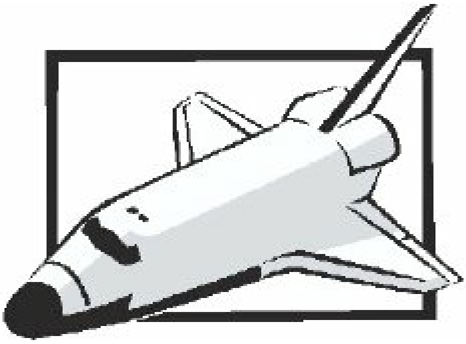


CHAPTER 2

The Engineering Profession

Scientists investigate that which already is;

Engineers create that which never has been.

— Theodore Von Karman

INTRODUCTION

This chapter will introduce you to the engineering profession. Look at it as a discussion of "everything you ever wanted to know about engineering" – and then some. Hopefully, when you are finished reading the chapter, you will have a comprehensive understanding of the engineering profession and perhaps have found the engineering niche that attracts you most. This information, coupled with knowledge of the personal benefits you will reap from the profession, is intended to strengthen your commitment to completing your engineering degree.

First, we'll answer the question, "What is engineering?" Through several standard definitions, you'll learn that engineering is essentially the application of mathematics and science to develop useful products or processes. We'll then discuss the engineering design process, which we will demonstrate through a case study of an actual student design project.

Next, we will discuss the rewards and opportunities that will come to you when you earn your B.S. degree in engineering. Having a clear picture of the many payoffs will be a key factor in motivating you to make the personal choices and put forth the effort required to succeed in such a challenging and demanding field of study.

The remainder of the chapter will be devoted to an in-depth look at engineering – past, present, and future.

To look at the past role of engineering in improving the quality of our lives, we will take stock of the Greatest Engineering Achievements of the 20th Century, selected by the National Academy of Engineering.

To look at the present state of engineering, we will examine the various engineering disciplines, the job functions performed by engineers, and the major industry sectors that employ engineers. The North American Industry Classification System (NAICS) will serve as a window into the vast organization of U.S. industry.

To gain some insights about the future of engineering, we will look at the Grand Challenges for Engineering presented by the National Academy of Engineering in 2008. These challenges provide an indication of those fields showing the greatest promise for future growth.

The last section of the chapter will focus on engineering as a profession, including the role of professional societies and the importance of professional registration.

2.1 WHAT IS ENGINEERING?

I'm sure you have been asked, ***"What is engineering?"*** I remember my grandmother asking me that question when I was in college. At the time, I didn't have much of an answer. Yet, when you think about it, it is a fundamental question, especially for a new engineering student like yourself. So, just what is engineering?

A good starting point for answering this question is the theme of *National Engineers Week*, held each February in honor of George Washington, considered our nation's first engineer. That theme depicts engineering according to its function:

Engineers turn dreams into reality.

Over the years, many variations of this theme have been put forth, from that of the famous scientist Count Rumford over 200 years ago:

> ***Engineering is the application of science to the common purpose of life.***

to the current standard definition of engineering provided by the Accreditation Board for Engineering and Technology (ABET):

> ***Engineering is the profession in which a knowledge of the mathematical and natural sciences, gained by study, experience, and practice, is applied with judgment to develop ways to utilize, economically, the materials and forces of nature for the benefit of [hu]mankind.***

Harry T. Roman, a well-known New Jersey inventor and electrical engineer, compiled 21 notable definitions of engineering. These are listed in Appendix B.

EXERCISE

Study the 21 definitions of engineering in Appendix B. Then compose your own definition. Write it down and commit it to memory. This may seem like an unnecessary exercise, but I assure you it isn't. Aside from impressing others with a quick informed answer to the question "What is engineering?" this exercise will help clarify your personal understanding of the field.

LEARNING MORE ABOUT ENGINEERING

As you learn more about the field of engineering, you will find there is no simple answer to the question "What is engineering?" Because engineers do so many different things and perform so many different functions, learning about engineering is a lifelong endeavor. Still, there is a variety of ways to start learning about and understanding engineering, one being to tap the tremendous amount of information available online.

One helpful website you should check out is www.eweek.org. At that website you can learn much about both engineering and National Engineers Week. The following additional websites will help further your understanding of engineering:

www.engineeringdegrees101.com
www.futuresinengineering.com
www.discoverengineering.org
www.tryengineering.org
www.careercornerstone.org
www.egfi-k12.org
www.dedicatedengineers.org
www.bls.gov/ooh/architecture-and-engineering/home.htm

Remember, by increasing your knowledge about engineering, you will strengthen your commitment to your studies and your desire to succeed.

ONE LAST POINT. The question is often asked: How is engineering different from science? An excellent answer was provided by astronaut Neil Armstrong in the foreword of *A Century of Innovation: Twenty Engineering Achievements That Changed Our Lives* [1]:

> ***Engineering*** is often associated with science and understandably so. Both make extensive use of mathematics, and engineering requires a solid scientific basis. Yet as any scientist or engineer will tell you, they are quite different. Science is

a quest for "truth for its own sake," for an ever more exact understanding of the natural world. It explains the change in the viscosity of a liquid as its temperature is varied, the release of heat when water vapor condenses, and the reproductive process of plants. It determines the speed of light. Engineering turns those explanations and understandings into new or improved machines, technologies, and processes – to bring reality to ideas and to provide solutions to societal needs.

2.2 THE ENGINEERING DESIGN PROCESS

At the heart of engineering is the *engineering design process*. The engineering design process is a step-by-step method to produce a device, structure, or system that satisfies a need.

Sometimes this need comes from an external source. For example, the U.S. Air Force might need a missile system to launch a 1,000-pound communications satellite into synchronous orbit around the earth.

Other times, the need arises from ideas generated within a company. For example, consumers did not initiate the need for various sizes of little rectangular yellow papers that would stick onto almost anything yet be removed easily when 3M invented "Post-its" [2].

Whatever the source, the need is generally translated into a set of specifications ("specs"). These include performance specifications (e.g., weight, size, speed, safety, reliability), economic specifications (e.g., cost), and scheduling specifications (e.g., production and delivery dates).

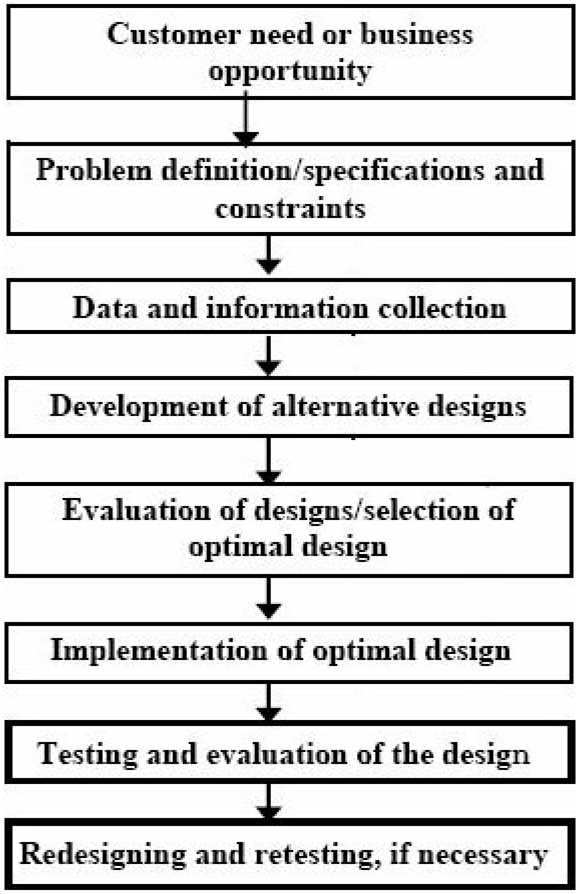
Your Alarm Clock Is an Example

Virtually everything around you was designed by engineers to meet certain specifications. Take the start of your day, for example. You likely wake up to an electrically-powered alarm clock. Every design feature of the clock was carefully considered to meet detailed specifications. The alarm was designed to be loud enough to wake you up but not so loud as to startle you. It may even have a feature in which the sound level starts very low and increases progressively until you wake up. The digital display on your clock was designed to be visible day and night. Batteries may be included to provide redundant power so the alarm will work even if there is a power outage. These batteries must meet life, safety, and reliability requirements. Economic considerations dictated material selection and manufacturing processes. The clock also had to look aesthetically pleasing to attract customers, while maintaining its structural integrity under impact loading, such as falling off your night stand.

The Engineering Design Process

Now that you have been introduced to the first two steps – identifying the need and then drawing up specifications to meet that need – a complete eight-step engineering design process can be illustrated by the schematic below.

The Engineering Design Process



From this schematic you can see that each step of the design process reflects a very logical, thorough problem-solving process. The customer need or business opportunity (Step 1) leads to a problem definition, including a description of the design specifications (Step 2).

Early in the design process, a number of constraints may be identified. Whatever these constraints may be – e.g., availability of parts and materials, personnel, and/or facilities – the final design must not only meet all design specifications but also satisfy any constraints.

The problem definition, specifications, and constraints will need to be supplemented by additional data and information (Step 3) before the development of possible solutions can begin. This step might, for example, involve learning about new technologies and where information is lacking, research may need to be done.

The process of developing and evaluating possible designs (Steps 4 and 5) involves not only creativity but also the use of computer-aided drafting (CAD), stress analysis, computer modeling, material science, and manufacturing processes. Engineers also bring common sense and experience to the design process. At the conclusion of Step 5, based on a comparative evaluation, the optimal design will be selected.

Step 6 involves implementing the optimal design, which in many cases involves fabrication of a device. Fabrication of several designs may be required in order to test how well each meets the performance specifications. In Step 7, the final design is tested and evaluated, and if necessary, redesigned and retested (Step 8).

Many iterations through the engineering design process may be required before a design is found that meets the need or opportunity and all specifications and satisfies all constraints.

It should be noted that the engineering design process is part of the broader product development cycle that begins with the perception of a market opportunity and ends with the production, sale, and delivery of a product. An excellent resource on this subject is the book *Product Design and Development* by Karl Ulrich and Steven Eppinger [3].

The engineering design process is succinctly stated through the motto of Lamar University's College of Engineering:

Imagine it. Design it. Build it. Improve it.

HOW THINGS WORK - *REVERSE ENGINEERING*

As an engineering student, you should take every opportunity to learn as much as you can about how things work. Much of your engineering coursework will deal with mathematical modeling of physical problems (analysis). You will get some exposure to the "real world" in your laboratory courses and in courses that focus on engineering design. But as they say, "You can't get enough of a good thing." The more you know and understand the physical world, the better engineer you will be.

I suggest you take initiative in this regard. It's one thing to study about a subject; it's another to take things apart and analyze how they work.

STUDYING ABOUT HOW THINGS WORK. A great source of information on how things work is the "How Stuff Works" website: www.howstuffworks.com. To get a feel for what's there, select something you know little or nothing about but would like to know more about (e.g., da Vinci surgical system, synthesizers, fuel injection systems, optical mice, intelligent highways). And go to the HowStuffWorks website and enter the device name.

You can also learn about how things work and keep up with changing technologies by reading trade magazines such as *Popular Mechanics*, *PC World, Popular Science, Wired*, and *Discover Magazine*.

Professional engineering societies also have magazines and websites that are good sources of technical information, although some may only be available to members. Examples of those non-members can access are:

IEEE Spectrum – www.spectrum.ieee.org

ASME Mechanical Engineering – www.asme.org/kb/newsletters

ASCE Civil Engineering – www.asce.org/cemagazine

REVERSE ENGINEERING. A more formal topic related to understanding how things work is called *reverse engineering.* Reverse engineering is the process of taking apart a device, object, or system to see how it works in order to duplicate or enhance it. Reverse engineering had its origins in the analysis of hardware for commercial or military advantage. This practice is now frequently used on computer software.

Reverse engineering of hardware might be done out of curiosity or as an academic learning experience. Have some fun! Look for opportunities to take things apart and figure out how they work.

More often reverse engineering is done by businesses to make a three-dimensional record of their products or to assess competitors' products. It's also done to retrieve the source code of a software program, improve the performance of a program, correct an error in the program, identify a virus, or adapt a program written for one microprocessor for use with another.

REFLECTION

Before you read the next section of this chapter, reflect on the task of designing and building a human-powered helicopter. Do you think this is possible? Do you think it has ever been done? How long could a human-powered helicopter stay aloft? What altitude could it reach? Make a sketch of how you think a human-powered helicopter would look.

2.3 CASE STUDY: HUMAN-POWERED HELICOPTER

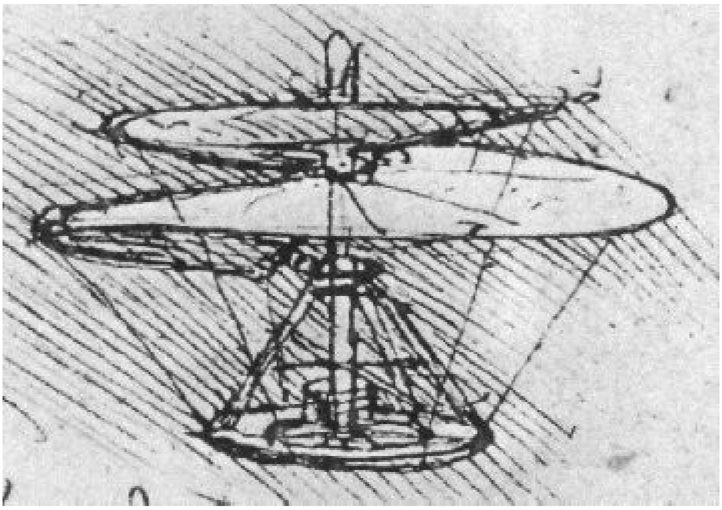
The eight steps of the engineering design process make most sense when they are seen in action. The following case study of the design, construction, and test of a human-powered helicopter by a team of faculty and students at the University of Maryland will enable you to see each step of the process at work.

STEP 1 - CUSTOMER NEED OR BUSINESS OPPORTUNITY

In 2008 a team of University of Maryland faculty and students was formed to try to win the American Helicopter Society's Igor I. Sikorsky Human-Powered Helicopter Prize.

The Sikorsky Prize was initially established in 1980 to promote fulfillment of the dream of human-powered hovering flight. A $250,000 cash award was pledged to the first team to fly a helicopter, under human power only, for at least 60 seconds, and reach an altitude of three meters above the ground momentarily during the flight without drifting outside of a ten-square-meter area.

In this case, the opportunity or need – the first step in the engineering design process – was created by the American Helicopter Society. (Information about the Sikorsky Prize can be found at: www.vtol.org/awards-and-contests/human-powered-helicopter.)



The idea of a human-powered helicopter was inspired more than 500 years ago by famous artist and inventor Leonardo Da Vinci's conceptual illustration of an "airscrew." Da Vinci's flying machine consisted of a 15-ft-diameter airscrew designed to be powered by four men. Although the machine was never built and could not have flown, Da Vinci's airscrew concept is the basis for the propellers used in propeller-driven aircraft and for rotors used in helicopters.

Because of the university's mascot, the Terrapin, the University of Maryland team took on the name *Gamera* from a giant flying turtle in Japanese horror movies.

The Gamera team was well aware that although several teams had attempted to win the Sikorsky Prize in the 32 years since it was established, none had been successful. Several human-powered helicopters had hovered for short times including the Da Vinci III (eight seconds) built by a team from Cal Poly San Luis Obispo in 1989 and the Yuri-I (19.5 seconds) built by a team from Nihon University in Japan in 1994.

