aircraft in 1903. The increasing altitude, payload, and speed capabilities of airplanes made them powerful weapons in World War I. Such advances improved flying skills, designs, and performance, though at a terrible cost in lives.

The monoplane design superseded the fabric-and-wire biplane and triplane designs of World War I. The helicopter was developed during World War II and quickly became an indispensable tool for medical evacuation and search and rescue. The jet engine, developed in the 1940s and used on the Messerschmitt 262 and Junkers aircraft by the Luftwaffe and the Gloster Meteor by the British, quickly enabled flight in the stratosphere at speeds sufficient to generate enough lift to climb in the thin air. Such innovations led to smooth, long-range flights in pressurized cabins and shirtsleeve comfort. Fatal crashes of the de Havilland Comet airliner in 1953 and 1954 focused attention on the science of metal fatigue.

The Boeing 707 opened up intercontinental air travel, followed by the Boeing 747, the supersonic Concorde, and the EADS Airbus A380. A series of crewed research aircraft designated X-planes since


*Space Shuttle Atlantis on a Shuttle Carrier Aircraft. Photo via NASA/Wikimedia Commons. [Public domain.]*

not necessarily physical in nature, although this is the most common circumstance. The execution of the instructions in a computer program represents an automated process, as does the repeated execution of a series of specific welds in a robotic weld cell. The two are often inextricably linked, as the control of the physical process has been given to such digital devices as programmable logic controllers (PLCs) and computers in modern facilities.

Physical regulation and monitoring of mechanical devices such as industrial robots is normally achieved through the incorporation of servomechanisms. A servomechanism is a device that accepts information from the system itself and then uses that information to adjust the system to maintain specific operating conditions. A servomechanism that controls the opening and closing of a valve in a process stream, for example, may use the pressure of the process stream to regulate the degree to which the valve is opened.

Another essential component in the functioning of automated processes and servomechanisms is the feedback control systems that provide self-regulation and auto-adjustment of the overall system. Feedback control systems may be pneumatic, hydraulic, mechanical, or electrical in nature. Electrical feedback may be analog in form, although digital electronic feedback methods provide the most versatile method of output sensing for input feedback to digital electronic control systems.

## BACKGROUND AND HISTORY

Automation begins with the first artificial construct made to carry out a repetitive task in the place of a person. One early clock mechanism, the water clock, used the automatic and repetitive dropping of a specific amount of water to measure the passage of time accurately. Water-, animal-, and wind-driven mills and threshing floors automated the repetitive action of processes that had been accomplished by humans. In many developing areas of the world, this repetitive human work remains a common practice.

With the mechanization that accompanied the Industrial Revolution, other means of automatically controlling machinery were developed, including self-regulating pressure valves on steam engines. Modern automation processes began in North America with the establishment of the assembly line as a standard industrial method by Henry Ford. In this method, each worker in his or her position along the assembly line performs a limited set of functions, using only the parts and tools appropriate to that task.

Servomechanism theory was further developed during World War II. The development of the transistor in 1951 enabled the development of electronic control and feedback devices, and hence digital electronics. The field grew rapidly, especially following the development of the microcomputer in 1969. By the twenty-first century, digital logic and machine control could be interfaced in an effective manner, enabling automated systems to function with an unprecedented degree of precision and dependability.

## HOW IT WORKS

An automated process is a series of repeated, identical operations under the control of a master operation or program. While simple in concept, it is complex in practice and difficult in implementation and execution. The process control operation must be designed in a logical, step-by-step manner that will provide the desired outcome each time the process is cycled. The sequential order of operations must be set so that the outcome of any one step does not prevent or interfere with the successful outcome of any other step in the process. In addition, the physical parameters of the desired outcome must be established and made subject to a monitoring protocol that can then act to correct any variation in the outcome of the process.

also utilize more renewable resources and more recyclable parts.

Though it may be a difficult initial transition for some companies, shifting to ecodesign as a priority has the potential to increase the long-term profits of a company. For example, designing a product to use fewer resources during construction also lowers the amount of raw materials that the company must pay to procure, increasing the profit margin for the product. Designing factories in an energy-efficient manner lowers the constant cost of running the factory in addition to helping the environment. Finding more efficient means of shipping product can reduce the amount of fossil fuels released into the atmosphere while also reducing shipping costs. Finding the minimum amount of necessary packaging required to safely deliver the product to the consumer cuts down on waste and reduces the amount of packaging materials that companies need to purchase.

In most cases, ecodesign can be broken down into four phases. The first phase, adopting responsible procurement, means procuring the materials necessary for a product in an environmentally sustainable manner. The second phase, optimizing design, means designing and packaging a product in an ecologically sustainable and efficient manner. The third phase, improving end-of-life management, means minimizing the impact that the product will have on the environment after its primary purpose has ended. The fourth stage, communication, involves communicating effective practices with other companies so that they can be replicated.

—*Tyler Biscontini*

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# Electric Automobile Technology

**ABSTRACT**

*Electric vehicles have been around even longer than internal combustion engine cars. With health issues resulting from the modern use of internal combustion engines, the automotive industry is intensifying its efforts to produce novel machines that run on electricity. Many cars come with drivetrains that can accept electric propulsion, offering quieter, healthier transportation options.*

## DEFINITION AND BASIC PRINCIPLES

An electric vehicle is driven by an electric motor. The electricity for this motor can come from different sources. In vehicle technology, electrical power is usually provided by batteries or fuel cells. The main advantages of these devices are that they are silent, operate with a high efficiency, and do not have tailpipe emissions harmful to humans and the transformation of materials, substances, or components into new products."

