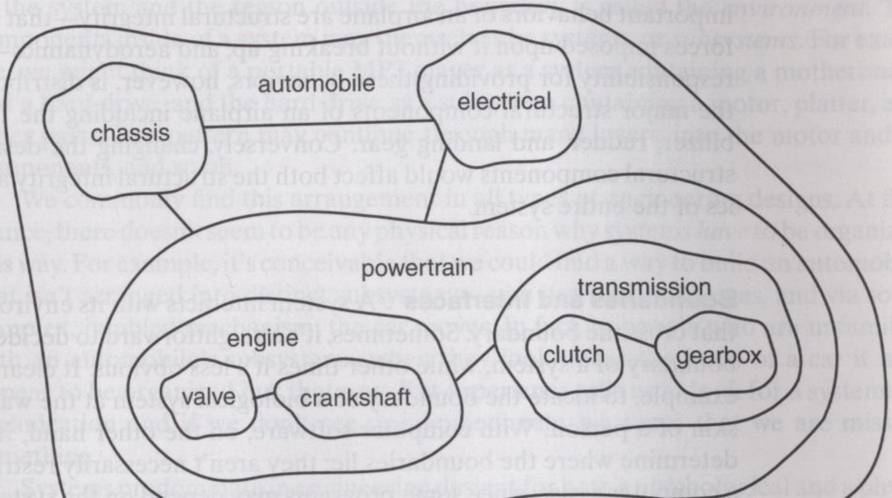

Figure 1.11 Using subsystems leads to a better breakdown of the automobile design problem.

1.4 ENGINEERING DISCIPLINES AND MAJORS

1.4.1 Introduction

Viewing a complex organization in terms of systems and subsystems makes it easier to manage, as well as easier to see the big picture. Inside of each subsystem, however, there is a lot of detail that requires specialized knowledge to comprehend. Looking again at an automobile, for example, a single person might easily learn how the power train connects to the electrical system and the chassis, but could spend an entire career trying to master the knowledge required to design each of these on her or his own. Because no one can be an expert at everything, the study and practice of engineering has evolved into a set of *majors* and *disciplines*. The main purpose of this section is to provide an overview of the most common engineering disciplines.

Before doing so, however, it's important to emphasize that engineering is inherently *multidisciplinary*. Engineers commonly work in teams of people from many different backgrounds. Engineers don't need to know the inner workings of each discipline, but they should understand the interfaces between them. Also, engineers need to be prepared to adapt; an informal survey of the author's friends and colleagues—mostly 20–25 years out of college—showed that most have switched areas more than once, and few are currently working in the area that they majored in, or are doing what they thought they would be doing when they graduated.

We believe that making the choice to study engineering—and developing a foundation that you can build on—is much more important than the choice of which field in engineering to major in. Society *needs* engineers of all disciplines in order to face the challenges ahead. Further, beyond the engineering profession, society would also benefit from more people in business and public policy who see the world from an engineer's perspective.

1.4.2 Overview of Engineering Disciplines

Because engineering is such a diverse and dynamic field constantly adapting to meet society's needs, it's impossible to summarize each area in detail and still stay relevant. Fortunately, there are excellent resources available on the WWW that provide regular updates on the state of the profession, as well as educational opportunities. In particular, as a starting point, we refer readers to the *Sloan Career Cornerstone Center* (www.careercornerstone.org), a non-profit resource center for those exploring career paths in science, technology, engineering, mathematics, computing, and medicine supported by the Alfred P. Sloan Foundation. Much of the material on individual disciplines that follows is derived, with permission, from their materials. The Career Cornerstone web site contains extensive information, including descriptions of and links to degree programs, professional societies, "day in the life" scenarios, and employment data. Another excellent web site, *TryEngineering* (www.tryengineering.org), is geared toward pre-college students and includes tips on preparation for engineering, as well as life profiles, lesson plans, and games.

Aerospace Engineering Aerospace engineers create machines, from airplanes that weigh over half a million pounds to spacecraft that travel over 17,000 miles an hour. They design, develop, and test aircraft, spacecraft, and missiles and supervise the manufacture of these products. Aerospace engineers who work with aircraft are called aeronautical engineers, and those working specifically with spacecraft are astronautical engineers.