Knowing that so few teams had even tried for the Sikorsky Prize and that those who did fell far short of the requirements for the prize made the challenge even more exciting for the Gamera team.

They also knew that a recent paper titled "On the Possibility of Human-Powered Vertical Flight" [4] had concluded that, under the most optimistic assumptions, "hovering … is in principle possible with a single crew member, provided that the rotorcraft has enough longitudinal and lateral stability." At least the task was theoretically possible!

Step 2 - Problem Definition/Specifications and Constraints

The primary design specifications, Step 2 of the engineering design process, were established by the regulations of the Sikorsky Human-Powered Helicopter Competition. They included the following requirements:

- Type of machine: Rotary wing capable of vertical takeoff and landing
- Vehicle size: No limitation
- Flight requirements: Hover for 60 seconds
- Altitude of flight: Exceed three meters momentarily
- Drift: A reference point on the non-rotating part of the machine stays within the confines of 10×10 meter square.
- Crew: No limitation on number. One member of crew shall be non-rotating.
- Power: Powered by crew during entire flight including accelerating rotor up to takeoff speed
- Control: Controlled by crew (No remote control)
- Energy storage devices: None permitted
- Lighter-than-air gases: Prohibited
- Jettison: No part of the machine shall be jettisoned nor any member of the crew leave the aircraft during flight.
- Ground conditions: Level ground (<1/100 slope)
- Air conditions: Still air (< 1 meter/sec)

For the Gamera team, these requirements led to additional problem definitions and specifications. Who would lead the team? What additional capabilities would need to be represented on the team? How much money would the project cost? How would it be financed? What facilities would be required? What would be the general configuration of the machine? What materials would be needed to fabricate it? What sort of manufacturing techniques would be needed? Could the vehicle be tested outdoors or would the capacity of available indoor facilities limit the size of the vehicle?

Step 3 - Data and Information Collection

The Gamera team realized it faced many daunting challenges. Before developing alternative designs, the team first had to collect extensive data and information – Step 3 of the engineering design process. They needed to learn the technologies associated with low-speed airfoil design, design of lightweight structures, rotor ground effects, vehicle stability, power transmission, and human power capability.

Valuable information could be obtained from reviewing the human-powered helicopter literature and from the experience of the Da Vinci III [5] and Yuri I [6] projects. Lessons could also be learned from the successful human-powered aircraft projects: the Gossamer Condor [7] and the Gossamer Albatross [8].

A major issue was ground effect. Ground effect is a well-known phenomenon in which rotorcraft experience an increase in performance when operating near the ground. Since no data existed for the large rotors and low rotation speeds expected for the Gamera I vehicle, a comprehensive research and test program was needed. The information from these studies would be key since ground effect would reduce the power required to produce a specific amount of lift by as much as 60 percent.

Extensive testing of both sub-scale and full-scale rotors was done to gain information needed to optimize the rotor blade designs. Variables examined included rotational speed, blade pitch, and height above the ground,

Other studies included pilot power production for various lengths of time from ten seconds to 60 seconds both with and without hand cranking.

Step 4 - Development of Alternative Designs

Once the team had collected sufficient basic data, it was time to move to Step 4 of the design process: developing alternative designs. In the design of the Gamera vehicle, many design tradeoffs had to be considered and many decisions had to be made. The team knew that the major component parts of a human-powered helicopter are:

- Rotors
- Airframe
- Cockpit
- Power transmission system
- Power plant (pilot)

The team faced many questions and design tradeoffs for each of these components.

ROTORS. For the rotors, many choices had to be made. How many rotors? What airfoil shape would be used for each rotor? What should be the radius of each rotor? The cord length? The angle of attack? Should the rotor blades be tapered and/or twisted? What would be the allowable weight of each rotor, and could that weight be achieved while still maintaining structural integrity? How stiff would each rotor need to be? What tip speed should the rotor operate at?

AIRFRAME. As the support for the rotors and the cockpit, the airframe needed to be as lightweight as possible while still maintaining structural integrity.

COCKPIT. The cockpit needed to be comfortable and structurally sound while being as lightweight as possible. It also needed to be able to accommodate pilots of different heights and weights.

POWER TRANSMISSION SYSTEM. Choices existed for the power transmission system as well. How would the power be transmitted from the pilot to the rotors? Would the power be generated by legs only or could arms be used as well? How should the power be transmitted from the pilot-side pulley to the rotor pulley? Choices might be chain drive, belt drive, shaft drive, or winch drive. What sizes should the pulleys be?

POWER PLANT (PILOT). One of the most important aspects of the project was the selection and training of the pilot. What would be the optimal weight of the pilot? How should the pilot be trained for maximum power output? How much power could be generated for five seconds? For 20 seconds? For 60 seconds? What would be the optimal RPM for the pilot to maximize power input?

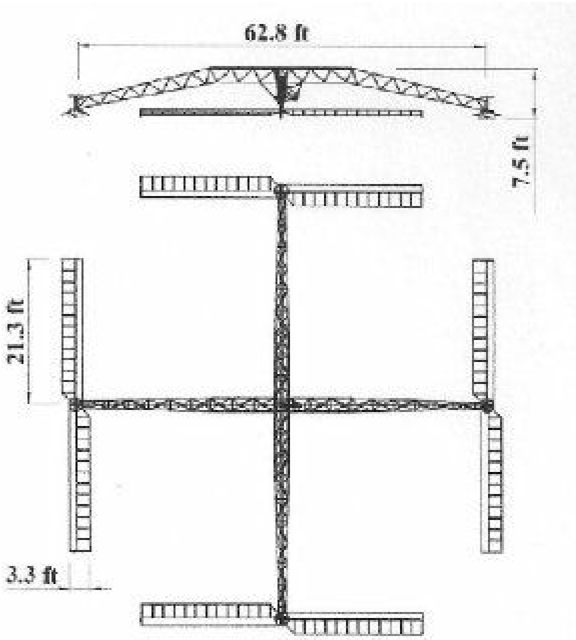
Coupled with optimizing the design for each component was the critical issue of how the components would be configured into an overall vehicle design.

Step 5 - Evaluation of Designs/Selection of Optimal Design

This is one of the most difficult, challenging, and time-consuming steps in the engineering design process. For many engineers, however, it is also the most interesting and rewarding one, for here is where ideas really begin to turn into reality.

A brief overview of the design decisions made by the Gamera team is presented here. You can find detailed discussion of the Gamera I design features in "Design and Development of Gamera: A Human Powered Helicopter from the University of Maryland" [9].

The first fundamental design decision made was that the vehicle would be a quadrotor helicopter with an airframe consisting of interconnecting trusses and a cockpit. As indicated by the diagram, the Gamera I design consisted of an X-shaped fuselage frame spanning 63 ft. At the terminus of each end of the frame resides a 42.6-ft-long rotor.



Overall vehicle design weight was selected to be 101 pounds broken down by components as follows:

Rotor blades – 55%

Airframe – 30%

Transmission – 6%

Cockpit – 9%

The airframe design consisted of four 31.4-ft lightweight trusses. The allowable design weight of eight pounds for each truss was to be achieved using unidirectional carbon fiber tubes. Significant analysis and testing of one-third scale models of the truss configuration were conducted to ensure adequate stiffness and resistance to buckling.

The four rotors were designed to the following specifications:

Airfoil: Eppler387

Rotor radius: 21.3 ft.

Chord: 3.3 ft.

Taper: None

Weight (Eight rotor blades): 58.3 lbs.

Design speed: 17-18 RPM

Design weight for the cockpit was set at 9.5 lbs. The cockpit design consisted of three stiff, 2-D trusses (see photo) connecting the seat, hand cranks, and foot cranks to the airframe structure at three nodes.

Power from the pilot would be transferred to the rotors via hand and foot pedals in the cockpit suspended beneath the aircraft structure. A string drive system, similar to a rod and reel, was chosen based on low weight and high efficiency. A high strength fiber line wound around each rotor pulley was "reeled in" to the pilot pulley through the foot cranks and hand cranks.

Through tradeoff studies, the pilot design weight was selected to be 107 pounds. Testing indicated that a pilot of that weight could generate 0.79 hp (590 watts) for a 10-second flight and 0.76 hp (565 watts) for a 20-second flight.

Step 6 - Implementation of Optimal Design

Once the design phase was completed there was no time to waste. The Gamera team was well aware that other teams were chasing the Sikorsky Prize, including the formidable AeroVelo team from Canada.

The fabrication and construction of a 101-pound vehicle that would fill a gymnasium brought significant challenges. Because of the size of the vehicle, components had to be modular and easily assembled on site. Due to the fragile nature of each component, backup parts were needed.

Particular care needed to be taken in constructing the eight 7.4-pound rotors because they represented a significant portion (55 percent) of the vehicle weight. Building the 10.6-ft-long rotors with spars made of trusses of carbon fiber composite material, polystyrene foam, and balsa strips, and covered by a lightweight Mylar film took significant time and handiwork.

The four trusses comprising the airframe were made from "microtrusses" in which spindles of carbon fiber were wrapped around a truss of three carbon-fiber rods. Fabrication of the airframe required intricate handwork, which introduced the potential for human error, so great care was required to prevent unexpected failures.

Finally, the cockpit and power transmission system were constructed. The cockpit consisted of stiff, 2-D planar trusses and foot pedals and cranks for delivering the power to the rotors. The rotor side pulleys were made of an expanded polystyrene foam core with four poles reinforced with carbon composite rods (see photo on the right).

Step 7 - Test and Evaluation of Gamera I

On May 11, 2011, almost three years in the making, the Gamera I vehicle was finally ready for testing. The pilot was 24-year-old University of Maryland life sciences graduate student Judy Wexler. She would have to generate sustained power approaching 0.75 hp.

First, three test runs were made in which the rotors were brought up to the design speed of 18 RPM without liftoff. Finally, it was time to attempt liftoff: The aircraft became airborne a few inches above the ground for at least four seconds, and the flight was the first ever by a woman.

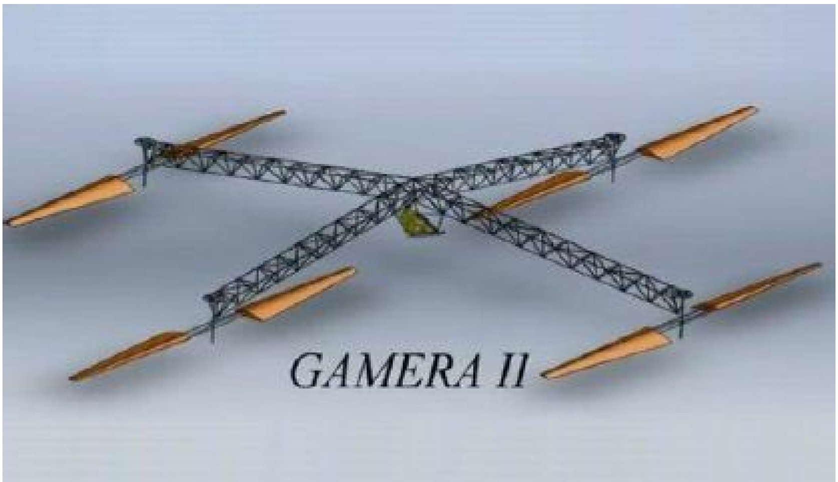
A few weeks later, on July 13, the Gamera I (again piloted by

Wexler) flew in controlled hover for 11.4 seconds. The attempt set a new United States record for flight duration. The team was awarded the Igor I. Sikorsky International Trophy from American Helicopter Society. Successful Gamera I flights can be viewed at www.YouTube.com/watch?v=n-qFhcL9mg4.

The project was deemed a huge success. Records had been set, and Gamera I was the first human-powered helicopter to lift off in more than 17 years. However, it became clear through observations of the vehicle dynamics and pilot fatigue that Gamera I was not capable of achieving the flight conditions required for the Sikorsky Prize, and the vehicle was retired.

Step 8 - Redesign

The Gamera team knew winning the Sikorsky Prize would require improved performance, so they immediately set about re-designing the vehicle toward that end. The Gamera II project was born.



The team would benefit from the many lessons learned in the design, construction, and testing of Gamera I.

The same overall quadrotor layout of Gamera I was retained due to familiarity with the design and the stability it offered. The four rotor diameters were kept at 13 meters (due to the space limitation of indoor testing locations).

Substantial improvements were made in vehicle weight. The rotor weight was reduced from 58 pounds to 35 pounds, and the airframe truss weight was reduced from 32 pounds to 19 pounds using specially developed micro-truss members and improved manufacturing techniques.

The rotor blades were redesigned with a thicker Selig S8037 airfoil, and a 3:1 taper was incorporated. These improvements reduced bending deflections of the rotor blades, which increased the ground effect (and hence reduced the power needed to hover) and reduced the danger of the rotor blades striking the airframe structure overhead.

Pilot recruiting and training were expanded. A fly-wheel was added to smooth the power delivery and structural improvements were made to the cockpit to improve power transfer from the pilot to the rotors.

On June 21, 2012, the Gamera II vehicle piloted by Maryland mechanical engineering graduate student Kyle Gluesenkamp set a world record for flight duration of 49.9 seconds. Several weeks later a record height of eight feet was reached for a shorter time.

However, on September 1, 2012, the Gamera II crashed after momentarily reaching a record altitude of 9.4 feet, just five inches below the 9.84 feet required for the Sikorsky Prize. You can view all of the major Gamera II flights at www.YouTube.com (Search under "Gamera II"). You can read more about the Gamera I and Gamera II projects in a number of excellent papers written by University of Maryland students and faculty [10, 11].

Whether the Gamera team (or any other team) will have won the Sikorsky Prize by the time you read this is anybody's guess. As the team learned, flying a human-powered helicopter for 60 seconds to a momentary height of three meters while staying in a 10 × 10 meter area is no easy task.

THE NEEDS AND OPPORTUNITIES FOR ENGINEERING DESIGN ARE BOUNDLESS

The purpose of chronicling the University of Maryland's human-powered helicopter project was to illustrate the engineering design process in action. Now that you have seen the logic and demand that each step of the process entails, you should easily be able to come up with a list of many other problems, needs, and opportunities that would suit its step-by-step approach. Here are just a few ideas that occurred to me. What ideas would you add to this list? Remember, it is entirely possible that, down the road, you will be the engineer who turns one of these needs into reality:

- A device carried by a police officer that would detect a bullet fired at the officer and intercept it
- A device that would mark the precise location of a football when

the referee blows the whistle
- A fail-safe system that prevents an automobile from being stolen
- A device that would program a DVR to skip the commercials while taping your favorite TV show
- A machine that would serve ping-pong balls at different speeds and with different spins
- A device that identifies vehicles that are carrying explosives
- A car alarm that goes off if the driver falls asleep.
- An in-the-ground, AC-powered sound/vibration emitter to repel gophers
- A device that cuts copper tubing in tight places
- An in-home composting and recycling system that eliminates the need for sewer or septic systems
- A device that prevents elderly people from being injured when they fall down
- A portable solar-charged lamp that can provide two hours of reading light
- Software that turns your computer monitor into a mirror
- A travel toothbrush with toothpaste dispenser attached
- A cordless hairdryer that can be used when camping
- An affordable, fuel-cell-powered automobile that only emits water vapor
- A system that continues to tape your favorite morning radio program after you arrive at work so you can listen to it on the way home
- A high-rise building with an "active suspension system" that responds to ground movement (earthquakes)

REFLECTION

Think about "customer needs and business opportunities" for each of the engineering design ideas listed above. Could you get excited about working on any of those items? Could you add to this list by thinking of something that would improve the quality of life that is not currently available?

