make sure it is meeting the necessary standards.

System Integration – is the process of integrating all physical and virtual components of an organization's system.[x] This includes horizontal and vertical integration of information systems beyond Computer Integrated Manufacturing (CIM) – which is the process of using computers to control the entire manufacturing process – of the 1990s[xi]. Regardless of the varying industries such as utilities, manufacturing or transportation, companies want to get more from their existing assets and are retrofitting existing systems to include system integration. With Industry 4.0, companies, departments, functions, and capabilities will become much more cohesive, as cross-company, universal data-integration networks evolve and enable truly automated value chains.

Example from the field: Total systems integration experts like Siemens[xviii] provide solutions for all industries including, but not limited to Transportation, Energy, Manufacturing, Healthcare, and many more. See the short video for examples.

Simulation – This is the capability to perform virtual prototyping and automation in manufacturing industries is critical as industries seek to reduce the time moving through each engineering phase.

Example from the field: Systems simulations experts like Siemens[xviiii] provide solutions for all industries including, but not limited to Transportation, Energy, Manufacturing, Healthcare, and many more. See the short video for examples of simulations imbedded into systems integrations.

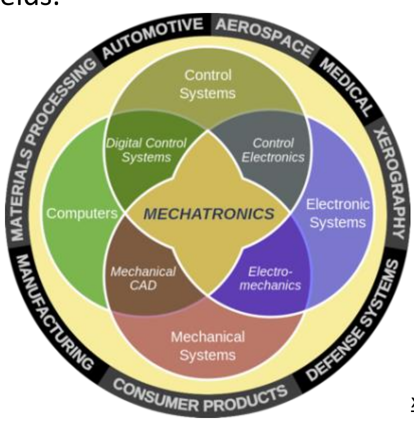
Artificial Intelligence (AI) – describes the ability of machines to imitate human mental prowess and make decisions. AI has multiple applications in Industry 4.0 including, machine s, software, and IOT. Machines, including robots, can be fitted with electrical circuits and electronic chips for control and command. Software programs are not programmed for pre-determined functions alone, the software will also contain a feedback or loop design to facilitate learning and adaptation. With IOT, hooking the AI system to the cloud is very useful for workers to perform refined data analytics, adaptive research, and real-time communications[xii].

Example from the field: [xx] Today, there are scores of machine learning algorithms in use that sense, think, and act in a variety of different applications. Yet many of these algorithms are considered "black boxes," offering little if any insight into how they reached their outcome. [Explainable AI] is a movement to develop machine learning techniques that produce more explainable models while maintaining prediction accuracy.

Augmented Reality (AR) – is a technology that layers computer-generated enhancements atop an existing reality in order to make it more meaningful by allowing the user to virtually interact with it.[xiii] It allows companies to provide workers with real-time information to improve decision making and work procedures by blending digital components with the real world.

Example from the field: AR can support manufacturing in a variety of services, such as selecting parts in a warehouse and sending repair instructions over mobile devices. Mitsubishi has used this technology to confirm maintenance procedures with the manual[xiv].

Mechatronics – Mechatronics is a multidisciplinary field of science involving the analysis, design, synthesis, and selection of systems that combine electronics and mechanical components with modern controls and microprocessors.[xv] Mechatronics' aim is a design process that unifies these subfields.



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Example from the field: There have been rapid changes and improvements in the fields of electronics, computer and control systems over the last years. As a result of this, computer-controlled systems have been in increase in almost every field. The number of only mechanically operating systems is very few. The applications of artificial intelligence techniques have been put into use in design, production and maintenance. Therefore, the design, production and maintenance of advanced products are no longer a single subject. It has become a must to use mechanics, electrics and electronics, hydraulics and pneumatic and computer technologies together. This made Mechatronics emerge as a new discipline. What Mechatronics covers ranges from home technologies to advanced medical devices and from computer-controlled benches to robots.

The application fields of Mechatronics [xxi] can be illustrated as follows:

- Control Systems (position, level, pressure and heat control systems…)
- Robots (transport and welding robots)
- Industrial Automation (barcode systems and production belts)
- Building Automation (security systems, automatic air conditioning and automatic door systems)
- Home appliances (washing machines and dish washers)
- Automotive (air bag, antilock braking system)
- Defense Industry (mine detection robots, automatically guided vehicles)
- Medical Applications (magnetic resonance, arthroscopic devices, ultrasonic probes etc.)
- Aeronautical Engineering (automatic pilots, unmanned aerial vehicles)
- Image and Sound Processing (automatic focusing devices, sound-operated devices)
- Production (Computerized Numerical Control -CNC, Numerical Control -NC)
- Laser optical systems (barcode)
- Intelligent measuring devices (calibration devices, testing and measuring sensors.)

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