Aerospace engineers develop new technologies for use in aviation, defense systems, and space exploration, often specializing in areas such as structural design, guidance, navigation and control, instrumentation and communication, or production methods. They often use computer-aided design (CAD) software, robotics, and lasers and advanced electronic optics. Some specialize in a particular type of aerospace product, such as commercial transports, military fighter jets, helicopters, spacecraft, or missiles and rockets. Other aerospace engineers are experts in aerodynamics, thermodynamics, celestial mechanics, propulsion, acoustics, or guidance and control systems.

Aerospace engineers typically work in the aerospace product and parts industry, although their skills are becoming increasingly valuable in other fields. For example, in the motor vehicles manufacturing industry, aerospace engineers design vehicles that have lower air resistance and, thus, increased fuel efficiency.

Agricultural Engineering Agricultural engineers combine engineering principles with biological and agricultural sciences. They work to develop equipment, systems, and processes that improve how the world's food supply is produced and distributed. They're involved in problem solving and analyzing current systems with expertise in improving the current process. They often have to look beyond a specific challenge, such as a machine or storage solution, and consider a larger system, and how improvements or changes would affect the whole.

Agricultural engineers often work in teams and their duties involve analysis of current methods and equipment applied to the production, packing, and delivery of food products. They might work in a group with other engineers, or those outside of engineering, to solve problems related to systems, processes, and machines. They may be involved in designing a water irrigation system, or in determining alternative uses for agricultural byproducts. They may participate in legal or financial consulting regarding agricultural processes, equipment, or issues.

Some agricultural engineers focus on machinery and design equipment important in agriculture and construction. Such engineers might have a special interest in crop handling, hydraulic power, or the growth of specific crops, and work for machine manufacturing firms. Other agricultural engineers design buildings or other structures used for livestock, storage of grains, or experimental growing facilities. Still other agricultural engineers focus on developing systems for food processing, such as drying processes, distillation, or long-term storage.

The type of job agricultural engineers have often determines whether they work inside or outside. However, most work inside a majority of the time. Some agricultural engineers whose tasks require visits to farms, animal operations, or seed manufacturers may find that they travel frequently. Many agricultural engineers find that working directly with growers, for example, provides immediate job satisfaction as it allows them to interact with people their work affects.

Architectural Engineering Architectural engineers apply engineering principles to the construction, planning, and design of buildings and other structures. They often work with other engineers and with architects, who focus on function layout or aesthetics of building projects. Architectural engineering often encompasses elements of other engineering disciplines, including mechanical, electrical, fire protection, and others. The architectural engineers are responsible for the different systems within a building, structure, or complex. Architectural engineers focus on several areas, including:

- the structural integrity of buildings,
- the design and analysis of heating, ventilating, and air conditioning systems,
- efficiency and design of plumbing, fire protection and electrical systems,
- acoustic and lighting planning, and
- energy conservation issues.

Most architectural engineers work in the construction industry or related areas. Others choose to work at non-profit organizations or firms. They spend most of their time in offices, consulting with clients and working with other engineers and architects. In addition, they often visit construction sites to review the progress of projects. Architectural engineers also work in different geographic locations based on the site of a construction project.

Bioengineering By combining biology and medicine with engineering, biomedical engineers develop devices and procedures that solve medical and health-related problems. Many do research, along with life scientists, chemists, and medical scientists, to develop and evaluate systems and products for use in the fields of biology and health, such as artificial organs, prostheses (artificial devices that replace missing body parts), instrumentation, medical information systems, and health management and care delivery systems.

Bioengineers design devices important for various medical procedures, such as computers that analyze blood or laser systems that perform corrective eye surgery. They develop artificial organs, imaging systems such as magnetic resonance, ultrasound, and x-ray, and devices for automating insulin injections or controlling body functions. Most engineers in this field require a sound background in one of the basic engineering specialties, such as mechanical or electronics engineering, in addition to specialized biomedical training. Some specialties within bioengineering or biomedical engineering include biomaterials, biomechanics, medical imaging, rehabilitation engineering, and orthopedic engineering.

Approximately 40 percent of biomedical engineers work for companies that manufacture products, primarily in the pharmaceutical, medicine manufacturing, and medical instruments and supplies industries; many others work for hospitals. Some also work for government agencies or as independent consultants.

Chemical Engineering Chemical engineers work in manufacturing, pharmaceuticals, healthcare, design and construction, pulp and paper, petrochemicals, food processing, specialty chemicals, polymers, biotechnology, and environmental health and safety industries, among others. Within these industries, chemical engineers rely on their knowledge of mathematics and science, particularly chemistry, to overcome technical problems safely and economically. And, of course, they draw upon and apply their engineering knowledge to solve any technical challenges they encounter. Their expertise also applies to law, education, publishing, finance, and medicine, as well as many other fields that require technical training.

