

Engineers

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Significant Points

- Overall job opportunities in engineering are expected to be good, but to vary by specialty.
- A bachelor's degree is required for most entry-level jobs.
- Starting salaries are significantly higher than those of college graduates in other fields.
- Continuing education is critical to keep abreast of the latest technology.

Nature of the Work

Engineers apply the theories and principles of science and mathematics to research and develop economical solutions to technical problems. Their work is the link between perceived social needs and commercial applications. Engineers design products, machinery to build those products, factories in which those products are made, and the systems that ensure the quality of the products and efficiency of the workforce and manufacturing process. Engineers design, plan, and supervise the construction of buildings, highways, and transit systems. They develop and implement improved ways to extract, process, and use raw materials, such as petroleum and natural gas. They develop new materials that both improve the performance of products and take advantage of advances in technology. They harness the power of the sun, the Earth, atoms, and electricity for use in supplying the Nation's power needs, and create millions of products using power. They analyze the impact of the products they develop or the systems they design on the environment and people using them. Engineering knowledge is applied to improving many things, including the quality of health care, the safety of food products, and the efficient operation of financial systems.

Engineers consider many factors when developing a new product. For example, in developing an industrial robot, engineers determine precisely what function the robot needs to perform; design and test the robot's components; fit the components together in an integrated plan; and evaluate the design's overall effectiveness, cost, reliability, and safety. This process applies to many different products, such as chemicals, computers, gas turbines, helicopters, and toys.

In addition to design and development, many engineers work in testing, production, or maintenance. These engineers supervise production in factories, determine the causes of breakdowns, and test manufactured products to maintain quality. They also estimate the time and cost to complete projects. Some move into engineering management or into sales. In sales, an engineering background enables them to discuss technical aspects and assist in product planning, installation, and use. (See the statements on engineering and natural sciences managers and sales engineers elsewhere in the *Handbook*.)

Most engineers specialize. More than 25 major specialties are recognized by professional societies, and the major branches have numerous subdivisions. Some examples include structural, environmental, and transportation engineering, which are subdivisions of civil engineering; and ceramic, metallurgical, and polymer engineering, which are subdivisions of materials engineering. Engineers also may specialize in one industry, such as motor vehicles, or in one field of technology, such as turbines or semiconductor materials.

This statement, which contains an overall discussion of engineering, is followed by separate statements on 14 engineering branches: aerospace; agricultural; biomedical; chemical; civil; computer hardware; electrical and electronics, except computer; environmental; industrial, including health and safety; materials; mechanical; mining and geological, including mining safety; nuclear; and petroleum engineering. (Computer software engineers are discussed elsewhere in the *Handbook*.) Some branches of engineering not covered in detail in the Handbook, but for which there are established college programs, include architectural engineering—the design of a building's internal support structure; and marine engineering—the design and installation of ship machinery and propulsion systems.

Engineers in each branch have a base of knowledge and training that can be applied in many fields. Electronics engineers, for example, work in the medical, computer, communications, and missile guidance fields. Because there are many separate problems to solve in a large engineering project, engineers in one field often work closely with specialists in other scientific, engineering, and business occupations.

Engineers use computers to produce and analyze designs; to simulate and test how a machine, structure, or system operates; and to generate specifications for parts. New communications technologies using computers are changing the way engineers work on designs. Engineers can collaborate on designs with other engineers around the country or even abroad, using the Internet or related communications systems. Many engineers also use computers to monitor product quality and control process efficiency. They spend a great deal of time writing reports and consulting with other engineers, as complex projects often require an interdisciplinary team of engineers. Supervisory engineers are responsible for major components or entire projects.

Working Conditions

Most engineers work in office buildings, laboratories, or industrial plants. Others may spend time outdoors at construction sites, mines, and oil and gas exploration and production sites, where they monitor or direct operations or solve onsite problems. Some engineers travel extensively to plants or worksites.

Many engineers work a standard 40-hour week. At times, deadlines or design standards may bring extra pressure to a job. When this happens, engineers may work longer hours and experience considerable stress.

Employment

In 2000, engineers held 1.5 million jobs. The following tabulation shows the distribution of employment by engineering specialty.