2.4 REWARDS AND OPPORTUNITIES OF AN ENGINEERING CAREER

Engineering is a unique and highly selective profession. Among the 128 million people employed in the United States, only about 1.5 million (1.2 percent) list engineering as their primary occupation [12]. This means the overwhelming majority of people employed in this country do something **other than engineering**.

These employment figures are reflected by national higher-education statistics. Engineering typically represents less than five percent of college graduates, as the following table shows [13]:

Major	Number of 2009/10 College Graduates	Percent of Total
Business	358,293	21.7%
Social Sciences	172,780	10.5%
Health Professions	129,634	7.9%
Science and Mathematics	125,809	7.6%
Education	101,265	6.1%
Psychology	97,216	5.9%
Visual and Performing Arts	91,802	5.6%
Communication Studies	81,266	4.9%
Engineering	**72,654**	**4.4%**
TOTAL	1,650,014	100.0%

So why choose to study engineering? Why strive to become one of those 4.4 percent of college graduates who receive their B.S. degree in engineering? I'll tell you why. **Job satisfaction!**

Job Satisfaction – An Overarching Issue

What would you say is the number one cause of unhappiness among people in the United States? Health problems? Family problems? Financial problems? No. Studies have shown that, by far, the number one cause of unhappiness among people in the U.S. is **job dissatisfaction**. Furthermore, Americans are growing increasingly unhappy with their jobs. A study conducted in 2012 for the Conference Board, a leading business membership and research organization, indicated that only 47.2 percent of all Americans are satisfied with their jobs, down from 61 percent in 1987 [14].

Do you know people who dislike their job? People who get up every morning and wish they didn't have to go to work? People who watch the clock all day and can't wait until their workday is over? People who look forward to Fridays and dread Mondays? People who work only to earn an income so they can enjoy their time off? Maybe you have been in one of these situations. Lots of people are.

Throughout my career, it has been very important to me to enjoy my work. After all, I spend eight hours or more a day, five days a week, 50 weeks a year, for 30 or 40 years working. This represents about 40 percent of my waking time. Which would you prefer? Spending 40 percent of your life in a career (or series of jobs) you despise? Or spending that 40 percent in a career you enjoy and love? I'm sure you can see why it is extremely important to find a life's work that is satisfying, work that you want to do.

Engineering could very well be that life's work. It certainly has been for me and for many of my colleagues over the years. But what exactly does "job satisfaction" mean?

What is it about engineering that is so satisfying? My personal "Top

Ten List" of the personal and career rewards of an engineering career is presented below. Although your list may differ from mine, I am going to discuss each briefly – if only to help you realize more fully the many rewards, benefits, and opportunities an engineering career holds for you.

Ray's Top Ten List

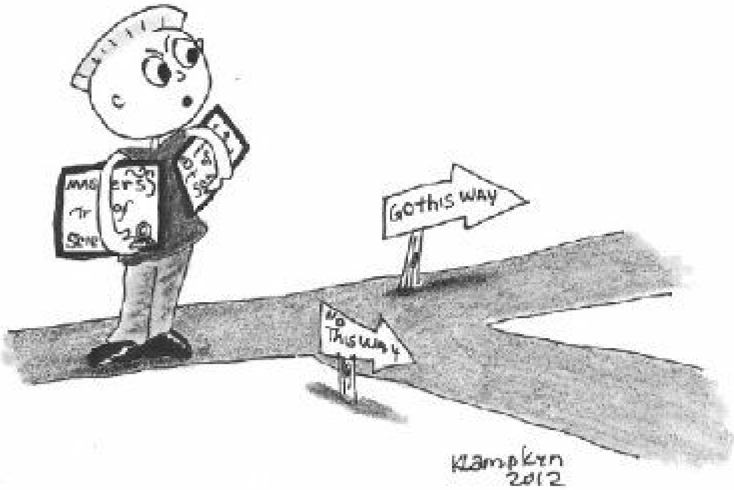
1. Varied Opportunities
2. Challenging Work
3. Intellectual Development
4. Social Impact
5. Financial Security
6. Prestige
7. Professional Environment
8. Understanding How Things Work
9. Creative Thinking
10. Self-Esteem

After studying my list and developing your own, hopefully you will find yourself more determined to complete your engineering studies. You may also find yourself somewhat puzzled by the skewed statistics that opened this section. With so many benefits and job opportunities a career in engineering promises, you'd think that college students would be declaring engineering majors in droves.

I guess engineering really is a unique and highly selective profession. Consider yourself lucky to be one of the "chosen few."

1. Varied Opportunities

While the major purpose of this chapter is to help you understand the engineering profession, you have just skimmed the surface thus far. Your introduction to the engineering field has largely been a "functional" one, starting with the idea that engineering is the process of "turning dreams into reality," followed by a detailed look at the engineering design process: more function.



As you'll learn subsequently, engineering entails much more than just functions governed by a rigid eight-step design process. I like to think of engineering as a field that touches almost every aspect of a person's life. I often point out to students that the day you walk up the aisle to receive your degree in engineering, you have closed no doors. **There is nothing you cannot become from that time forward!** Doctor. Lawyer. Politician. Teacher. Astronaut. Entrepreneur. Manager. Salesperson. Practicing engineer. All these and many others career opportunities are possible.

Here are examples of people educated as engineers and the professions they ended up in:

ENGINEER	**PROFESSION**
Neil Armstrong	Astronaut/First Person on Moon
Herbert Hoover	President of the United States
Jimmy Carter	President of the United States
Alfred Hitchcock	Film Director/Producer
Eleanor Baum	First Woman Dean of Engineering
Herbie Hancock	Jazz Musician
Frank Capra	American Film Director
Paul MacCready	Inventor/Winner of Kremer Prize
Ellen Ochoa	Space Shuttle Astronaut
Hyman G. Rickover	Father of the Nuclear Navy

Bill Nye	Host of TV Show “Bill Nye, The Science Guy”
Boris Yeltsin	President of Russia
Alexander Calder	Sculptor
Bill Koch	Yachtsman/Captain of America Cup Team
W. Edwards Deming	Father of Modern Management Practice (TQM)
Grace Murray Hopper	U.S. Navy Rear Admiral/Computer Engineer
Ming Tsai	Restaurateur and Star on TV’s Food Network
Hu Jintao	President of the People’s Republic of China
Montel Williams	Syndicated Talk Show Host
John H. Sununu	Political Pundit/Governor of New Hampshire
Samuel Bodman	U.S. Secretary of Energy
Donald Thompson	CEO and President, McDonald’s Corp.
Rowan Atkinson	British Actor/Comedian/Screenwriter
Rudolph Diesel	Inventor of the Diesel Engine
Michael Bloomberg	Billionaire/Mayor of New York City
Lonnie G. Johnson	Inventor (SuperSoaker®)
A. Scott Crossfield	X-15 Test Pilot
Don Louis A. Ferre	Governor of Puerto Rico
Yasser Arafat	Palestinian Leader/Nobel Peace Prize Laureate
Tom Landry	Dallas Cowboys’ Head Coach
Igor Sikorsky	Inventor of Single Rotor Helicopter
Mohamed Morsi	President of Egypt
Shiela Widnall	Secretary of the Air Force
David A. Wolf	Astronaut/Medical Doctor/Electrical Engineer
Robert A. Moog	Father of Synthetic Music
Chester Carlson	Inventor of Xerox Process
John A. McCone	Director of Central Intelligence Agency
Arthur C. Nielsen	Developer of Nielsen TV Ratings

Although none of the above individuals ended up working as a practicing engineer, I expect they would all tell you that their engineering education was a key factor in their subsequent successes. You can learn more about these and other famous “engineers” from these websites: www.sinc.sunysb.edu/Stu/hnaseer/interest.htm and www.engology.com/engpg5profiles.htm

Personal Story

When I was an engineering student, I had no idea that the career path I have taken even existed. After completing my B.S. and M.S. degrees in Mechanical Engineering at MIT, I worked for five years as a practicing engineer at Rocketdyne, a Division of Rockwell International. Through part-time teaching to supplement my salary, I developed an interest in an academic career and was offered a position on the engineering faculty at California State University, Northridge.

Although I enjoyed teaching, my interests shifted more to administration and working with students outside of the classroom. I started the first Minority Engineering Program in California and directed it for ten years. The administrative and management experience I gained led me to the position of Dean of Engineering.

My engineering career thus evolved from practicing engineering to teaching it; from teaching it to creating and directing a special program for minority engineering students; and finally from directing a program to managing an entire engineering college.

Within engineering practice itself there is an enormous diversity of job functions. There are analytical engineers, design engineers, test engineers, development engineers, sales engineers, and field service engineers. The work of analytical engineers most closely resembles the mathematical modeling of physical problems you do in school. But only about ten percent of all engineers fall into this category, pointing to the fact that engineering *study* and engineering *work* can be quite different.

- If you are imaginative and creative, **design engineering** may be for you.
- If you like working in laboratories and conducting experiments, you

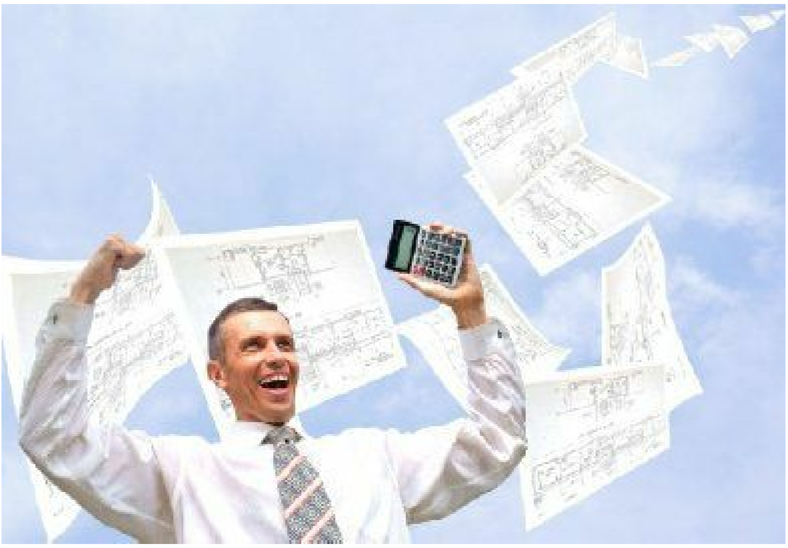
might consider **test engineering**.

- If you like to organize and expedite projects, look into becoming a **development engineer**.
- If you are persuasive and like working with people, **sales or field service engineering** may be for you.

Later in this chapter, we will examine the wide variety of engineering job functions in more detail. Then, in Chapter 8, we will explore less traditional career paths for which engineering study is excellent preparation, such as medicine, law, and business.

2. Challenging Work

Do you like intellectual stimulation? Do you enjoy tackling challenging problems? If so, you'll get plenty of both in engineering. Certainly, during your period as an engineering student, you will face many challenging problems. But, as the saying goes, "you ain't seen nothing yet." When you graduate you'll enter the engineering work world, where there is no shortage of challenging, open-ended problems.

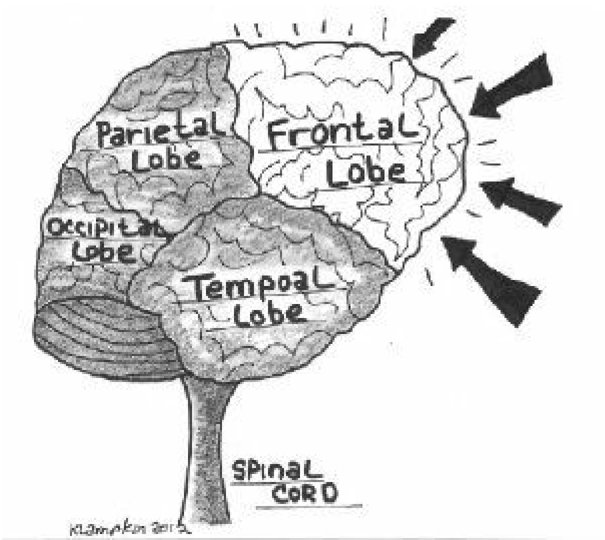


By "open-ended," I mean there is rarely one "correct" solution, unlike many of the problems you are assigned in school. Open-ended problems typically generate many possible solutions, all of which equally meet the required specifications. Your job is to select the "best" one of these and then convince others that your choice is indeed the optimal one.

It certainly would be helpful if you had more exposure to open-ended problems in school. But such problems are difficult for professors to create, take more time for students to solve, and are excessively time-consuming to grade. Regardless, however, of the kind of problem you are assigned (open-ended or single answer, in school or the engineering work-world), they all challenge your knowledge, creativity, and problem-solving skills. If such challenges appeal to you, then engineering could be a very rewarding career.

3. Intellectual Development

Engineering education exercises your brain much the way weight-lifting or aerobics exercises your body – and the results are remarkably similar. The only difference is that physical exercise improves your body, while mental exercise improves your mind. As your engineering studies progress your abilities to solve problems and think critically will grow stronger.



This connection between mental exercise and growth is by no means "news" to educators. But recent research in the cognitive sciences has uncovered knowledge that explains how and why this process works [15]. We now know, for example, that the brain is made up of as many as 180 billion neuron cells. Each neuron has a very large number of tentacle-like protrusions called dendrites. The dendrites make it possible for each neuron to receive signals (synapses) from thousands of neighboring neurons. The extent of these neural networks is determined in large part by the demands we place on our brains – i.e., the “calisthenics” we require of them. So the next time your find yourself reluctant to do a homework assignment or study for a test, just think of all those neural networks you could be building.

One of the things I value most about my engineering education is that it has developed my logical thinking ability. I have a great deal of confidence in my ability to deal effectively with problems. And this is not limited to engineering problems. I am able to use the critical thinking and problem-solving skills I developed through my engineering education to take on such varied tasks as planning a vacation, searching for a job, dealing with my car breaking down in the desert, organizing a banquet to raise money, purchasing a new home, or writing this book. I’m sure you also will come to value the role your engineering education plays in your intellectual growth.

4. Social Impact

I hope you are motivated by a need to do something worthwhile in your career: something to benefit society. Engineering can certainly be an excellent career choice to fulfill such humanitarian goals.

The truth is, just about everything engineers do benefits society in some way. Engineers develop transportation systems that help people and products move about so easily. Engineers design the buildings we live and work in. Engineers devise the systems that deliver our water and electricity, design the machinery that produces our food, and develop the medical equipment that keeps us healthy. Almost everything we use was made possible by engineers.

Depending on your value system, you may not view <u>all</u> engineering work as benefiting people. Some engineers, for example, design military equipment like missiles, tanks, bombs, artillery, and fighter airplanes. Others are involved in the production of pesticides, cigarettes, liquor, fluorocarbons, and asbestos. As an engineer, you will need to weigh the merits of such engineering functions and make your career choices accordingly.

My view is that engineering holds many more beneficial outcomes for society than detrimental ones. For example, opportunities exist for engineers to use their expertise in projects designed to clean up the environment, develop prosthetic aids, develop clean and efficient transportation systems, find new sources of energy, solve the world's hunger problems, and improve the standard of living in underdeveloped countries.