Under the 2017 revision of the North American Industry Classification System (NAICS), the Census Bureau breaks down the manufacturing sector into twenty-one broad subsectors, each labeled by a three-number code. Subsectors include food manufacturing (NAICS 311), wood product manufacturing (NAICS 321), and primary metal manufacturing (NAICS 331). The Census Bureau breaks down each subsector further into multiple, more detailed segments with four-, five-, and six-number NAICS codes. For example, the transportation manufacturing subsector, NAICS 336, is further broken down into segments such as motor vehicle manufacturing (NAICS 3361) and ship and boat building (NAICS 3366). Each subsector reflects specific production methods associated with material inputs, production equipment, and employee skills.

This article will consider the manufacturing processes of three subsectors within the manufacturing sector:

- Apparel manufacturing
- Chemical manufacturing
- Transportation equipment manufacturing

These three subsectors will provide the framework for a discussion of some of their unique manufacturing processes.

## APPLICATIONS

This section will define the basic processes for apparel manufacturing, chemical manufacturing, and transportation equipment manufacturing. These are crucial, but general processes; each process may include multiple subprocesses that are unique to the industry or product.

**Apparel manufacturing process.** The apparel manufacturing sector consists of establishments that turn fabric into clothing. The process of turning fabric into clothing is relatively straightforward and requires five main actions:

- Designing the clothing item
- Creating a pattern for the clothing item
- Purchasing fabric and materials for the clothing item
- Preparing the fabric and materials for construction into the clothing item
- Constructing the clothing item

An apparel manufacturing company may complete all or some of the actions in-house. For example, some companies might also weave their own fabric. Others may purchase patterns and fabrics. Others might contract out certain facets, such as the design of products, while still others may employ outsourcing for part of the process, such as pattern making or the sewing of the clothing item, to one or more persons or organizations outside the company.

**Chemical manufacturing process.** The chemical manufacturing subsector consists of establishments that transform organic and inorganic raw materials through a chemical process that allows for the formation of new products. The process for manufacturing chemicals requires controlled manufacturing conditions and highly skilled personnel with a knowledge of chemicals, their melting and boiling points, and reactive properties.

The process for manufacturing a chemical includes the following steps:

- Identifying the chemical to manufacture and establish the quantity needed
- Identifying the type and quantities of raw materials required to make the chemical
- Gathering information about the chemical properties of the raw materials, their reactive qualities, their melting and boiling points, and any byproducts that will result from the synthesizing and manufacturing processes

cipline into the areas of aerodynamics, sports surfaces, impact, and friction. Although the specific field of sports engineering is new, the fundamentals that make up this subdiscipline are based on centuries of study.

The earliest recorded Olympic competition dates back to ancient Greece. As technology improves it has been applied to virtually all sports. Even clothing has advanced to provide sports specific advantages such as improved aerodynamics, breathable fabric, thinner insulating fabrics, and superior waterproofing. Sports engineers also work with the governing bodies of sports organizations to meet the regulations of those specific sports.

The fields of engineering evolved from physics and mathematics. The first societies were formed in the nineteenth century. As the specific field of mechanical engineering evolved, the principles of physics and mathematics were already being applied to sports equipment. Biomechanics and kinesiology developed as specialized fields in the subject of human movement; however, these fields did not specifically address sports equipment. The University of Sheffield provided a focused area of study in sports equipment and venues by founding the sports engineering program along with the Sports Engineering Research Group (SERG). The International Sports Engineering Association (ISEA) was then founded to provide a forum for engineers interested in this subject. There are now a handful of universities around the world that offer degrees in sports engineering and other mechanical engineering programs that offer classes in sports engineering.

## HOW IT WORKS

Mechanical engineering applies mathematics and physics to the design and study of physical and mechanical processes. Sports engineering uses mechanical engineering knowledge to focus on the study and design of sports equipment and venues. Refinements in equipment lead to improved performance by athletes as well as improved safety for participants. Regulations of various sports have been modified in order to accommodate new forms of equipment while maintaining fairness between competitors and improving sports safety. It is useful to use the University of Sheffield's divisions of aerodynamics, sports surfaces, impact, and friction to understand the areas of study that make up sports engineering.

**Aerodynamics.** Aerodynamics uses mathematics and physics to describe and model the airflow around objects. For any sport that uses balls, it is helpful to understand the trajectories that may result under different circumstances to develop techniques for improved accuracy and speed. Aerodynamics also applies to any sports that involve speed. Skeleton, speed skating, bobsledding, sprinting, downhill skiing, and many other sports use specialized equipment and clothing to reduce the effects of air flow on performance.

To study the aerodynamics of sports equipment, there are a variety of techniques that can be employed. Wind-tunnel tests and laser scanners are used in the study of sports aerodynamics along with sophisticated mathematics techniques such as computational fluid dynamics (CFD). Forces such as lift and drag can be calculated using these methods. Variations in surface roughness of a ball or of clothing, spin on a ball, or other factors will change the way an object moves through space. The most familiar example of this is the variation in the behavior of a baseball depending on the pitch.

**Sports surfaces.** The interactions of athletic shoes or equipment and the sports surface play a large role in performance and can result in injuries. Surfaces may vary even within a sport, such in as tennis and soccer. Information about these interactions is used by shoe manufacturers and other manufacturers to design equipment that will reduce injuries and optimize performance. Traction-test devices are used to simulate conditions in some cases. A trac-