<i>Specialty</i>	<i>Employment</i>	<i>Percent</i>
Total, all engineers	1,465,000	100
Electrical and electronics	288,000	20
Civil	232,000	16
Mechanical	221,000	15
Industrial, including health and safety	198,000	14
Computer hardware	60,000	4
Environmental	52,000	4
Aerospace	50,000	3
Chemical	33,000	2
Materials	33,000	2
Nuclear	14,000	1
Petroleum	9,000	1
Biomedical	7,200	<1
Mining and geological, including mining safety	6,500	<1
Marine engineers and naval architects	5,100	<1
Agricultural	2,400	<1
All other engineers	253,000	17

Almost half of all wage and salary engineering jobs were found in manufacturing industries, such as transportation equipment, electrical and electronic equipment, industrial machinery, and instruments and related products. About 401,000 wage and salary jobs were in services industries, primarily in engineering and architectural services, research and testing services, and business services, where firms designed construction projects or did other engineering work on a contractual basis. Engineers also worked in the construction and transportation, communications and utilities industries.

Federal, State, and local governments employed about 179,000 engineers in 2000. Almost half of these were in the Federal Government, mainly in the Departments of Defense, Transportation, Agriculture, Interior, and Energy, and in the National Aeronautics and Space Administration. Most engineers in State and local government agencies worked in highway and public works departments. In 2000, about 43,000 engineers were self-employed, many as consultants.

Engineers are employed in every State, in small and large cities, and in rural areas. Some branches of engineering are concentrated in particular industries and geographic areas, as discussed later in this chapter.

Training, Other Qualifications, and Advancement

A bachelor's degree in engineering is required for almost all entry-level engineering jobs. College graduates with a degree in a physical science or mathematics occasionally may qualify for some engineering jobs, especially in specialties in high demand. Most engineering degrees are granted in electrical, electronics, mechanical, or civil engineering. However, engineers trained in one branch may work in related branches. For example, many aerospace engineers have training in mechanical engineering. This flexibility allows employers to meet staffing needs in new technologies and specialties in which engineers are in short supply. It also allows engineers to shift to fields with better employment prospects or to those that more closely match their interests.

Most engineering programs involve a concentration of study in an engineering specialty, along with courses in both mathematics and science. Most programs include a design course, sometimes accompanied by a computer or laboratory class or both.

In addition to the standard engineering degree, many colleges offer 2- or 4-year degree programs in engineering technology. These programs, which usually include various hands-on laboratory classes that focus on current issues, prepare students for practical design and production work, rather than for jobs which require more theoretical and scientific knowledge. Graduates of 4-year technology

programs may get jobs similar to those obtained by graduates with a bachelor's degree in engineering. Engineering technology graduates, however, are not qualified to register as professional engineers under the same terms as graduates with degrees in engineering. Some employers regard technology program graduates as having skills between those of a technician and an engineer.

Graduate training is essential for engineering faculty positions and many research and development programs, but is not required for the majority of entry-level engineering jobs. Many engineers obtain graduate degrees in engineering or business administration to learn new technology and broaden their education. Many high-level executives in government and industry began their careers as engineers.

About 330 colleges and universities offer bachelor's degree programs in engineering that are accredited by the Accreditation Board for Engineering and Technology (ABET), and about 250 colleges offer accredited bachelor's degree programs in engineering technology. ABET accreditation is based on an examination of an engineering program's student achievement, program improvement, faculty, curricular content, facilities, and institutional commitment. Although most institutions offer programs in the major branches of engineering, only a few offer programs in the smaller specialties. Also, programs of the same title may vary in content. For example, some programs emphasize industrial practices, preparing students for a job in industry, whereas others are more theoretical and are designed to prepare students for graduate work. Therefore, students should investigate curricula and check accreditations carefully before selecting a college.

Admissions requirements for undergraduate engineering schools include a solid background in mathematics (algebra, geometry, trigonometry, and calculus) and sciences (biology, chemistry, and physics), and courses in English, social studies, humanities, and computers. Bachelor's degree programs in engineering typically are designed to last 4 years, but many students find that it takes between 4 and 5 years to complete their studies. In a typical 4-year college curriculum, the first 2 years are spent studying mathematics, basic sciences, introductory engineering, humanities, and social sciences. In the last 2 years, most courses are in engineering, usually with a concentration in one branch. For example, the last 2 years of an aerospace program might include courses in fluid mechanics, heat transfer, applied aerodynamics, analytical mechanics, flight vehicle design, trajectory dynamics, and aerospace propulsion systems. Some programs offer a general engineering curriculum; students then specialize in graduate school or on the job.