5. Financial Security

When I ask a class of students to list the rewards and opportunities that success in engineering study will bring them, money is almost always number one. In my "Top Ten List," it's number five. It's not that engineers don't make good money. They do! It's just that money is not a primary motivator of mine.

I've always held the view that if you choose something you like doing, work hard at it, and do it well, the money will take care of itself. In my case, it has. Of course, you may discount my philosophy because of my credentials and career successes. But remember, my engineering career began much the same way yours will: working in industry as a practicing engineer. My subsequent career moves, however, were never motivated by money alone.

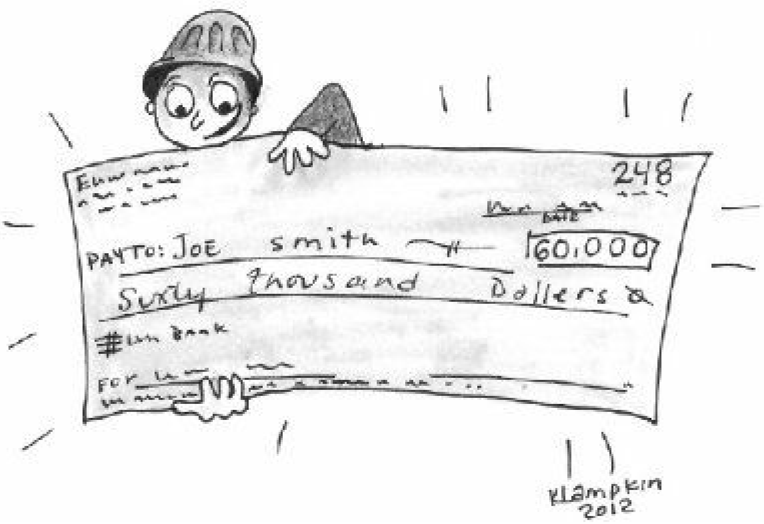
I hope you too don't make money your primary reason for becoming an engineer. Other reasons, like challenging work, intellectual development, and opportunities to benefit society hopefully will prove to be more important factors. If they are, you will find the quality of your life enriched tremendously. And I guarantee the money will take care of itself, as it has for me.

Let's not lose sight of reality, however. If you do become an engineer, **you will be rewarded financially**. Engineers, even in entry-level positions, are well paid. In fact, engineering graduates receive the highest starting salary of any discipline, as shown in the data below for 2012 graduates [16].

Beginning Offers to 2012 Bachelor's Degree Graduates

Discipline	Avg. Salary
Engineering	**$60,639**
Computer Sciences	60,038
Business	51,541
Health Sciences (including Nursing)	46,567
Mathematics and Sciences	42,355
Communications	42,286
Education	39,080
Humanities & Social Sciences	36,319
Average for All Disciplines	**$44,259**

As indicated, the $60,639 average starting salary for 2012 engineering graduates is 37 percent higher than the $44,259 average starting salary for all bachelor's degree graduates.



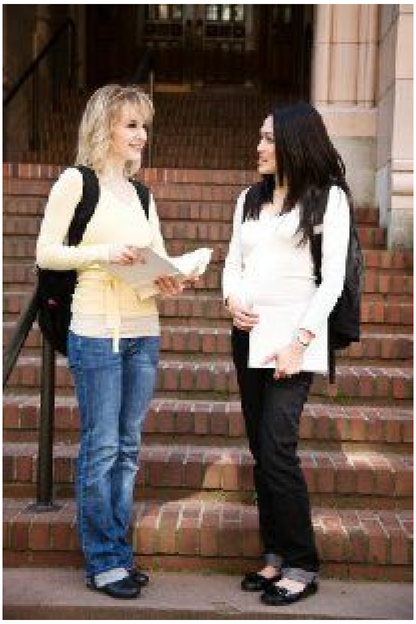
If the starting salary data has not convinced you that engineering is a financially rewarding career, perhaps you will be convinced by the fact that many of the world's wealthiest people started their careers with a degree in engineering. You will find a listing of some of these people in Appendix C. As reported by *Forbes Magazine* [17], the personal wealth of these individuals ranges from a high of $69 billion down to $5.3 billion. I hope this brings the idea home that "the sky is the limit."

EXERCISE

Pick one of the 30 individuals listed in Appendix C among the world's wealthiest engineers. Find out as much as you can about the person by googling his or her name. What was their engineering discipline in college? What did they do early in their career? How did they become so wealthy? What lessons can you learn from their success?

6. PRESTIGE

What is *prestige*? The dictionary defines it as "the power to command admiration or esteem," usually derived from one's social status, achievements, or profession. Engineering, both as a field of study and a profession, confers prestige. You may have already experienced the prestige associated with being an engineering major. Perhaps you have stopped on campus to talk with another student and during the conversation, he or she asked, "What's your major?" What reaction did you get when you said, "Engineering"? Probably one of respect, awe, or even envy. To non-engineering majors, engineering students are "the really smart, studious ones." Then, if you reciprocated by asking about that student's major, you may wish you hadn't after getting an apologetic response like, "I'm still undecided."



This hypothetical conversation between an engineering and non-engineering student is not far-fetched. In fact, variations of it take place all the time. Everyone knows that engineering study requires hard work, so people assume you must be a serious, highly capable student.

I often ask students to name a profession that is more prestigious than engineering. Medicine always comes up first. I tend to agree. Physicians are well paid and highly respected for their knowledge and commitment to helping people live long and healthy lives. So if you think you want to be a medical doctor and have the ability, arrange to meet with a pre-med advisor as soon as possible and get started on your program. I certainly want to have the most capable people as my doctors.

After medicine, law and accounting are typically cited as more prestigious professions than engineering. Here, however, I disagree, arguing against these and **every other profession** as conferring more prestige than engineering. Anyone who knows anything about engineering would agree that engineers play critical, ubiquitous roles in sustaining our country's international competitiveness, in maintaining our standard of living, in ensuring a strong national security, in improving our health, and in protecting public safety. I can't think of any other profession that affects our lives in so many vital, significant ways.

Engineers are critical to our:

International competitiveness

Standard of living

National security

Personal health

Public safety

7. Professional Work Environment

Although engineers can perform a variety of functions and work in many different settings, most new engineering graduates are hired into entry-level positions in "hi-tech" companies. While the nature of your work and status within the company may quickly change, there are certain standard characteristics of all professional engineering work environments.

For one, you will be treated with respect – both by your engineering colleagues and by other professionals. With this respect will come a certain amount of freedom in choosing your work and, increasingly, you will be in a position to influence the directions taken by your organization.

As a professional, you also will be provided with adequate workspace, along with whatever equipment and staff support you need to get your work done.

Another feature of the engineering work environment is the number of opportunities you will have to enhance your knowledge, skills, self-confidence, and overall ethos as a professional engineer. Experienced engineers and managers know that new engineering graduates need help in making the transition from college to the "real world." From the outset, then, your immediate supervisor will closely mentor you, giving you the time and guidance to make you feel at home in your new environment. Your supervisor will carefully oversee your work assignments, giving you progressively more challenging tasks and teaming you with experienced engineers who will teach you about engineering and the corporate world.

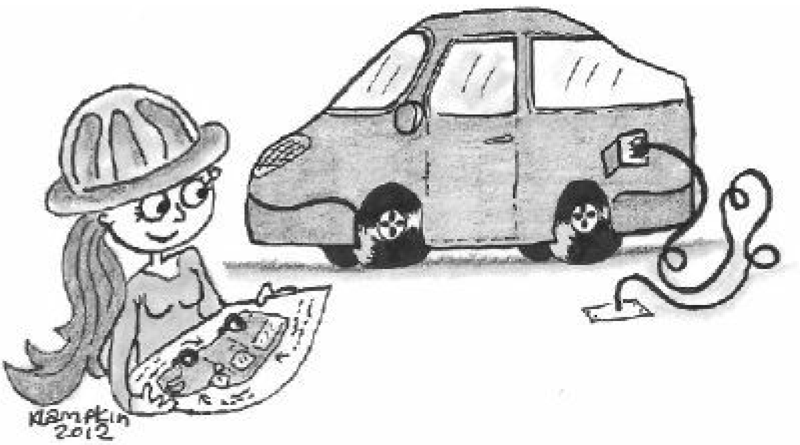
Once you are acclimated to your position, your company will see to it that your engineering education and professional development continue. You will frequently be sent to seminars and short courses on a variety of topics, from new engineering methods to interpersonal communications. You may be given a travel allotment so you can attend regional or national meetings of professional engineering societies. You also may discover that your company has a reimbursement program to pay your tuition and fees for courses at a local university for professional development or graduate education.

You can expect yearly formal assessments of your performance, judged on the merits of your contributions to the company. As a professional, you will not be required to punch a clock, for your superiors will be more concerned about the quality of your work, not your "time-on-tasks." If you have performed well, you can usually expect a salary increase, plus other bonuses for a job particularly well done. Promotions to higher positions are another possibility, although they generally have to be earned over an extended period of time.

Finally, as a professional, you will receive liberal benefits, which typically include a retirement plan, life insurance, medical and dental insurance, sick leave, paid vacations and holidays, and savings or profit-sharing plans.

8. Understanding How Things Work

Do you know why golf balls have dimples on them? Do you understand how the loads are transmitted to the supports on a suspension bridge? Do you know what nanotechnology is? How optical storage devices work? How fuel cells work? When you drive on a mountain road, do you understand why the guard rails are designed the way they are? Do you know why split-level houses experience more damage in earthquakes? Do you know why we use alternating current (AC) rather than direct current (DC)? One of the most valuable outcomes of my engineering education is understanding how things around me work.



Furthermore, there are many issues facing our society that depend on an understanding of technology. Why are there so few zero-emission electric vehicles rather than cars powered by highly polluting internal combustion engines? Should we stop building nuclear reactors? Will we be ready to tap alternate energy sources when the earth’s supply of oil becomes prohibitively costly or runs out?

Should we have supersonic aircraft, high-speed trains, and automated highways? Is it technically feasible to develop a "Star Wars" defense system that will protect us against nuclear attacks? Why are the Japanese building higher quality automobiles than we are? Can we produce enough food to eliminate world hunger? Do high-voltage power lines cause cancer in people who live near them?

Your engineering education will equip you to understand the world around you and to develop informed views regarding important social, political, and economic issues facing our nation and the world. Who knows? Maybe this understanding will lead you into politics.

9. Creative Thinking

Engineering is by its very nature a creative profession. The word "engineer" comes from the same Latin word *ingenium* as the words "genius" and "ingenious." This etymological connection is no accident: Engineers have limitless opportunities to be ingenious, inventive, and creative. In the next section, we will talk about engineering in the past by listing the "Greatest Engineering Achievements of the 20th Century." You can be sure that creativity played a major role in each of these achievements.

Sometimes new engineering students have difficulty linking "creativity" with "engineering." That's because, at first glance, the terms are likely to invoke their stereotypical connections: "creativity" with art; "engineering" with math, science, and problem solving. The truth, though, is that creativity is an essential ingredient of engineering. Consider, for example, the following definition of "creativity" from *Creative Problem Solving and Engineering Design* [18]:

This is just what engineers do. In fact, this definition of "creativity" could almost be a definition of "engineering."

Playing with imagination and possibilities while interacting with ideas, people, and the environment, thus leading to new and meaningful connections and outcomes

To experienced engineers who regularly engage in solving open-ended, real-world problems, the need for creativity in the engineering process is a given. Creativity is particularly important, for example, during Steps 4, 5, and 6 of the engineering design process described in Section 2.2, which involve developing and evaluating alternative solutions, followed selecting the best one. Without an injection of creativity in these steps, the actual best solution may be overlooked entirely.

However, these are not the only steps of the engineering design process that involve creativity. Indeed, creativity enters into <u>every</u> step of the process. It would be a good exercise for you to review the eight steps of the engineering design process to see how creativity can come into play at each step.

Beyond the engineering process itself, the need for engineers to think creatively is greater now than ever before, because we are in a time when the rate of social and technological changes has greatly accelerated. Only through creativity can we cope with and adapt to these changes. If you like to question, explore, invent, discover, and create, then engineering would be an ideal profession for you.

A wonderful place to explore the way human creativity in

art, technology, and ideas has shaped our culture is The Engines of Our Ingenuity web page: www.uh.edu/engines. There you will find the text of more than 2,800 episodes originally presented on National Public Radio for more than two decades by John Lienhard, professor of mechanical engineering at the University of Houston.

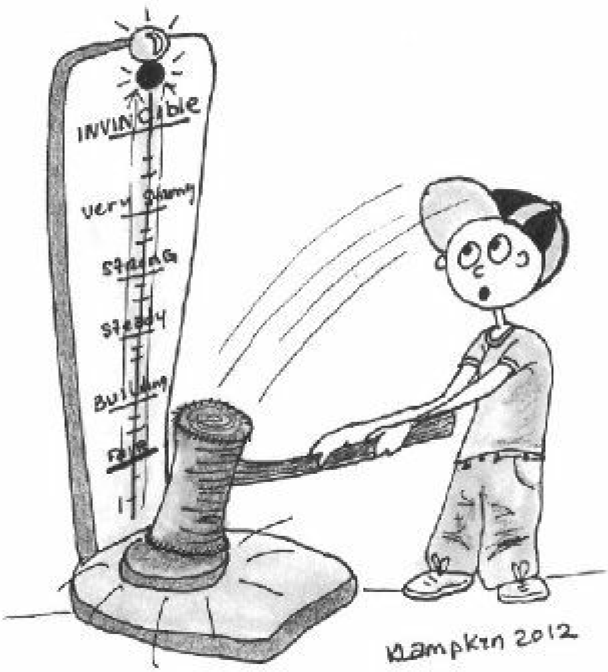
10. Self-Esteem

Self-esteem is a critically important factor in virtually every aspect of our life. It influences what we choose to do, how we treat others, and whether we are happy or not. In Chapter 6 we will discuss self-esteem as a fundamental human need.

As you will learn, self-esteem is made up of two interrelated components:

Self-efficacy - your sense of competence

Self-respect - your sense of personal worth



Through your career, you will have a unique opportunity to enhance your self-esteem by building your self-efficacy <u>and</u> your self-respect.

As you gain experience, you will become more knowledgeable and more technically competent. Your ability to think both critically and creatively will improve. Your communication skills will strengthen, as will your effectiveness in working on teams.

Additionally, your understanding of engineering and information technology fundamentals will grow. All of these gains will increase your confidence to excel in your work and achieve whatever goals you set for yourself. Through this process, you will build your self-efficacy.

You will have ample opportunities to build your self-respect as well. Success on the job will bring positive feedback from your managers and your colleagues. More tangible rewards such as challenging work assignments, leadership roles, and merit salary increases will be yours.

More importantly you will benefit from the satisfaction of doing a good job on projects that will make a difference in the world. You may have opportunities to write papers on your work and present them at local, regional, or national conferences. These accomplishments will be respected by others and will enhance your sense of self-worth.

REFLECTION

Review my top ten list of rewards and opportunities that will come to you if you are successful in getting your engineering degree. Which item on the list is most important to you? Money? Prestige? Challenging work? Making a difference in the world? Reflect on the one you chose. Why did you choose it? Why is that one so important to you?

