Engineering Opportumities in the 21st Century

An Online Continuing Education Course for Engineers

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Engineering Opportunities in the 21st Century

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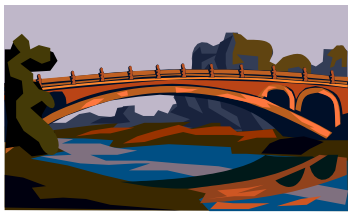
Introduction

Engineers had a major impact on society in the last century. They developed machines that did things faster and better, and designed and built larger and more complex structures. Mechanization and automation has made farms and industries substantially more productive. An individual's access to the world has greatly increased with the faster transportation and better communications. The National Academy of Engineering was formed in the realization of the importance engineering has in moving the country forward technologically. This examines two of their publications and other reports that identify areas where engineers are needed in this century. In 2003, the National Academy published the Twenty Greatest Engineering Achievements of the Twentieth Century. They followed that with the Fourteen Grand Challenges for this century. These recognize what has been achieved in the last century and challenges for the next century. This examines these and other reports to identify opportunities for engineers in this century.

A Short History of Modern Engineering



Modern engineering uses science to develop advanced machines and complex structures. Scientific knowledge originated from detailed observations of the natural world. It was first met with resistance because of the disagreements with previous accepted knowledge, but was recognized for providing a better explanation of the natural world. Isaac Newton's defined laws of motion which formed the basis of mechanics (1687). The modern study of engineering began in 1747, at the National School of Bridges and Highways, in France. The name of the school was changed to Ecole Polytechnique and it became a model for engineering schools that followed. This college was created as part of France's defense education and remains that way today. The West Point Academy was the first college in the United States to teach modern engineering. In engineering schools, the scientific laws formed the fundamentals rather than traditional practices as in the medieval crafts. Mathematics and physical sciences were the foundations for the study of engineering. Engineers were categorized as civil engineers, who designed and built bridges, highways and water distribution systems or military engineers, who designed and built fortifications, castles and war machines.

In the nineteenth century, scientific discoveries in mechanics, chemistry, thermodynamics and electricity enabled building more efficient and powerful engines and machinery. Michael Faraday defined the law of induction and established principles to generate electricity (1821), which became the basis for electrical engineering.

Mechanical and electrical engineering became new engineering disciplines. During this time, the Brooklyn Bridge, the Transcontinental Railroad, the Transatlantic Cable and the Panama Canal were constructed. Steam powered machines increased production and the railroads enabled distribution of goods over longer distances. These developments provided more opportunities for civil and mechanical engineers. One could travel across the country in a week. Before the railroads, it took several months or longer to go across the country. Discoveries in electricity were applied to creating electric generators, lights and motors and provided opportunities for electrical engineers. Chemical engineering became an engineering discipline that focused on the mass production of chemicals. Engineering societies formed to promote the separate disciplines. Engineering societies provided engineering standards and recognized new methods and accomplishments. The American Society of Civil Engineers originated in 1852. In 1862, Abraham Lincoln signed the Morrill Land-Grant Act to establish a government support of colleges for teaching agriculture and engineering in each state. Massachusetts Institute of Technology was one of the colleges which have been noted for excellent engineering education. The American Society of Mechanical Engineers was founded in 1880. The forerunner of the Institute of Electrical and Electronic Engineers formed soon after in 1884. The telegraph had become a major means of long distance communications. At the end of the century, the number of practicing engineers in the United States was around 45,000.

In the twentieth century, industrialization expanded with the mass production of automobiles, air conditioning, aircraft, electric generators and motors, electronics, telephones, and radio. World War II involved substantial engineering of war equipment. After the war, television, nuclear reactors, imaging technology, computers, spacecraft, laser and fiber optics, the Internet, health technologies became major influences. The development of these products and technologies are described in detail in the American Academy of Engineering's list of the Twenty Greatest Engineering Achievements in the Twentieth Century.

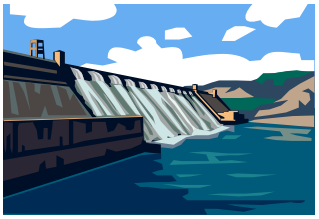
1. Electrification
2. Automobile
3. Airplane
4. Water Supply and Distribution
5. Electronics
6. Radio and Television
7. Agricultural Mechanization
8. Computers
9. Telephone
10. Air Conditioning and Refrigeration
11. Highways
12. Spacecraft
13. Internet
14. Imaging
15. Household Appliances
16. Health Technologies
17. Petroleum and Petrochemical Technologies
18. Laser and Fiber Optics
19. Nuclear Technologies
20. High-performance Materials

Electrification provided electrical power to homes and industry. Developments in electrical power generation and distribution continued through the century. The Tennessee Valley Authority was noted for development of electric power generation for the Tennessee Valley. The Hoover and Grand Coulee Dams and nuclear power plants were recognized along with geothermal and solar and wind electrical power generation systems. Today, about 45 percent

of the electrical power is from coal fired plants. Another 23 percent is from natural gas powered plants. Nuclear energy is a source of about 20 percent of the electrical power generated. The rest is from alternative sources: hydroelectric, solar, wind, biomass and others.

The **automobile** has been a fundamental industry throughout the twentieth century. It was the largest industry in mid-century. The automobile enabled unparalleled freedom of movement, redefined cities and became a major form of transportation. The formation of General Motors, the Model T, the moving assembly line, and advances to the automobile such as power steering, air-conditioning, anti-lock brakes, and air bags were some of the noted accomplishments. The automobile and three other of the great achievements depended largely on mechanical engineering: farm mechanization, air conditioning and refrigeration, and household appliances.

