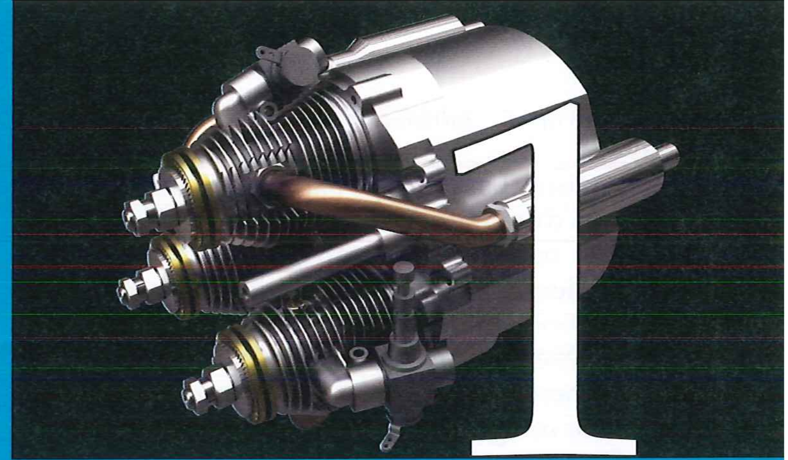
# Drafting and the Drafter



## Learning Objectives

After studying this chapter, you will be able to:

- Define the role of drafting in industry.
- Explain the purpose of technical drawings.
- Describe how sketches are used to communicate ideas.
- List and describe the four steps in the design method.
- Explain the importance of models in industry.
- Identify the types of careers available in drafting and related fields.
- Describe the educational background and skills required for careers in drafting and related fields.
- Describe the duties associated with different types of careers in drafting.

## Technical Terms

Aerospace engineer
Agricultural engineer
Algorithms
Architects
Brainstorming
Ceramic engineer
Chemical engineer
Checker
Civil engineer
Design
Design drafter
Design method
Detail drafter
Detailer
Drafting
Drafting trainee
Electrical engineer
Heuristics
Industrial designer
Industrial engineer
Landscape architecture
Layout drafter
Mechanical drawings
Mechanical engineer
Metallurgical engineer
Mockup
Model
Nuclear engineer
Petroleum engineer
Presentation drawings
Problem
Problem solving
Prototype
Scale model
Sketches
Stereolithography
Technical drawing
Technical illustrator
Virtual reality

Never in history has the world been so technically oriented. With so many new developments in industry, science, medicine, technology, and space, the universal language of drafting has become even more essential in solving problems, creating designs, and communicating ideas to others.

***Drafting*** is the process of creating technical drawings. A ***technical drawing*** is a graphic representation of a real thing—an idea, an object, a process, or a system, **Figure 1-1**. Graphic representation has evolved along two related, but separate, directions according to purpose: artistic and technical.

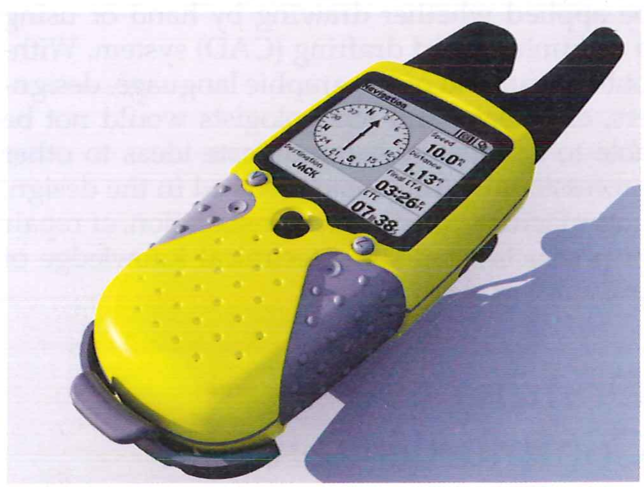


**Figure 1-1**. A technical drawing is the most efficient method of communication between designers, engineers, and technologists. Shown is a rendered solid model of a Global Positioning System (GPS) device created with computer-aided drafting (CAD) software. (Garmin International)

Artists have long expressed their ideas through drawings. Drawings allow abstract concepts to be communicated in ways that people can understand. Frequently, pictures are better understood than words. Historically, images were preserved through simple pictures or drawings. There were no photographs or electronic forms of images until relatively recently.

From the earliest times, technical drawings were used as the method of representing the design of objects to be made or constructed. Evidence that drawings existed in ancient times can be seen in the ruins of complex structures such as aqueducts, bridges, fortresses, pyramids, and palaces. These structures could not have been built without technical drawings to serve as a guide for the work. Over time, the "universal graphic language" evolved. Today, the basic principles of this universal language are known throughout the world. Even though people around the world speak different languages, the graphic language has remained common. Graphic language is a basic and natural form of communication that is universal and timeless.

The technology for making technical drawings has advanced far beyond hand sketching and typical mechanical techniques. However, the knowledge of the basic concepts of representing objects graphically still provides the foundation for clear communication. These concepts or principles are well-established and must be applied whether drawing by hand or using a computer-aided drafting (CAD) system. Without a command of the graphic language, designers, engineers, and technologists would not be able to adequately communicate ideas to other professionals. All people involved in the design, manufacture, construction, installation, or repair of products need some technical knowledge of this universal language.