2.5 ENGINEERING PAST - *GREATEST ENGINEERING ACHIEVEMENTS OF THE 20TH CENTURY*

Although engineering achievements have contributed to the quality of human life for more than 5,000 years [19], the 20th century stands out for its remarkable engineering progress and innovation. In recognition of this, as we entered the 21st century, the National Academy of Engineering launched a project to select the 20 “Greatest Engineering Achievements of the 20th Century.”

The primary selection criterion was the impact of engineering achievements on the quality of life in the 20th century. William A. Wulf, president of the National Academy of Engineering, summed it up well:

> ***<u>Engineering</u> is all around us, so people often take it for granted, like air and water. Ask yourself, what do I touch that is not engineered? Engineering develops and delivers consumer goods, builds the networks of highways, air and rail travel, and the Internet; mass produces antibiotics; creates artificial heart valves; builds lasers; and offers such wonders as imaging technology and conveniences like microwave ovens and compact discs. In short, engineers make our quality of life possible.***

Following are the “Greatest Engineering Achievements,” presented by Neil Armstrong at the National Press Club in Washington, D.C., on February 22, 2000:

#20 - High Performance Materials
#19 - Nuclear Technologies
#18 - Laser and Fiber Optics
#17 - Petroleum and Gas Technologies
#16 - Health Technologies
#15 - Household Appliances
#14 - Imaging Technologies
#13 - Internet
#12 - Space Exploration
#11 - Interstate Highways
#10 - Air Conditioning and Refrigeration
#9 - Telephones

#8 - Computers
#7 - Agricultural Mechanization
#6 - Radio and Television
#5 - Electronics
#4 - Safe and Abundant Water
#3 - Airplanes
#2 - Automobiles
#1 - Electrification

Brief descriptions of each are presented in Appendix D. Detailed descriptions of each great achievement can be found on the web at www.greatachievements.org and also in an excellent book titled *A Century of Innovation: Twenty Engineering Achievements that Transformed Our Lives* [1].

REFLECTION

Review the "Greatest Engineering Achievements of the 20th Century." How important are each of these achievements to the quality of our lives? Think about the role of engineers in each of these achievements. Do you think engineers get the credit they deserve for making our lives better? If you don't think they do, why do you think that is?

2.6 ENGINEERING DISCIPLINES

At this point you should have a general understanding of what engineering is and what engineers do – along, of course, with the many rewards and opportunities that engineering offers. Our goal in the remainder of this chapter is to clarify and broaden that understanding. We'll start by looking at engineering from a new perspective: how engineers can be classified by their academic discipline.

Until recently, engineering has consisted of five major disciplines, which graduate the largest number of students. In rank order, these disciplines are:

- **Mechanical engineering**
- **Electrical engineering**
- **Civil engineering**
- **Chemical engineering**
- **Industrial engineering**

A sixth discipline, **computer engineering**, has now been added to this list as has the rapidly growing disciplines of **bioengineering and biomedical engineering,** which as a combined field has passed up industrial engineering as the fifth largest discipline.

Initially a subspecialty within electrical engineering (and still organized that way at many institutions), computer engineering has grown so quickly that institutions are increasingly offering separate accredited B.S. degrees in this field. (Given these changes, computer engineering is treated separately in the discussion of engineering disciplines in Appendix E.)

In addition to the largest traditional disciplines, there are many other more specialized, non-traditional fields of engineering. Aerospace engineering, materials engineering, ocean engineering, petroleum engineering, mining engineering, nuclear engineering, and manufacturing engineering are examples of these.

The following table shows the number of accredited programs in each engineering discipline and degrees awarded in 2010/11 in that discipline. You might note that two-thirds of the B.S. degrees awarded were in electrical (including computer), mechanical, and civil engineering.

To find out which of these engineering programs are offered at each of the 389 institutions in the U.S. that have at least one accredited engineering program, visit the Accreditation Board for Engineering and Technology website at: main.abet.org/aps/accreditedprogramsearch.aspx. There you can search for listings of accredited engineering programs by discipline (e.g., electrical, mechanical, civil, etc.) and by geographical location (region or state).

An overview of each engineering discipline is presented in Appendix

E. For the top eight disciplines, more information is provided, while the smaller disciplines are given briefer descriptions.

The page number where you will find the description of each discipline is shown in the table on the next page. If you have already decided on your discipline, I would encourage you to carefully study the information provided about that discipline. If you have not yet decided on your discipline, reviewing the descriptions of all of the disciplines you might be interested in can help you with that decision.

ENGINEERING DISCIPLINES RANKED BY NUMBER OF B.S. DEGREES AWARDED: 2010/11 [20]

Discipline/Location of Description	Number of Accredited Programs/B.S. Degrees Awarded in 2010-11
Mechanical engineering/Page 287	289/19,016
Civil engineering/Page 290	224/13,175
Electrical and electronics engineering/Page 285	297/12,005
Computer engineering/Page 292	218/11,610
Chemical engineering/Page 296	158/6,297
Bioengineering and biomedical engineering/Page 297	73/4,293
Industrial engineering/Page 298	93/3,423
Aerospace engineering/Page 299	65/3,286
General engineering/engineering physics/engineering science	73/2,812
Materials engineering/metallurgical engineering/Page 299	65/1,134
Petroleum engineering/Page 301	17/994
Environmental engineering/Page 301	59/740
Architectural engineering/Page 300	17/730
Naval architecture/marine	16/578

engineering/ocean engineering/Page 301	
Engineering management/Page 303	11/504
Systems engineering/Page 300	16/472
Nuclear and radiological engineering/Page 302	20/463
Agricultural engineering/biological engineering/Page 300	47/427
Mining engineering/metallurgical engineering/geological engineering/Page 302	35/417
Manufacturing engineering/Page 302	21/146
Ceramic engineering/Page 302	3/52
Software engineering/Page 302	21/**
Construction engineering/Page 303	12/**
Optics engineering/Page 303	5/**
Surveying and geomatics engineering/Page 303	5/**
Engineering mechanics	5/**
Telecommunications engineering/Page 304	2/**
Welding engineering	1/**
Fire protection engineering	1/**
Other	xx/2,014
TOTAL	**1,885/84,599**

** - Included in disciplines with degrees awarded listed as "Other"

REFLECTION

Reflect on the 25 engineering disciplines described in Appendix E. Have you already decided which one you will major in? Why did you choose it? If you haven't yet chosen a specific engineering discipline, which one is the most appealing to you at this point? What about it do you find appealing?

2.7 ENGINEERING JOB FUNCTIONS

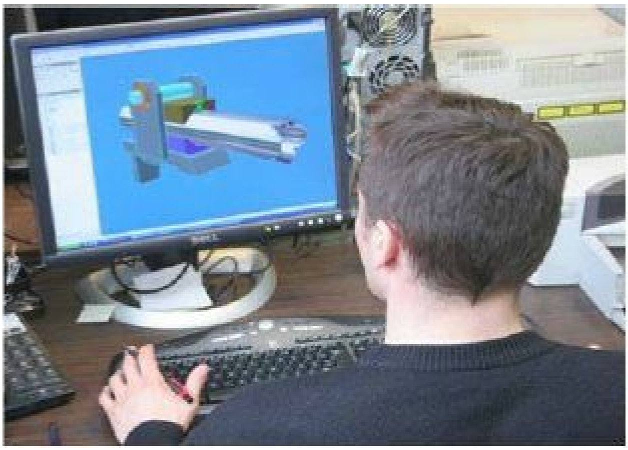
As noted earlier in this chapter, another way to understand the engineering profession is to examine engineers from the perspective of the work they do or the job functions they perform. For example, an electrical engineer could also be referred to as a *design* engineer, a *test* engineer, or a *development* engineer – depending on the nature of his or her work. Following is a description of the ten main engineering job functions.

Analysis

The **analytical engineer** is primarily involved in the mathematical modeling of physical problems. Using the principles of mathematics, physics, and engineering science – and making extensive use of engineering applications software – the analytical engineer plays a critical role in the initial stage of a design project, providing information and answers to questions that are easy and inexpensive to obtain. Once the project moves from the conceptual, theoretical stage to the actual fabrication and implementation stage, changes tend to be time-consuming and costly.

Design

The **design engineer** converts concepts and information into detailed plans and specifications that dictate the development and manufacture of a product. Recognizing that many designs are possible, the design engineer must consider such factors as production cost, availability of materials, ease of production, and performance requirements. Creativity and innovation, along with an analytic mind and attention to detail, are key qualifications for a design engineer.



TEST

The **test engineer** is responsible for developing and conducting tests to verify that a selected design or product meets all specifications. Depending on the product, tests may be required for such factors as structural integrity, performance, or reliability – all of which must be performed under all expected environmental conditions. Test engineers also conduct quality control checks on existing products.

DEVELOPMENT

The **development engineer**, as the title indicates, is involved in the development of products, systems, or processes. The context in which such development occurs, however, can vary considerably. Working on a specific design project, the development engineer acts as a kind of intermediary between the design and test engineers. He helps the design engineer formulate as many designs as possible that meet all specifications. Once a design is selected, the development engineer oversees its fabrication – usually in the form of a prototype or model. The results of his collaboration with the design engineer and subsequent supervision of the prototype's fabrication are bound to affect the kind and amount of testing the test engineer will then need to conduct.

In a more general context, the development engineer is instrumental in turning concepts into actual products or applying new knowledge to improve existing products. In this capacity, she is the "D" in "R&D," which, as you probably know, stands for research and development.

Here, the development engineer is responsible for determining how to actualize or apply what the researcher discovers in the laboratory, typically by designing, fabricating, and testing prototypes or experimental models.

SALES

The **sales engineer** is the liaison person between the company and the customer. In this role, the sales engineer must be technically proficient in order to understand the product itself and the customer's needs. That means he must be able to explain the product in detail: how it operates, what functions it can perform, and why it will satisfy the customer's requirements. He also needs to maintain a professional working relationship as long as the customer is using his company's products. He must be able to field questions about the product, explain its features to new users, and arrange prompt service should the customer experience problems with the product. Obviously, along with solid technical knowledge, the sales engineer must possess strong communication skills and "people" skills.

RESEARCH

The work of the **research engineer** is not unlike that of a research scientist in that both are involved in the search for new knowledge.

However, the difference lies in what motivates their work. Scientific researchers are generally interested in the new knowledge itself: what it teaches or uncovers about natural phenomena. Engineering researchers are interested in ways to apply the knowledge to engineering practices and principles. Research engineers thus explore mathematics, physics, chemistry and engineering sciences in search of answers or insights that will contribute to the advancement of engineering.

Given the nature and demands of their work, research engineers usually need to have an advanced degree. Indeed, most positions available in engineering research require a Ph.D.

Management

If you are successful as an engineer and have strong leadership skills, within a few years of graduation you could very well move into management. Opportunities exist primarily in two areas: **line management** and **project management**.

In a company, the technical staff is generally grouped into a "line organization." At the base of this "line" are units of ten to 15 engineers, managed by a unit supervisor. At the next level up the line, these units report to a group manager. This organizational line continues up to department managers, a chief engineer or engineering vice president, and finally the president. Often the president of a technical company is an engineer who worked his or her way up through the line organization.

Project management is a little different, as the personnel are organized according to a specific project or assignment. At the head of each project is a project manager. For a small project, one manager is usually sufficient to oversee the entire project; for a larger project, the project manager is assisted by a professional staff, which can range from one to several hundred people. The overall responsibility of the project manager and staff is to see that the project is completed successfully, on time, and within budget.

Consulting

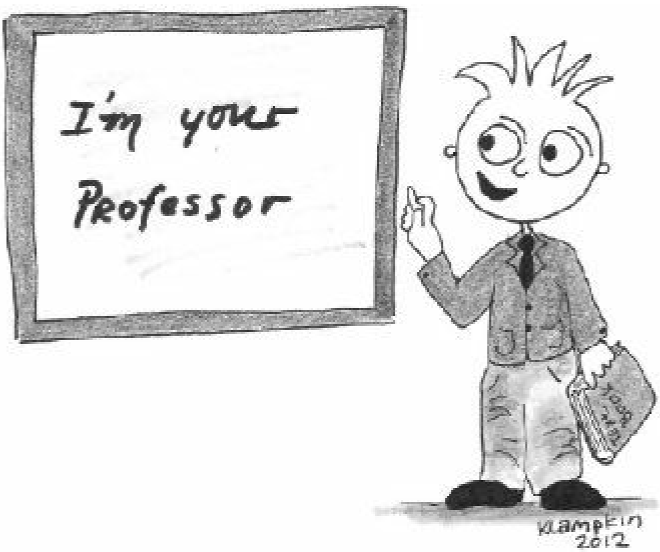
The work of the **consulting engineer** differs from that of all other engineers in that a consulting engineer performs services for a client on a contractual basis. Some consulting engineers are self-employed, while others work for consulting firms that hire out their engineers to companies that either lack the expertise the consulting engineer can provide or want an outside evaluation of their organization's performance. Depending on the client's specific needs, the consulting engineer's work can vary considerably. Investigations and analyses; preplanning, design and design implementation; research and development; construction management; and recommendations regarding engineering-related problems are just a few examples.

The time a consulting engineer puts into each assignment also can vary. Sometimes the work can be done in a day; other times it can require weeks, months, or even years to complete.

Last, engineering consulting is increasingly becoming a global enterprise. Both the public and private sectors of developing nations have growing technological needs and turn to U.S. consulting firms for technical assistance. If the diversity of work and the opportunity to travel catch your interest, a career in engineering consulting could be for you.

TEACHING

The **engineering professor** has three primary areas of responsibility: teaching, research, and service. Teaching includes not only classroom instruction, but also course and curriculum development, laboratory development, and the supervision of student projects or theses. Research involves the pursuit of new knowledge, which is then disseminated throughout the professional engineering community by papers published in engineering journals, presentations at scholarly meetings, textbooks, and software.



The research demands of the engineering educator also include success in generating funds to support research projects as well as participation in professional societies.

"Service" is a catch-all term that refers to the many functions expected of engineering professors. These include such activities as community involvement, participation in faculty governance, public service, and consulting.

The Ph.D. degree in engineering is virtually mandatory to qualify for a full-time position on an engineering faculty at a four-year institution, while an M.S. degree is generally sufficient for a teaching position at a community college. More information about academic careers in engineering can be found in Reference 21.

ENTREPRENEUR

An *entrepreneur* is a person who starts a new business venture. If you are able to combine your strong technical expertise with qualities of inventiveness, risk-taking, and a sense of adventure, someday you may be the president of your own company. There are many examples of engineer entrepreneurs. Some of the most prominent examples are William Hewlett and David Packard (Hewlett-Packard), Jeff Bezos (Amazon.com), Pierre Omidyar and Jeffrey Skoll (E-Bay), Larry Page and Sergey Brin (Google), Andrew Grove (Intel), Leonard Bosack (Cisco Systems), and Jack Gifford (AMD). And these are not exceptions. A 2009 report by the Kaufman Foundation [22] estimated that slightly more than 17,000 companies have been founded by living MIT engineering graduates.

The fact that many engineers become entrepreneurs should come as no surprise. Engineers develop products or processes to meet desired needs. The creative and analytical skills of an engineer can also be put to use in developing a business, particularly one that focuses on high-tech products or services. A list of the traits of successful entrepreneurs would include disciplined, confident, open-minded, a self-starter, competitive, creative, determined, strong work ethic, strong people skills, passionate. If you combine these traits with a strong technical background, you may someday be the CEO of your own company.