Specifically, chemical engineers improve food processing techniques and methods of producing fertilizers, to increase the quantity and quality of available food. They also construct the synthetic fibers that make our clothes more comfortable and water-resistant; they develop methods to mass-produce drugs, making them more affordable; and they create safer, more efficient methods of refining petroleum products, making energy and chemical sources more productive and cost-effective. They also develop solutions to environmental problems such as pollution control and remediation.

Civil Engineering From the pyramids of Egypt to the space station Freedom, civil engineers have always faced the challenges of the future, advancing civilization and building our quality of life. Today, the world is undergoing vast changes: the technological revolution, population growth, environmental concerns, and more. All create unique challenges for civil engineers of every specialty. The next few decades will be most creative, demanding, and rewarding for civil engineers.

Today, civil engineers are in the forefront of technology. They are users of sophisticated high-tech products, applying the latest concepts in computer-aided design (CAD) during design, construction, project scheduling, and cost control. Civil engineering is about community service, development, and improvement—the planning, design, construction, and operation of facilities essential to modern life, ranging from transit systems to offshore structures to space satellites. Civil engineers are problem solvers, meeting the challenges of pollution, traffic congestion, drinking water and energy needs, urban redevelopment, and community planning. Our future as a nation will be closely tied to space, energy, the environment, and our ability to interact with and compete in the global economy. Civil engineers will perform a vital role in linking these themes and improving quality of life for the 21st century. As the technological revolution expands, as the world's population increases, and as environmental concerns mount, civil engineers' skills will become increasingly essential.

Civil Engineering branches into seven major divisions of engineering: Structural, Environmental, Geotechnical, Water Resources, Transportation, Construction, and Urban Planning. In practice, these aren't always hard and fixed categories, but they offer a helpful way to review a very diverse and dynamic field.

Computer Engineering, Computer Science, and Software Engineering Computer technology and information processing have become an important part of all engineering disciplines. Computer Engineering, Computer Science, and Software Engineering are three closely related fields that focus on developing the technology that many other disciplines depend upon. While there's significant overlap among them, they are separate fields that we summarize below.

Computer engineers analyze, design, and evaluate computer systems, both hardware and software. They might work on system such as a flexible manufacturing system or a "smart" device or instrument. Computer engineers often find themselves focusing on problems or challenges that result in new state-of-the-art products that integrate computer capabilities. They work on the interface between different pieces of hardware and strive to provide new capabilities to existing and new systems or products. The work of a computer engineer is grounded in the hardware—from circuits to architecture—but also focuses on operating systems and software. Computer engineers must understand logic design, microprocessor system design, computer architecture, and computer interfacing, and continually focus on system requirements and design. While software engineers primarily focus on creating the software systems individuals and businesses use, computer engineers, too, may design and develop some software applications.

Computer scientists impact society through their work in many areas. Because computer technology is embedded in so many products, services, and systems, computer scientists work in almost every industry. Design of next-generation computer systems, computer networking, biomedical information systems, gaming systems, search engines, web browsers, and computerized package distribution systems are all examples of projects a computer scientist might work on. Some computer scientists focus on improving software reliability, network security, and information retrieval systems, or even work as consultants to a financial services company.

Computer software engineers apply the principles and techniques of computer science, engineering, and mathematical analysis to the design, development, testing, and evaluation of the software and systems that enable computers to perform their many applications. Software engineers working in applications or systems development analyze users' needs and design, construct, test, and maintain computer applications software or systems. Software engineers can be involved in the design and development of many types of software, including software for operating systems and network distribution, and compilers, which convert programs for execution on a computer. In programming, or coding, software engineers instruct a computer, line by line, how to perform a function. They also solve technical problems that arise. Software engineers must possess strong programming skills, but are more concerned with developing algorithms and analyzing and solving programming problems than with actually writing code.

Electrical Engineering Electrical and electronics engineers conduct research, and design, develop, test, and oversee the development of electronic systems and the manufacture of electrical and electronic equipment and devices. From the global positioning system that continuously provides the location of a vehicle to giant electric power generators, electrical and electronics engineers are responsible for a wide range of technologies. Electrical engineering has many subfields, some of the most common of which we outline below.

Telecommunications is a prime growth area for electrical/electronics engineers. This includes developing services for wired and wireless networks for homes and