Some engineering schools and 2-year colleges have agreements whereby the 2-year college provides the initial engineering education, and the engineering school automatically admits students for their last 2 years. In addition, a few engineering schools have arrangements whereby a student spends 3 years in a liberal arts college studying pre-engineering subjects and 2 years in an engineering school studying core subjects, and then receives a bachelor's degree from each school. Some colleges and universities offer 5-year master's degree programs. Some 5- or even 6-year cooperative plans combine classroom study and practical work, permitting students to gain valuable experience and finance part of their education. All 50 States and the District of Columbia usually require licensure for engineers who offer their services directly to the public. Engineers who are licensed are called Professional Engineers (PE). This licensure generally requires a degree from an ABET-accredited engineering program, 4 years of relevant work experience, and successful completion of a State examination. Recent graduates can start the licensing process by taking the examination in two stages. The initial Fundamentals of Engineering (FE) examination can be taken upon graduation. Engineers who pass this examination commonly are called Engineers in Training (EIT) or Engineer Interns (EI). The EIT certification

usually is valid for 10 years. After acquiring suitable work experience, EITs can take the second examination, the Principles and Practice of Engineering Exam. Several States have imposed mandatory continuing education requirements for relicensure. Most States recognize licensure from other States. Many civil, electrical, mechanical, and chemical engineers are licensed as PEs.

Engineers should be creative, inquisitive, analytical, and detail-oriented. They should be able to work as part of a team and to communicate well, both orally and in writing. Communication abilities are becoming more important because much of their work is becoming more diversified, meaning that engineers interact with specialists in a wide range of fields outside engineering.

Beginning engineering graduates usually work under the supervision of experienced engineers and, in large companies, also may receive formal classroom or seminar-type training. As new engineers gain knowledge and experience, they are assigned more difficult projects with greater independence to develop designs, solve problems, and make decisions. Engineers may advance to become technical specialists or to supervise a staff or team of engineers and technicians. Some may eventually become engineering managers or enter other managerial or sales jobs. (See the statements under management and business and financial operations occupations, and sales and related occupations elsewhere in the *Handbook*.)

Job Outlook

Overall engineering employment is expected to increase more slowly than the average for all occupations. However, overall job opportunities in engineering are expected to be good through 2010 because the number of engineering degrees granted is not expected to increase significantly over the 2000-10 period. Projected employment growth and, thus, job opportunities vary by specialty, ranging from a decline in employment of mining and geological engineers to faster-than-average growth among environmental engineers. Competitive pressures and advancing technology will force companies to improve and update product designs and to optimize their manufacturing processes. Employers will rely on engineers to further increase productivity, as investment in plant and equipment increases to expand output of goods and services. New computer and communications systems have improved the design process, enabling engineers to produce and analyze various product designs much more rapidly than in the past and to collaborate on designs with other engineers throughout the world. Despite these widespread applications, computer technology is not expected to limit employment opportunities. Finally, additional engineers will be needed to improve or build new roads, bridges, water and pollution control systems, and other public facilities.

Many engineering jobs are related to developing technologies used in national defense. Because defense expenditures—particularly expenditures for aircraft, missiles, and other weapons systems—are not expected to return to previously high levels, job outlook may not be as favorable for engineers working in defense-related fields although defense expenditures are expected to increase.

The number of bachelor's degrees awarded in engineering began declining in 1987 and has continued to stay at about the same level through much of the 1990s. The total number of graduates from engineering programs is not expected to increase significantly over the projection period.

Although only a relatively small proportion of engineers leaves the profession each year, many job openings will arise from replacement needs. A greater proportion of replacement openings is created by engineers who transfer to management, sales, or other professional occupations than by those who leave the labor force.