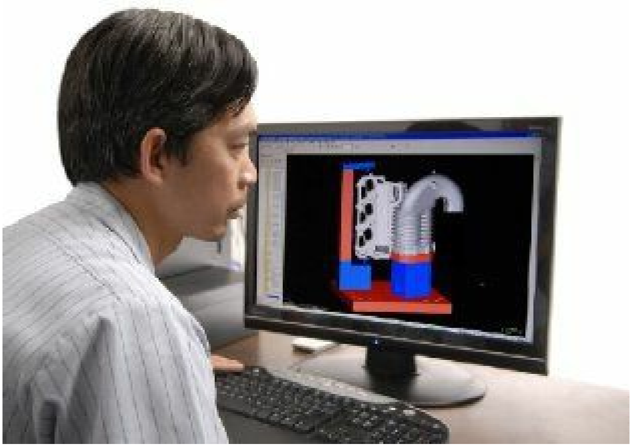
The opportunity for engineers to start businesses is on the increase as technology plays a more and more important role in our lives. One reflection of this is that a growing number of universities are developing courses or even entire programs on entrepreneurship for engineers.

REFLECTION

Consider the ten engineering job functions described in this section. Which of them appeals to you? Analysis? Design? Test? Development? Sales? Research? Could you see yourself in management? Could you see yourself as a consulting engineer? How about being an engineering professor or entrepreneur?

2.8 EMPLOYMENT OPPORTUNITIES

When you graduate in engineering, you will face a number of choices. The first will be whether you want to continue your education full time or seek work as a practicing engineer. If you elect to continue your education, you next need to decide whether you want to pursue an M.S. degree in engineering or do graduate work in another field, such as business administration, law, or medicine. (Opportunities for graduate study are discussed in Chapter 8.)



If you decide to seek a full-time engineering position, many opportunities and choices await you. The field of engineering practice is so vast and the job opportunities so varied, you may well need to devote a substantial amount of time to fully understand the opportunities and areas of practice available to you.

Rather than waiting until you graduate to learn about these many opportunities, you should make this an objective early on in your engineering studies. Besides saving time and energy when you launch your job search later, knowing NOW about the many areas in which engineers are needed and the diverse opportunities that await you will be a strong incentive for you to complete your engineering studies.

Let's start, then, with a "big picture" view of the major areas in which most engineers work. The table below, which lists these areas, along with the percentages in each [23]:

Employed Individuals with Engineering Degrees

Employment Area	Percentage
Business/Industry	80.3%
Federal Government	5.4%
State/Local Government	5.7%
Educational Institutions	5.1%
Self-Employed	3.5%
Total	**100%**

As you can see, the first area, "Business/Industry," is clearly the largest, employing 80.2 percent of engineers. You should know, however, that "industry" is a blanket term for two distinct categories: (1) manufacturing, and (2) non-manufacturing (or service). *Manufacturing* is involved in converting raw materials into products, while *non-manufacturing* concerns the delivery of services. Government, the next highest area, employing 11.1 percent of engineers, has needs for engineers at the local, state, and federal levels. Following business, industry, and government come educational institutions, which employ 5.1 percent of engineers, both as engineering professors and as researchers in university-operated research laboratories. Finally, there is a small but significant area of self-employed engineers, most of whom are consulting engineers.

Organization of Industry in the United States

If 80 percent of engineers work in business and industry, it is likely that you, too, will find yourself working in this area. Although we briefly mentioned the two categories into which industry is divided (manufacturing and non-manufacturing), we have barely scratched the surface of this huge, complex field. For a comprehensive look at the many diverse fields that comprise U.S. business and industry, the **2012 North American Industry Classification System (2012 NAICS)** [24] is the best resource available.

Developed and maintained by the U.S. government, the 2012 NAICS system dissects the monolithic term “business and industry” into 1,067 “national industries,” each identified by a six-digit classification code. It then lists all the products or services that each national industry provides.

To give you an idea of how the 2012 NAICS works, I randomly selected ten of the 1,067 national industries in the NAICS classification system:

211111 Crude petroleum and natural gas extraction
221112 Electric power generation, fossil fuel (e.g., coal, oil, gas)
237310 Highway, street, and bridge construction

325611 Soap and other detergent manufacturing
334510 Electromedical and electrotherapeutic apparatus manufacturing
335311 Power, distribution, and specialty transformer manufacturing
335921 Fiber-optic cable manufacturing
336414 Guided missile and space vehicle manufacturing
517210 Wireless telecommunications carriers (except satellite)
541330 Engineering services

The first two digits designate a major "Economic Sector," and the third digit designates an "Economic Subsector." For example, all of the industry subgroups above starting with 33 are part of the "Manufacturing" Economic Sector. The two national industries in the list whose first three digits are 335 fall under the "Electrical Equipment, Appliance, and Component Manufacturing" Economic Subsector. The remaining digits of each six-digit classification code further subdivide the subsectors into industry groups (4 digits), NAICS industries (5 digits), and national industries (6 digits).

As an example, consider the Economic Sector, "33 – Manufacturing." Under this economic sector, there are eight "Economic Subsectors":

331 – Primary metal manufacturing

332 – Fabricated metal product manufacturing

333 – Machinery manufacturing

334 – Computer and electronic product manufacturing

335 – Electrical equipment, appliance, and component manufacturing

336 – Transportation equipment manufacturing

337 – Furniture and related product manufacturing

339 – Miscellaneous manufacturing

Take one of the "Economic Subsectors," say NAICS 334, "Computer and electronic product manufacturing." Under this Economic Subsector, there are six "Industry Groups":

3341 – Computer and peripheral equipment manufacturing

3342 – Communications equipment manufacturing

3343 – Audio and video equipment manufacturing

3344 – Semiconductor and other electronic component manufacturing

3345 – Navigational, measuring, electromedical, and control instruments manufacturing

3346 – Manufacturing and reproducing magnetic and optical media

Now, take one of the "Industry Groups," NAICS 3345, for example: "Navigational, measuring, electromedical, and control instruments manufacturing." Under this industry group there are nine national industries:

334510 – Electromedical and electrotherapeutic apparatus manufacturing

334511 – Search, detection, navigation, guidance, aeronautical, and nautical system and instrument manufacturing

334512 – Automatic environmental control manufacturing for residential, commercial, and appliance use

334513 – Instruments and related products manufacturing for measuring, displaying, and controlling industrial process variables

334514 – Totalizing fluid meter and counting device manufacturing

334515 – Instrument manufacturing for measuring and testing electrical signals

334516 – Analytical laboratory instrument manufacturing

334517 – Irradiation apparatus manufacturing

334519 – Other measuring and controlling device manufacturing

If you pick just one of these nine national industries, for instance

334510 – Electromedical and electrotherapeutic apparatus manufacturing – you'll find listed more than 50 major product groups such as magnetic resonance imaging equipment, medical ultrasound equipment, pacemakers, hearing aids, electrocardiographs, and electromedical endoscopic equipment.

I hope this has given you an idea of the enormity of U.S. business and industry and the tools you need to access that industry. You can explore the North American Industry Classification System on your own online at www.census.gov/naics. Under "2012 NAICS Search," enter one of two types of keywords:

(1) a product or service (e.g., "fiber optic")

(2) a two- to six-digit NAICS classification (e.g., "541330")

Exercise

Go to the 2012 NAICS website at www.census.gov/naics. Conduct a search on Manufacturing (Economic Sector 33). Scroll down until you find a national industry you would be interested to work in. Click on the six-digit code for that national industry to see a listing of the products manufactured. Pick one of the products and conduct an Internet search to identify companies that compete in the marketplace for that product. Pick one of the companies and go to its website to see if you can identify job listings for engineers.

We learned earlier that 80 percent of engineers work in business and industry. The following sections briefly describe the economic subsectors that employ the largest number of engineers in both the manufacturing subsector and the service sector.

Manufacturing Subsectors

Below are brief descriptions of the six manufacturing subsectors employing the largest numbers of engineers.

Computer and Electronic Product Manufacturing. These industries are engaged in the manufacture of computers, computer peripherals, communication equipment, and related electronic equipment. Their manufacturing processes differ fundamentally from those of other machinery and equipment in that the design and use of integrated circuits and the application of highly specialized miniaturization technologies are common elements in the manufacturing processes of computer and electronic products.

TRANSPORTATION EQUIPMENT MANUFACTURING. These industries produce equipment and machinery needed for transporting people and goods. Their manufacturing processes are similar to those used in most other machinery manufacturing establishments: bending, forming, welding, machining, and assembling metal or plastic parts into components and finished products. Evidence of the equipment and machinery manufactured in this subsector can be found in a variety of products - motor vehicles, aircraft, guided missiles and space vehicles, ships, boats, railroad equipment, motorcycles, bicycles, and snowmobiles.

MACHINERY MANUFACTURING. These industries design and produce products that require mechanical force to perform work. Both general-purpose machinery and machinery designed to be used in a particular industry are included in this subsector. Examples of general-purpose machinery include heating, ventilation, air-conditioning, and commercial refrigeration equipment; metalworking machinery; and engine, turbine, and power transmission equipment. Special-purpose machinery are included: agricultural, construction, and mining machinery; industrial machinery; and commercial and service industry machinery.

FABRICATED METAL PRODUCT MANUFACTURING. These industries transform metal into intermediate or end products using forging, stamping, bending, forming, and machining to shape individual pieces of metal. They also use processes, such as welding and assembling, to join separate parts together. Examples of products include hand tools, kitchen utensils, metal containers, springs, wire, plumbing fixtures, firearms, and ammunition.

CHEMICAL MANUFACTURING. These industries manufacture three general classes of products: (1) basic chemicals, such as acids, alkalies, salts, and organic chemicals; (2) chemical products to be used in further manufacture, such as synthetic fibers, plastics materials, dry colors, and pigments; and (3) finished chemical products to be used for human consumption, such as drugs, cosmetics, and soaps; or products to be used as materials or supplies in other industries, such as paints, fertilizers, and explosives.

ELECTRICAL EQUIPMENT, APPLIANCE, AND COMPONENT MANUFACTURING.

These industries manufacture products that generate, distribute, and use electrical power. Electric lighting equipment, household appliances, electric motors and generators, batteries, and insulated wire and wiring devices are but a few of the many products that come under this manufacturing subsector.

SERVICE SECTORS

The following provides brief descriptions of the eight service sectors that employ the greatest number of engineers.

PROFESSIONAL, SCIENTIFIC, AND TECHNICAL SERVICES. This sector includes industries from three large areas, only one of which – "Technical Services" – applies to engineering. Under "Technical Services," however, NAICS includes a broad, varied list of both engineering and computer services. Engineering services may involve any of the following: provision of advice (i.e., engineering consulting), preparation of feasibility studies, preparation of preliminary plans and designs, provision of technical services during the construction or implementation stages of a project, inspection and evaluation of completed projects, and related services. Computer services are equally varied, including activities such as programming, computer-integrated systems design, data preparation and processing, information retrieval, facilities management, as well as computer leasing, maintenance, and repair.

<u>INFORMATION</u>. These industries focus on three main processes: (1) producing and distributing information and cultural products; (2) providing the means to transmit or distribute these products, along with data or communications; and (3) processing data. Subsectors include publishing industries, motion picture and sound recording industries, broadcasting and telecommunications, and information and data processing services.

<u>CONSTRUCTION.</u> These industries cover three broad areas of construction: (1) building construction, such as dwellings, office buildings, commercial buildings, stores, and farm buildings; (2) heavy construction other than buildings, such as highways, streets, bridges, sewers, railroads, irrigation projects, flood control projects, and marine construction; and (3) special trades for heavy construction such as painting, electrical work, plumbing, heating, air-conditioning, roofing, and sheet metal work.

<u>WHOLESALE TRADE</u>. Wholesale trade includes: (1) merchant wholesalers who take title to the goods they sell; (2) sales branches or offices maintained by manufacturing, refining, or mining enterprises; and (3) agents, merchandise or commodity brokers, and commission merchants. The merchandise includes the output of agriculture, mining, manufacturing, and certain information industries, such as publishing.

<u>ADMINISTRATION AND SUPPORT</u>. These service industries perform routine support activities for the day-to-day operations of other organizations. These essential activities are often undertaken in-house by establishments in many sectors of the economy. Activities include office administration, personnel employment and placement, document preparation and other clerical services, solicitation, collection, security and surveillance, and waste disposal.

MANAGEMENT OF COMPANIES AND ENTERPRISES. This sector involves (1) holding securities of (or other equity interests in) companies and enterprises for the purpose of owning a controlling interest or influencing management decisions, or (2) administering, overseeing, and managing companies. Engineers who are provided to companies on a contract basis are included in this economic sector.

UTILITIES. These industries are engaged in providing electric power, natural gas, steam, water, and sewage removal. Providing electric power includes generation, transmission, and distribution, while natural gas only involves distribution. Supplying steam includes provision and/or distribution; supplying water involves treatment and distribution. Sewage removal includes collection, treatment, and disposal of waste through sewer systems and sewage treatment facilities.

MINING. These industries extract naturally occurring mineral solids, such as coal and ores; liquid minerals, such as crude petroleum; and gases, such as natural gas. The term “mining” is used in the broad sense to include quarrying, well operations, beneficiating (e.g., crushing, screening, washing, and flotation), and other preparatory functions customarily done at the mine site.

2.9 IMPORTANT FIELDS FOR THE FUTURE

We are in a period of intense change. One way to underscore this is to reflect on the fact that none of the 50 technological inventions listed below existed as recently as 1982 (30 years ago).

50 Greatest Technological Inventions of Past 25 Years

50	Hybrid cars
49	Mini disc
48	Color plasma display
47	Optical computer mouse
46	LED headlights
45	Electronic tolls
44	OLED TV
43	Blu-ray
42	Satellite TV
41	Recordable DVDs
40	Lithium rechargeable batteries
39	DVD
38	CD-R
37	Voice mail
36	Online stock trading
35	Doppler radar
34	MPEG-4
33	Flash memory
32	Bluetooth
31	Commercialized GPS
30	Home audio editing
29	Home video editing

28	Camcorders
27	Digital SLR cameras
26	Multi-core processors
25	Satellite radio
24	Flip phones
23	Digital HDTV
22	Instant messaging
21	Consumer digital cameras
20	JPEG
19	Microblogging
18	Caller ID
17	Mobile broadband
16	Blogs
15	MP3 players
14	Electronic word processing
13	DVR
12	DNA profiling
11	Social networking service
10	Genetic sequencing
9	Web-based email
8	Search engines
7	Smart phones
6	Text messaging
5	Wi-Fi
4	MP3
3	Broadband Internet
2	Personal computers
1	World Wide Web

This list was compiled by *Complex Magazine* and published in August, 2010 [26]. Not only have these inventions changed our ways of communicating and locating information, they have created exciting new opportunities for engineers. The ranking is based on which inventions affect our lives the most.

REFLECTION

Review the "50 Greatest Technological Inventions of the Past 25 Years." Which items will help you reach your goal of becoming an engineer? How so? More importantly, which ones have the potential to interfere with your goal of becoming an engineer? What can you do to ensure that they don't keep you from achieving your goal of becoming an engineer?

Many of the inventions listed above have resulted in a "flattening" of the world. To see what this means, check out Thomas L. Friedman's profound book *The World Is Flat: A Brief History of the Twenty-First Century* [25]. Doing so will help you understand the world in which you are living and working. Friedman explores the political and technological changes that have "flattened" the world, making it a smaller place. Such events such as the fall of the Berlin Wall, the explosion of the Internet, the dot-com bubble and bust, the outsourcing of jobs to India and China, and "globalization" have leveled the playing field for many emerging economies.