The **airplane** enabled carrying more people, longer distances, and much faster than before. New advances in aviation, metal construction, jet propulsion and long distance transport changed long distance transportation. Boeing and Douglas aircraft companies built commercial airliners which enabled long distance travel. A new engineering discipline, aeronautical engineering focused on developing more advance aircraft. Air travel replaced rail and ship transportation for long distance travel. The Concorde SST transported passengers across the oceans at twice the speed of sound. Spacecraft were capable of even higher speeds and longer distances for a select few. Spacecraft was also listed separately as an achievement. The launch of the Russian satellite, Sputnik I initiated the space race. Engineers were involved in launching satellites and spacecraft, peaking with the Apollo missions to the moon. Spacecraft have extended both distances and speed and have enabled better global communications. The launches of GPS satellites enabled location of position and tracking to within 20 feet on earth.



The reliable supply of **water** is essential for farming, industry and homes. Farms and industries use the bulk of the water, and with more people in urban areas there is a need for better urban water distribution and sewage removal. The Owens River Aqueduct and Catskill and Delaware Aqueducts were major projects to bring water to Los Angeles and Manhattan. Hoover Dam provides water for three states. Water treatment practices were developed that reduce pollution of lakes and rivers. The major improvement of highways is also listed as a Great Achievement. The success of the automobiles and trucks as major forms of transportation depended on the improvement of the roads. The development of the new highways included: The Holland Tunnel, Route 66, the Golden Gate Bridge, the Chesapeake Bay Bridge, Highway 70 and the interstate highway system. Civil engineering has grown with the need a better water distribution, water treatment and building the interstate highway system.

Electronics enabled communications over longer distances. The invention of the triode was followed by transistors and integrated circuits. A number of achievements depended on electronics: radios, television, imaging equipment, computers, the Internet, lasers and fiber optics. These achievements initiated mass communications and provided global access to events.

The **computer** was an unexpected success. Claude Shannon initiated the ground work through analysis of relay circuits. The development of electronic computers with stored instructions was a major advance in computing. Computer technology advanced quickly with faster capabilities to manipulated massive amounts of data. Computer and software engineering became a new engineering disciplines focusing on the design and fabrication of computing devices and software development, respectively. The invention of the personal computer made the capabilities of computers more available to everyone. The Internet provided global communications access to many. In fifty years, those in the computer field have grown to exceed the number of engineers. Computers are used in many areas: communications, health, entertainment, science, engineering, commerce, transportation, manufacturing and medicine.

The list of great achievements also included health technologies, petrochemicals and performance materials. **Health technologies** involve health equipment such as EKG, CT Scan, MRI, Ultrasound and replacement therapies such as heart valves, pacemakers, hip replacements, and laser surgery. **Petrochemical technologies** involve new extraction and processing technologies and products such as nylon and polystyrenes. These achievements resulted in two new engineering specialties: biomedical and petrochemical engineers. Steel has been an important high performance material and others such as plastics, nickel alloys, titanium, silicon and carbon fiber were further developed in the last century.

The advances in transportation enabled movement of more goods over longer distances**. Global trade** has become a significant influence. Global trade has also resulted in intense competition from companies based in foreign countries. The automobile industry was the United States largest industry in the middle of the last century, and General Motors was the largest corporation in the world. The automobile replaced the rail as a preferred method for travel for both short and longer distances. Then, manufacturing jobs consisted of 30% of the work force. Since then, importing more goods, automation of industrial plants and moving manufacturing outside the country have resulted in a decline of employment of workers in production industries. The ability of foreign countries to engineer and produce competitive products was exemplified in the success of Toyota. At the end of the century, Toyota had revenues similar to GM. Many electronic devices were engineered and produced outside the country. These developments impact the need for engineers in the United States, particularly in the private sector. Although the value of produced goods has increased, economic statistics show the percentage of wealth

created by production of goods has been declining relative to the wealth generated from services. The increase in productivity from automation can explain the increase in the value of produced goods while the number employed in production has declined. This is good for the investors, but not for the production workers. At the end of the century manufacturing jobs declined to less than 6% of the work force. Wal-Mart became the largest employer in the United States. This era has been referred to as the post-industrial age. During this time, the harm of some industries to the natural environment and public health resulted in a closer look at industrial practices that were harming the environment and the general public. This was referred to as the Environmental Movement. The fuel crisis brought attention to the dependence on limited oil resources. In the mid 1980's, the number of engineering bachelor degrees p hile biological, business, and behavior science degrees continued to ri

A number of artic st century and propose recommendations. Duderstadt of the University of Michigan is a co g in this next century. Eighty percent of th es and their future is highly dependent on the ch nhance the educational requirements for eng or traditional professional occupations such as ducational standards than most occupations. Th rement for a practicing engineer.

There has been a trend t the end of the century, around 35% of the gra er. This trend was not specific to engineering earning masters degrees. The advances g a more advanced education to be more c at the service oriented economy will result in ny has a broad range of occupations. Doctors p les. Similarly having an advanced degree in engineering u larger income.

Today, the **professional engineering** license is an established credential of the engineering profession. The engineering disciplines with highest licensing are civil, environmental, nuclear, petroleum and mechanical. Most architects are required to have licenses to practice. Manufacturing companies have avoided engineering licensing through industrial exceptions. This has attributed to less professional licensing than other professions. The exception allows industries to use the term, engineering to describe various jobs that do not in fact involve trained engineers. The disciplines with the lesser number of licensed engineers are computer, materials, biomedical, industrial and aerospace. A challenge for the next century would be to establish licensing as a mandatory requirement for those who practice engineering without exception. The advanced degree has been proposed to better establish engineering as a profession.