Most industries are less likely to lay off engineers than other workers. Many engineers work on long-term research and development projects or in other activities that continue even during

economic slowdowns. In industries such as electronics and aerospace, however, large cutbacks in defense expenditures and government research and development funds, as well as the trend toward contracting out engineering work to engineering services firms, have resulted in significant layoffs for engineers.

It is important for engineers, like those working in other technical occupations, to continue their education throughout their careers because much of their value to their employer depends on their knowledge of the latest technology. Although the pace of technological change varies by engineering specialty and industry, advances in technology have significantly affected every engineering discipline. Engineers in high-technology areas, such as advanced electronics or information technology, may find that technical knowledge can become obsolete rapidly. Even those who continue their education are vulnerable to layoffs if the particular technology or product in which they have specialized becomes obsolete. By keeping current in their field, engineers are able to deliver the best solutions and greatest value to their employers. Engineers who have not kept current in their field may find themselves passed over for promotions or vulnerable to layoffs, should they occur. On the other hand, it often is these high-technology areas that offer the greatest challenges, the most interesting work, and the highest salaries. Therefore, the choice of engineering specialty and employer involves an assessment not only of the potential rewards but also of the risk of technological obsolescence.

Related Occupations

Engineers apply the principles of physical science and mathematics in their work. Other workers who use scientific and mathematical principles include architects, except landscape and naval; engineering and natural sciences managers; computer and information systems managers; mathematicians; drafters; engineering technicians; sales engineers; science technicians; and physical and life scientists, including agricultural and food scientists, biological and medical scientists, conservation scientists and foresters, atmospheric scientists, chemists and materials scientists, environmental scientists and geoscientists, and physicists and astronomers.

Sources of Additional Information

High school students interested in obtaining a full package of guidance materials and information (product number SP-01) on a variety of engineering disciplines should contact the Junior Engineering Technical Society by sending \$3.50 to:

► JETS-Guidance, 1420 King St., Suite 405, Alexandria, VA 22314-2794. Internet: <http://www.jets.org>

High school students interested in obtaining information on ABET-accredited engineering programs should contact:

► The Accreditation Board for Engineering and Technology, Inc., 111 Market Place, Suite 1050, Baltimore, MD 21202-4012. Internet: <http://www.abet.org>

Non-licensed engineers and college students interested in obtaining information on Professional Engineer licensure should contact:

► The National Society of Professional Engineers, 1420 King St., Alexandria, VA 22314-2794. Internet: <http://www.nspe.org>

► National Council of Examiners for Engineers and Surveying, P.O. Box 1686, Clemson, SC 29633-1686. Internet: <http://www.ncees.org>

Information on general engineering education and career resources is available from:

► American Society for Engineering Education, 1818 N St. NW., Suite 600, Washington, DC 20036-2479. Internet: <http://www.asee.org>

Information on obtaining an engineering position with the Federal Government is available from the Office of Personnel Management (OPM) through a telephone-based system. Consult your telephone directory under U.S. Government for a local number or

call (912) 757-3000; Federal Relay Service: (800) 877-8339. The first number is not tollfree, and charges may result. Information also is available from the OPM Internet site: <http://www.usajobs.opm.gov>.

Non-high school students and those wanting more detailed information should contact societies representing the individual branches of engineering. Each can provide information about careers in the particular branch. The individual statements that follow also provide other information in detail on aerospace; agricultural; biomedical; chemical; civil; computer hardware; electrical and electronics, except computer; environmental; industrial, including health and safety; materials; mechanical; mining and geological, including mining safety; nuclear; and petroleum engineering.