The following is a list of some of the major events and changes that will influence your future as an engineer.

Major Events and Changes Affecting the Future

Fall of the Berlin Wall
Advances in computer technology
Advances in communications
The knowledge and information explosion
Globalization (outsourcing, off-shoring)
Environmental challenges/sustainability
World population explosion
Democratization
Pandemic diseases/drug resistant germs

Climate change/natural disasters
Nuclear proliferation
Events of September 11, 2001/threat of terrorism

Future Directions - *Grand Challenges for Engineering*

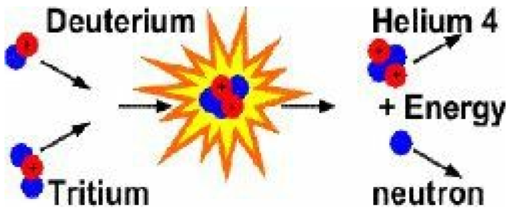
A good way to understand future directions for engineering is to examine the National Academy of Engineering's "Grand Challenges for Engineering." The 14 challenges, announced in 2008, were developed by a select committee with input from broad constituencies throughout the world. They address four themes considered "essential for humanity to flourish:" environmental sustainability, health, reducing our vulnerability, and adding to the joy of living.

1. Make solar energy economical.
2. Provide energy from fusion.
3. Develop carbon sequestration methods.
4. Manage the nitrogen cycle.
5. Provide access to clean water.
6. Restore and improve urban infrastructure.
7. Advance health informatics.
8. Engineer better medicines.
9. Reverse-engineer the brain.
10. Prevent nuclear terror.
11. Secure cyberspace.
12. Enhance virtual reality.

13. Advance personalized learning.
14. Engineer the tools of scientific discovery.

Understanding these challenges can help you prepare for the engineering fields that will be particularly important in the years ahead. The following sections briefly discuss each challenge. Detailed information on each can be found at www.engineeringchallenges.org.

MAKE SOLAR ENERGY ECONOMICAL. Sunshine has long offered a tantalizing source of environmentally-friendly power, bathing the earth with more energy each hour than the planet's population consumes in a year. But capturing that power, converting it into useful forms, and storing it for the proverbial rainy day, pose provocative engineering challenges.

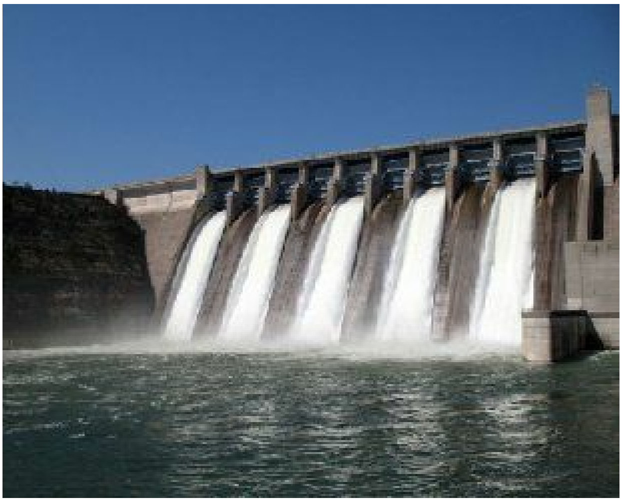


PROVIDE ENERGY FROM FUSION. Nuclear fusion, the artificial re-creation of the sun's source of power on Earth, offers the potential for long-term energy supply. Human-engineered fusion has already been demonstrated on a small scale. The challenges facing the engineering community are to find ways to scale up the fusion process to commercial proportions, in an efficient, economical, and environmentally friendly way.

DEVELOP CARBON SEQUESTRATION METHODS. Engineering solutions for solar power and nuclear fusion must be feasible not only technologically but also economically when compared with fossil fuels. Even with success, however, it remains unlikely that fossil fuels will be eliminated from the planet's energy budget anytime soon, leaving their impact on the environment for engineers to address. Most notoriously, evidence is mounting that the carbon dioxide pumped into the air by burning fossil fuels is increasing the planet's temperature and threatens to have disruptive effects on climate. Consequently, engineers will need to find ways of capturing and sequestering the carbon dioxide produced from fuel burning.

MANAGE THE NITROGEN CYCLE. A lesser known environmental concern involves nitrogen, the atmosphere's most abundant component. The natural cycle that extracts nitrogen from the air for its incorporation into plants – and hence food – has become altered by human activity. With widespread use of fertilizers and high-temperature industrial combustion, humans have doubled the rate at which nitrogen is removed from the air since pre-industrial times, contributing to smog and acid rain, polluting drinking water, and even worsening global warming. Engineers must design countermeasures for nitrogen-cycle problems, while maintaining the ability of agriculture to produce adequate food supplies.

PROVIDE ACCESS TO CLEAN WATER . The short supply of quality water for personal use – drinking, cleaning, cooking, and removal of waste – and large-scale use such as irrigation for agriculture, is a vital concern in many regions of the world. Engineers will play a role in meeting water needs through both the desalination of sea water and also the use of small-scale technologies for local water purification.



RESTORE AND IMPROVE URBAN INFRASTRUCTURE. America's infrastructure – water and sewer systems, hazardous and solid waste disposal systems, roads and bridges, rail networks, urban transportation systems, power and natural gas grids, and public buildings – is aging and failing. Engineers face the enormous challenge of renewing and sustaining these infrastructures while preserving ecological balances and enhancing the aesthetic appeal of living spaces.

ADVANCE HEALTH INFORMATICS. As computers have become critical to so many facets of human endeavors, there is now a consensus that a computer-based approach to health informatics – the acquisition, management, and use of information in health – can greatly enhance the quality and efficiency of medical care delivery and the response to widespread public health emergencies. Health and biomedical informatics encompass issues from the personal to the global, ranging from medical records for individual patients to sharing data about disease outbreaks. Maintaining a healthy world population in the 21st century will require systems engineering approaches to redesign care practices and integrate local, regional, national, and global health informatics networks.

ENGINEER BETTER MEDICINES. Doctors have long recognized that individuals differ in their susceptibility to disease and their response to treatments, but medical technologies have generally been offered as "one size fits all." Recent cataloging of the human genome, along with a better understanding of the body's complement of proteins and their biochemical interactions, offer the prospect of identifying the specific factors that determine sickness and wellness in any individual. Examples of engineering challenges are developing better systems to quickly assess a patient's genetic profile, collecting and managing massive amounts of data on individual patients, and creating new diagnostic devices such as gene chips and sensors able to detect minute amounts of chemicals in the blood.

REVERSE ENGINEER THE BRAIN. While some machines have mastered specific narrow thinking skills – playing chess, for instance – general-purpose artificial intelligence (AI) has remained elusive. Part of the problem, some experts now believe, is that artificial brains have been designed without enough attention to real ones. The secrets about how living brains work are bound to offer the best guide to engineering an artificial variety. Discovering those secrets by reverse-engineering the brain promises enormous opportunities for reproducing intelligence the way assembly lines turn out cars or computers.

PREVENT NUCLEAR TERROR. Since the beginning of the Nuclear Age, the materials needed to make a nuclear weapon have been accumulating around the world. Worse yet, the instructions for building explosive devices from such materials have been widely published, suggesting that access to the ingredients would make a bomb a realistic possibility.

Challenges for engineers include: (1) how to secure the materials, (2) how to detect hidden nuclear materials, (3) how to render a potential device harmless, (4) how to deal with the aftermath of a nuclear explosion, and (5) how to determine who is responsible for an attack.

Vulnerability to biological disaster is also of great concern, and technologies for early detection of such threats and rapid deployment of countermeasures (such as vaccines and antiviral drugs) rank among the most urgent of today's engineering challenges.

SECURE CYBERSPACE. It is clear that engineers need to develop solutions for a long list of cybersecurity problems. For one, better approaches are needed to authenticate hardware, software, and data in computer systems and to verify user identities. Biometric technologies, such as fingerprint readers, may be one step in that direction.

Engineering more secure software is a particularly critical need. One way to do this may be through better programming languages that have security protection built into the ways programs are written. Another challenge is to ensure that data transmitted over various routes on the Internet cannot be diverted, monitored, or altered.

ENHANCE VIRTUAL REALITY. For virtual reality systems to effectively simulate reality, several engineering hurdles must be overcome. The resolution of the video display must be high, with rapid refresh and update rates, for scenes to look like and change as they do in real life. The field of view must be wide enough and the lighting and shadows realistic enough to maintain the illusion of a real scene. And for serious simulations, reproducing sensations of sound, touch, and motion is necessary.

ADVANCE PERSONALIZED LEARNING. The external world is not the only place where engineering matters; the inner world of the mind can also benefit from improved methods of instruction and learning. Ways must be found to tailor the mind's growth to an individual's propensities and abilities. New methods of instruction, such as computer-created virtual realities, also apply to entertainment and leisure, furthering engineering's contributions to the joy of living.

ENGINEER THE TOOLS OF SCIENTIFIC DISCOVERY. The spirit of curiosity, whether in individual minds and in society as a whole, can be further promoted through engineering endeavors enhancing exploration at the frontiers of reality and knowledge. New tools are needed for investigating the vastness of the cosmos or the inner intricacy of life and subatomic particles.

2.10 SUSTAINABILITY

Sustainability is the capacity to endure. While many people disagree on exactly what that means, perhaps the best definition was offered by a commission of the United Nations in 1987:

***Sustainability* is meeting the needs of the present without compromising the ability of future generations to meet their own needs.**

I'm sure no one would disagree that this definition puts forth a worthy goal, but it is one we are a long way from achieving. Examples of major environmental problems that will be passed to future generations are:

- Global warming/climate change
- Ozone depletion
- Water quality and quantity
- Air pollution
- Dependence on fossil fuels/energy crisis
- Unsustainable agriculture
- Threat of disease
- Waste management and land pollution
- Over-consumption
- World hunger
- Loss of ecosystems/deforestation/animal extinction

These problems are the unintended consequences of rapid population growth, economic growth, and unbridled consumption of natural resources.

Although solutions to these problems involve complex interactions among economic, societal, and environmental factors, engineers will play key roles in achieving sustainability. It is no surprise that a number of the Grand Challenges for Engineering include making solar energy economical, providing energy from fusion, developing carbon sequestration methods, managing the nitrogen cycle, and providing access to clean water directly – all of which address one or more of these problems.

The role of the engineering design process in sustainability is underscored by the fact that one of the attributes of new engineering graduates required by ABET is:

> ***an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and <u>sustainability</u>***

The work of engineers in solving the environmental problems listed above is often called "green engineering." Green engineering focuses on the design of materials, processes, systems, and devices with the objective of minimizing overall environmental impact (including energy utilization and waste production) throughout the entire life cycle of a product or process.

Some of the important attributes of green engineering and sustainable designs are:

- Designs that use less energy or reduce emission
- Designs with minimal carbon footprints
- Designs that reduce material usage or waste in manufacturing
- Designs with no toxic materials
- Designs that comply with environmental standards and regulations
- Manufacturing processes that use less energy and natural resources
- Products that can be disposed of safely, including biodegradable materials and packaging
- Manufacturing processes that minimize the usage or production of substances of concern
- Designs that use renewable/recyclable/recycled materials
- Products that require less packaging

As a future engineer, you can help in answering the question: "How can engineering practice and technology help to move products, processes, and systems toward sustainability?" To this end, you will have limitless opportunities to be involved in technologies that use less energy, tap fewer natural resources, avoid polluting the environment, and are reusable. Needless to say, the need for creative and innovative thinking will be greater than ever – a reality best captured by the following prescient quote from Albert Einstein:

The significant problems we face cannot be solved at the same level of thinking we were at when we created them.

2.11 Engineering as a Profession

When you receive your B.S. degree in engineering, you will join the engineering profession. Engineering is considered a profession in that it meets the following characteristics of a learned professional group [27]:

- Knowledge and skill in specialized fields above that of the general public
- A desire for public service and a willingness to share discoveries for the benefit of others
- Exercise of discretion and judgment
- Establishment of a relation of confidence between the professional and client or employer
- Self-imposed (i.e., by the profession) standards for qualifications
- Acceptance of overall and specific codes of conduct
- Formation of professional groups and participation in advancing professional ideals and knowledge
- Recognition by law as an identifiable body of knowledge

Reflection

Review the above eight characteristics of a learned profession. Do they describe something you would like to be part of? Which characteristic would you welcome? Are there any that you would have a problem with? Do you have a desire for public service? Are you willing to share what you know to benefit others? Would you look forward to establishing a relation of confidence between you and your employer? Would you welcome the opportunity to learn about and practice codes of conduct? Would you enjoy being part of a profession that requires a great deal of discretion and judgment?

As an engineering professional, you will have certain rights and privileges, as well as certain responsibilities and obligations. As described above, you will be responsible for serving the public, sharing your discoveries for the benefit of others, exercising discretion and judgment, maintaining confidentiality with clients and employers, and abiding by specific codes of conduct.

As an engineering professional, you will have the legal right to represent yourself using the title of engineer. You will be eligible to participate in professional organizations. And you will have the right to seek registration as a *Professional Engineer.*

PROFESSIONAL REGISTRATION

You can formalize your status as a professional by seeking registration as a *Professional Engineer* (P.E.). Professional registration is an impressive credential, and you will find the title **P.E.** proudly displayed on the business cards of engineers who have acquired that status. For most engineers, professional registration is optional. However, in certain fields of work that involve public safety, professional registration may be mandatory. Approximately 30 percent of all practicing engineers are registered. The percentage is much higher for civil engineers because of the nature of their work.

NCEES
advancing licensure for engineers and surveyors

Professional registration is handled by the individual states, each of which has a registration board. Although the requirements and procedures differ somewhat from state to state, they are generally fairly uniform due to the efforts of the National Council of Examiners for Engineers and Surveyors (NCEES). For details about becoming a registered Professional Engineer, visit the NCEES webpage: www.ncees.org.

State boards are responsible for evaluating the education and experience of applicants for registration, administering an examination to those applicants who meet the minimum requirements, and granting registration to those who pass the exam.

Although registration laws vary, most boards require four steps:

1. Graduation from a four-year engineering program accredited by the Accreditation Board for Engineering and Technology (ABET)
2. Passing the Fundamentals of Engineering (FE) examination
3. Completing four years of acceptable engineering practice
4. Passing the Principles and Practice of Engineering (PE) examination

Once you complete these four steps, you will become licensed as a Professional Engineer in the state in which you wish to practice, and you will be certified to use the prestigious P.E. designation after your name. Most states provide for reciprocal licensure, so that once you become licensed in one state, you can become licensed in other states without further examination.

THE FUNDAMENTALS OF ENGINEERING EXAM. The Fundamentals of Engineering Exam (FE) is administered each year in April and October. It is an eight-hour, closed-book, multiple-choice exam. The only reference material that can be used is the *FE Supplied-Reference Handbook* [28] that will given to you to use during the exam but can be obtained and reviewed beforehand. The four-hour morning session is the same for all engineering disciplines and consists of 120 one-point questions on the following topics:

Mathematics (15%)

Engineering probability and statistics (7%)
Chemistry (9%)
Engineering economics (8%)
Computers (7%)
Ethics and business practice (7%)
Engineering mechanics (statics and dynamics) (10%)
Strength of materials (7%)
Material properties (7%)
Fluid mechanics (7%)
Electricity and magnetism (9%)
Thermodynamics (7%)

The four-hour afternoon exam is comprised of 60 two-point questions and covers one of seven engineering disciplines (electrical, mechanical, civil, industrial, chemical, environmental, general) chosen by you.

The FE exam can be taken prior to graduation, ideally sometime in your senior year or soon after you graduate. This is the time when you have the best command of engineering fundamentals. Once you have passed this exam and graduated, you are designated as an Intern-Engineer or Engineer-in-Training.

One note. Your engineering curriculum may not include courses that cover all of the topics included on the FE exam, so you may need to take an FE review course, do extensive self-study, or even elect to take an additional course or two during your undergraduate years.

Beginning in January 2014, the FE exam will be offered via computer-based testing (CBT) rather than a paper-and-pencil exam. Testing will be administered through Pearson Virtual University Enterprises (VUE) network of testing centers worldwide and will be offered periodically throughout the year rather than on two specific dates. You should expect changes in the exam format. Some of those under consideration include shortening the length of the test, integrating the common and discipline-specific sections, and broadening the types of question formats. You can find information on the status of the change to computer-based testing at: cbt.ncees.org.

THE PRINCIPLES AND PRACTICE OF ENGINEERING EXAM. After four years of experience as an Intern Engineer or Engineer-in-Training, you will be eligible to take the Principles and Practice of Engineering Exam (PE exam). Offered in April and October, the PE exam is an eight-hour, open-book exam in a specific engineering discipline (civil, mechanical, electrical, chemical, industrial, etc.). The exam consists of 40 multiple-choice questions in the four-hour morning session, and 40 multiple-choice questions in the four-hour afternoon session. If you take the exam in the civil, electrical, or mechanical engineering disciplines, the afternoon session will focus on a sub-specialty of the discipline selected by you.

The NCEES plans to transition the PE exam to computer-based testing at some point in the near future, but no sooner than 2015.

PROFESSIONAL SOCIETIES

Each of the engineering disciplines described in Appendix E has a professional society that serves the technical and professional needs of engineers and students in that discipline. These societies are usually organized on both national and local levels and most support the establishment of student chapters on university campuses. The societies publish technical journals and magazines, organize technical conferences, sponsor short courses for professional development, develop codes and ethical standards, and oversee the accreditation of engineering programs in their discipline.

The benefits of getting actively involved in the student chapter corresponding to your engineering discipline will be discussed in Chapter 7. Those societies responsible for each of the engineering disciplines accredited by ABET are listed below. The discipline(s) each society is responsible for and the society website are listed. You can gain valuable information about each engineering discipline by exploring the society website.

Professional Society	Discipline	Website
American Academy of Environmental Engineers (AAEE)	Environmental Engineering	www.aaee.net
American Ceramic Society (ACerS)	Ceramic Engineering	www.ceramics.org
American Congress on Surveying and Mapping (ACSM)	Surveying and Geomatics Engineering	www.acsm.net
American Institute of Aeronautics and Astronautics (AIAA)	Aeronautical and Aerospace Engineering	www.aiaa.org
American Institute of Chemical Engineers (AIChE)	Chemical Engineering	www.aiche.org
American Nuclear Society (ANS)	Nuclear and Radiological Engineering	www.ans.org
American Society of Agricultural and Biological Engineers (ASABE)	Agricultural and Biological Engineering	www.asabe.org
American Society of Civil Engineers (ASCE)	Architectural, Civil, and Construction Engineering	www.asce.org
American Society of Mechanical Engineers (ASME)	Engineering Mechanics and Mechanical Engineering	www.asme.org
American Society for Engineering Education	General Engineering, Engineering Physics, and	www.asee.org

(ASEE)	Engineering Science	
Biomedical Engineering Society (BMES)	Bioengineering and Biomedical Engineering	www.bmes.org
Computer Science Accreditation Board (CSAB)	Software Engineering	www.csab.org
Institute of Electrical and Electronics Engineers (IEEE)	Electrical and Electronics Engineering/ Computer Engineering	www.ieee.org
Institute of Industrial Engineers (IIE)	Industrial Engineering and Engineering Management	www.iienet2.org
Society of Fire Protection Engineers (SFPE)	Fire Protection Engineering	www.sfpe.org
Society of Manufacturing Engineers (SME)	Manufacturing Engineering	www.sme.org
Society for Mining, Metallurgy, and Exploration (SME-AIME)	Geological and Mining Engineering	www.smenet.org
Society of Naval Architects and Marine Engineers (SNAME)	Naval Architecture and Marine and Ocean Engineering	www.sname.org
Society of Petroleum Engineers (SPE)	Petroleum Engineering	www.spe.org
The Minerals, Metals & Materials Society (TMS)	Materials, Metallurgical, and Welding Engineering	www.tms.org

SUMMARY

This chapter introduced you to the engineering profession – past, present, and future. You were encouraged to take every opportunity to learn as much as you can about engineering. This will be a lifelong process, but it has already begun.

First, we helped you develop an articulate answer to a question you are likely to be asked frequently: "What is engineering?" You learned that, at its core, engineering is the process of developing a product or process that meets a customer need or perceived opportunity.

We then discussed the many rewards and opportunities that will be yours if you are successful in graduating in engineering. “Ray’s Top Ten” list provided you with a picture of how an engineering degree will enhance the quality of your life – as well as the lives of others. Many of the items on the list correlate with job satisfaction – something you should place a high value on and something a career in engineering can offer you.

We then gave you a view of engineering: past, present, and future.

A view of the past came through the Greatest Engineering Achievements of the 20th Century. Reading about these not only provided an interesting retrospective of the engineering field; hopefully, it also served as an incentive to you as a new engineering student, for the achievements of the 21st century are bound to be even more spectacular than those of the 20th century. And you may be responsible for one of the “Greatest Engineering Achievements of the 21st Century.” In any event, whether you look back at the past or forward towards the future, you can see what an important and exciting profession you have elected to join.

Next, we examined the present state of engineering by discussing the various academic disciplines, job functions, and employment opportunities for engineers. The North American Industry Classification System (NAICS) was used to give you a feel for the enormous economic engine that your engineering education is preparing you to be part of. We paid particular attention to the industry sectors that employ the largest numbers of engineers.

Then we discussed the future of engineering by looking at the National Academy of Engineering’s “Grand Challenges for Engineering.” Looking at future challenges will give you an indication of the technical fields that are expected to grow rapidly in the future. You may want to begin preparing yourself today for a career that will address one or more of those challenges.

Finally, we shined a light on the important topic of “sustainability.”

We pointed out the engineers will play a critical role not only in meeting the needs of the present but also doing so in such a way that the ability of future generations to meet their needs will not be compromised.

We closed the chapter by discussing engineering as a profession that you will enter when you graduate. We discussed the requirements that define a profession, including the rights and privileges that come with responsibilities and obligations. One of those rights is to become licensed as a registered Professional Engineer (P.E.).

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PROBLEMS

1. Review the definitions of engineering in Appendix B. Combine the best ideas from these definitions, write out your own definition, and memorize it. Ask people you come in contact with whether they know what engineering is. If they don't know, then recite your definition to them.

2. Review the National Engineers Week webpage: www.eweek.org and answer the following questions:

   a. Who are the sponsors of National Engineers Week?

   b. What is the purpose of National Engineers Week?

   c. What are some of the major activities planned for the next National Engineers Week celebration?

d. What are some of the products available to help promote National Engineers Week?

3. Write a one-page paper about the influences (teachers, parents, TV, etc.) that led you to choose engineering as your major.
4. Pick one of the engineering guidance websites listed at the end of Section 2.1. Explore the site to learn as much about engineering as you can. Write a one-page paper summarizing what you learned.
5. Write a list of specifications for a motorized wheelchair that could be used on a sandy beach. Include performance, economic, and scheduling specifications.
6. Review the list of needed products at the end of Section 2.3. Add five additional products that you think would sell if developed.
7. Pick one of the items from Problem 6 and write a set of design specifications for the proposed product.
8. Pick one of the 20 "Greatest Engineering Achievements of the 20th Century." Write a one-page paper describing the impact of that engineering achievement on the quality of your life.
9. Create a list of activities to increase your understanding of engineering careers. Develop a plan for implementing three of these activities.
10. Add ten or more additional items to the list of rewards and opportunities of an engineering career presented in Section 2.4. Pick your top ten from the total list and rank them in order of importance.
11. Write a three-page paper on "Why I Want to Be an Engineer" by expanding on your top four items from Problem 10 and explaining why each is important to you personally.
12. Have you ever had a job you didn't like? Describe the job. What didn't you like about it? If that job played any role in your subsequent decision to major in engineering, explain what that role was.
13. Read a biography of one of the famous people listed in Section 2.4 who were educated as an engineer. Make a list of the ways that person's engineering education supported their achievements.

14. Write down five non-engineering careers (e.g., politician, entrepreneur, movie director, etc.) that you might be interested in. Discuss with a fellow student how obtaining your B.S. degree in engineering could help you pursue each of those careers.
15. What is the most challenging problem you have ever tackled in your life? Were you able to succeed at solving the problem? Did you enjoy the experience? Write a two-page essay that addresses these questions.
16. Answer the following questions related to making money:
    a. What is the legal minimum wage (per hour) in the U.S.?
    b. What is the highest hourly wage you have ever made?
    c. What hourly wage would correspond to the average starting annual salary for engineering graduates in 2012 ($60,639)?
    d. What is the hourly wage of an engineering executive making $250,000 a year? Two million dollars a year?
17. As indicated in Section 2.4, engineering graduates make up only 4.4 percent of all college graduates. Go to your career center and find out how many employers interview on campus annually. What percentage of those employers interview engineering majors only? What percentage interview business majors only? What percentage interview all other majors? What is the significance of your findings?
18. Find out how the following things work (if you don't already know):
    a. Fuel cell
    b. Radar gun
    c. Microwave oven
    d. Solar cell
    e. Digital display

    Prepare a three-minute oral presentation about one of the items that you will give at the next meeting of your *Introduction to Engineering* course.
19. Go to the National Engineers Week website "Breaking Through: The Creative Engineer" (www.eweek.org/site/nbm/intro.html). There you

will find eight elements of creativity:

challenging	connecting
visualizing	collaborating
harmonizing	improvising
reorienting	synthesizing

Pick one of these elements. Look up the definition of the term in the dictionary, study the example on the National Engineers Week webpage, and conduct further research on the element. Write a one-page paper explaining why this "element of creativity" is important in engineering work.

20. Go to Professor John Lienhard's *The Engines of Our Ingenuity* webpage: www.uh.edu/engines. Pick three of the more than 2,800 episodes you will find there. Study those three. Write a two-page paper on why you picked the ones you did and what you learned from studying them.
21. In Section 2.6 and Appendix E you learned that engineering disciplines can be divided into two categories: (1) the eight largest disciplines (electrical, mechanical, civil, computer, chemical, biomedical, industrial, and aerospace), (2) a larger number of smaller, more specialized disciplines. Make a list of the advantages and disadvantages of selecting your major in one or the other of these two categories.
22. Which of the engineering disciplines listed in Section 2.6 and described in Appendix E are offered by your university? Find out how many students graduate annually from your institution in each of these disciplines.
23. Pick one of the engineering disciplines listed in Section 2.6 and described in Appendix E. Visit the webpage of the professional society corresponding to that discipline and note any information that applies specifically to engineering students. Share what you learned with your classmates in your next *Introduction to Engineering* class.
24. Pick one of the engineering disciplines listed in Section 2.6 and described in Appendix E. Write a three-page paper that would serve to inform a high school senior about that discipline.

25. Pick one of the technical divisions or societies of either the American Society of Mechanical Engineers (ASME), the Institute of Electrical and Electronics Engineers (IEEE), or the American Society of Civil Engineers (ASCE) listed in Appendix E that you would like to know more about. Research the division or society and write a one-page paper describing it.
26. Which of the civil engineering specialties described in Appendix E would provide you the greatest opportunity to benefit society? In what ways?
27. Go to the U.S. Bureau of Labor Statistics' web-based "Occupational Outlook Handbook" at: www.bls.gov/oco/ocos027.htm. Study the information there to learn as much as you can about "engineers." What does it say about the job outlook for engineers?
28. Go to the American Institute of Chemical Engineers (AIChE) "CareerEngineer" webpage: www.aiche.org/resources/careers. Click on "Find a Job," and read about the ones listed there. Which one appeals to you the most? Prepare a two-minute talk describing its appeal to your *Introduction to Engineering* classmates.
29. Interview a practicing engineer. Find out answers to the following questions:
    a. What engineering discipline did he or she graduate in?
    b. To what extent do the knowledge and principles of that discipline apply in his or her current job?
    c. What industry sector does he or she work in?
    d. What percentage of his or her time is spent in the various engineering job functions (design, test, development, management, etc.)?
30. Develop a list of attributes that would be desirable for each of the engineering job functions described in Section 2.7. Which of these job functions appeals to you? Be ready to explain your reasons in a discussion at the next meeting of your *Introduction to Engineering* class.
31. Familiarize yourself with the 2012 NAICS system by doing the

following exercise. Begin by accessing the Internet. Then proceed as directed below:

a. Go to: www.census.gov/naics.

b. Under “2012 NAICS Search,” enter “334.”

c. Browse through all the categories of products listed under NAICS 3345.

d. Find the products listed under NAICS 334510 and print them out.

32. Pick one of the products listed under NAICS 334510 from Problem 31 and research what companies manufacture that product. Contact that company and investigate how they use engineers in the design, manufacturing, and testing of that product, as well as in the marketing of it. Write a summary of what you learned.

33. Learn about the “Engineering Services” industries by following the steps outlined in Problem 31 and entering the six digit code “541330.” How many entries did you find? Would you be interested in working in this industry? Why or why not?

34. Obtain a list of employers that conduct on-campus interviews of engineering graduates through your career center. Try to identify which industry sector each employer belongs in, based on those listed in Section 2.8. Do some of the employers fit into more than one industry sector?

35. Identify the two or three engineering disciplines that you think would be most closely associated with each of the eight “Service” Economic Sectors and six “Manufacturing” Economic Subsectors described in Section 2.8.

36. Make a list of ten products that would be manufactured by each of the six “Manufacturing” Economic Subsectors listed in Section 2.8.

37. Pick one of the “50 Greatest Technological Inventions of the Past 25 Years.” Write a short paper discussing how the invention has improved the quality of your life. Also discuss the ways in which the invention might interfere with your goal of graduating in engineering. Develop a plan to minimize any negative impact the invention might have on your education.

38. Explain how each of the “Grand Challenges for Engineering” listed in Section 2.9 will impact your future. What effect will each have on the engineering job market? (Will it increase or decrease the number of jobs? In which disciplines? Will it change the nature of current jobs?)
39. Pick one of the ten “important attributes of green engineering and sustainable designs” listed on Page 77. Research the attribute and write a two-page paper explaining:
    a. What is meant by the attribute?
    b. Why is it important?
    c. What are some strategies for accomplishing it?
    d. What are some of the difficulties in accomplishing it?
40. Make a list of (1) the rights and privileges and (2) the responsibilities and obligations you will have when you join the engineering profession.
41. Obtain information about the process of becoming a registered Professional Engineer in your state. How do the requirements and procedures differ from those presented in Section 2.10? What engineering disciplines are licensed in your state? Set a personal goal of passing the FE Exam before or soon after you graduate. Develop a set of strategies that will ensure you are well prepared to pass the exam.