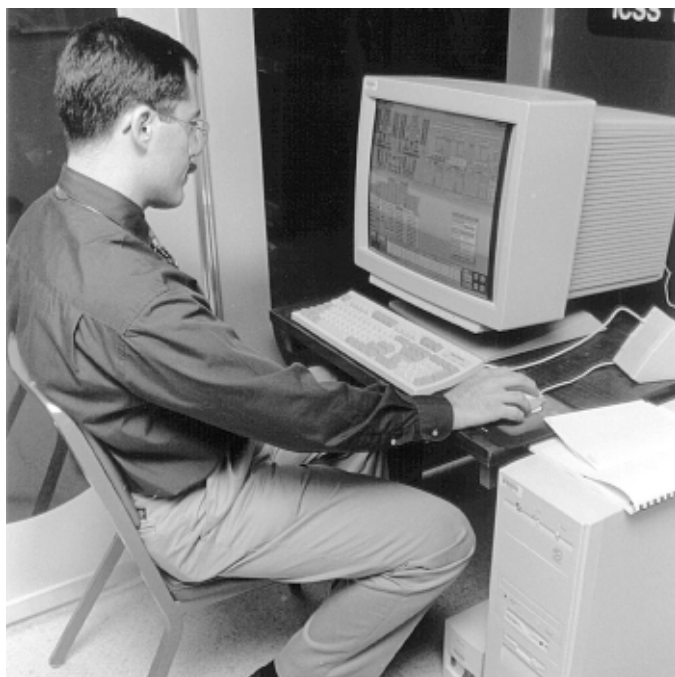
Aerospace Engineers

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Nature of the Work

Aerospace engineers are responsible for developing extraordinary machines, from airplanes that weigh over a 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 manufacturing of these products. Aerospace engineers who work with aircraft are considered *aeronautical engineers*, and those working specifically with spacecraft are considered *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), robotics, and lasers and advanced electronic optics to assist them. They also may specialize in a particular type of aerospace product, such as commercial transports, military fighter jets, helicopters, spacecraft, or missiles and rockets. Aerospace engineers may be experts in aerodynamics,



Aerospace engineers use computer-aided design to develop new technologies.

thermodynamics, celestial mechanics, propulsion, acoustics, or guidance and control systems.

Aerospace engineers typically are employed within the aerospace industry, although their skills are becoming increasingly valuable in other fields. For example, aerospace engineers in the motor vehicles manufacturing industry design vehicles that have lower air resistance, increasing the fuel efficiency of vehicles.

Employment

Aerospace engineers held about 50,000 jobs in 2000. Almost one-half worked in the aircraft and parts and guided missile and space vehicle manufacturing industries. Federal Government agencies, primarily the Department of Defense and the National Aeronautics and Space Administration, provided almost 15 percent of jobs. Engineering and architectural services, research and testing services, and search and navigation equipment firms accounted for most of the remaining jobs.

Job Outlook

Employment of aerospace engineers is expected to grow about as fast as the average for all occupations through 2010. The decline in Defense Department expenditures for military aircraft, missiles, and other aerospace systems has restricted defense-related employment opportunities in recent years. However, an expected increase in defense spending in these areas may result in increased employment of aerospace engineers in defense-related areas during the 2000-10 period. Demand should increase for aerospace engineers to design and produce civilian aircraft, due to the need to accommodate increasing passenger traffic and to replace much of the present fleet with quieter and more fuel-efficient aircraft. Additional opportunities for aerospace engineers will be created with aircraft manufacturers to search for ways to use existing technology for new purposes. Some employment opportunities also will occur in industries not typically associated with aerospace, such as motor vehicles. Most job openings, however, will result from the need to replace aerospace engineers who transfer to other occupations or leave the labor force.

Earnings

Median annual earnings of aerospace engineers were \$67,930 in 2000. The middle 50 percent earned between \$56,410 and \$82,570. The lowest 10 percent earned less than \$47,700, and the highest 10 percent earned more than \$94,310. Median annual earnings in the industries employing the largest numbers of aerospace engineers in 2000 were:

Federal Government	\$74,170
Search and navigation equipment	71,020
Aircraft and parts	68,230
Guided missiles, space vehicles, and parts	65,830

According to a 2001 salary survey by the National Association of Colleges and Employers, bachelor's degree candidates in aerospace engineering received starting offers averaging \$46,918 a year, master's degree candidates were offered \$59,955, and Ph.D. candidates were offered \$64,167.

Sources of Additional Information

For further information about aerospace engineers, contact:

► Aerospace Industries Association, 1250 Eye St. NW., Washington, DC 20005. Internet: <http://www.aia-aerospace.org>

► American Institute of Aeronautics and Astronautics, Inc., Suite 500, 1801 Alexander Bell Dr., Reston, VA 20191-4344. Internet: <http://www.aiaa.org>

(See introduction to the section on engineers for information on working conditions, training requirements, and other sources of additional information.)