# Drafting as a Communication Tool

The primary purpose of drafting is to communicate an idea, plan, or object to some other person, **Figure 1-2**. However, this is not the only reason for making technical drawings. The process also serves as a problem-solving method, a design tool, and a way to record acceptable solutions. However, drafting is a basic form of communication and the drafter should always remember that the drawings produced are for someone else. Drawings must be clear and specific. They must follow accepted rules and utilize standard symbols and conventions. Standards developed by the American National Standards Institute (ANSI) serve as the basic guide for technical drafting. Some large companies have adopted standards that suit their own needs. These company standards may not conform in every respect to the ANSI standards. However, most companies do follow ANSI standards.

There are many types of technical drawings used to communicate ideas. Some of the most common are sketches, mechanical drawings, sets of drawings, and presentation drawings.

## Sketches

***Sketches*** are very useful in communicating undeveloped ideas. They are normally drawn freehand, **Figure 1-3**. A product usually begins as an idea in the mind. The form, dimensions, and details of the product are not yet clear, but the basic concept is there. By sketching the mental image on paper, the idea can be communicated, manipulated, and refined. Others can participate in the process by adding their ideas, or the basic idea can be saved for future reference. This is the creative phase of technical communication.

Sketches may be detailed or schematic in form. The type of sketch will depend on the nature of the idea and degree of visualization associated with the idea. However, the sketch will provide a quick image of the concept "contained in the head" of the designer when words alone cannot describe something new or unfamiliar.

## Mechanical Drawings

***Mechanical drawings*** show an idea or product in a more refined or improved state than sketches. They are typically generated as CAD drawings. Mechanical drawings represent ideas that have moved from the idea or conceptual stage to a more practical solution. Size, shape, and form have been developed to provide a scaled representation of the object.

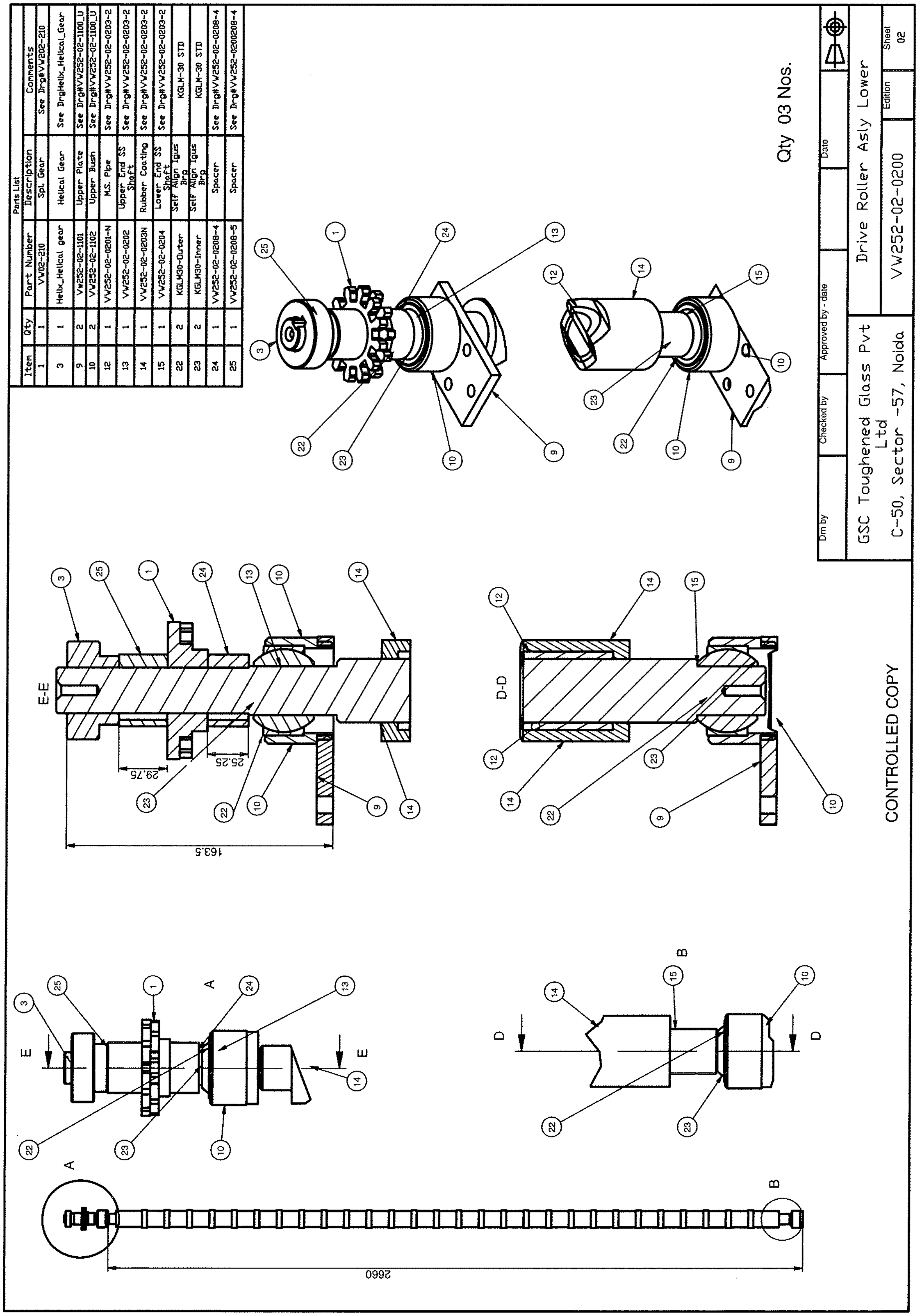



**Figure 1-2**. Drawings are used to describe objects. Shown is a CAD-based assembly drawing with information about parts and dimensions used in manufacturing. Orthographic, section, and pictorial views are used to describe the assembly. (Autodesk, Inc.)

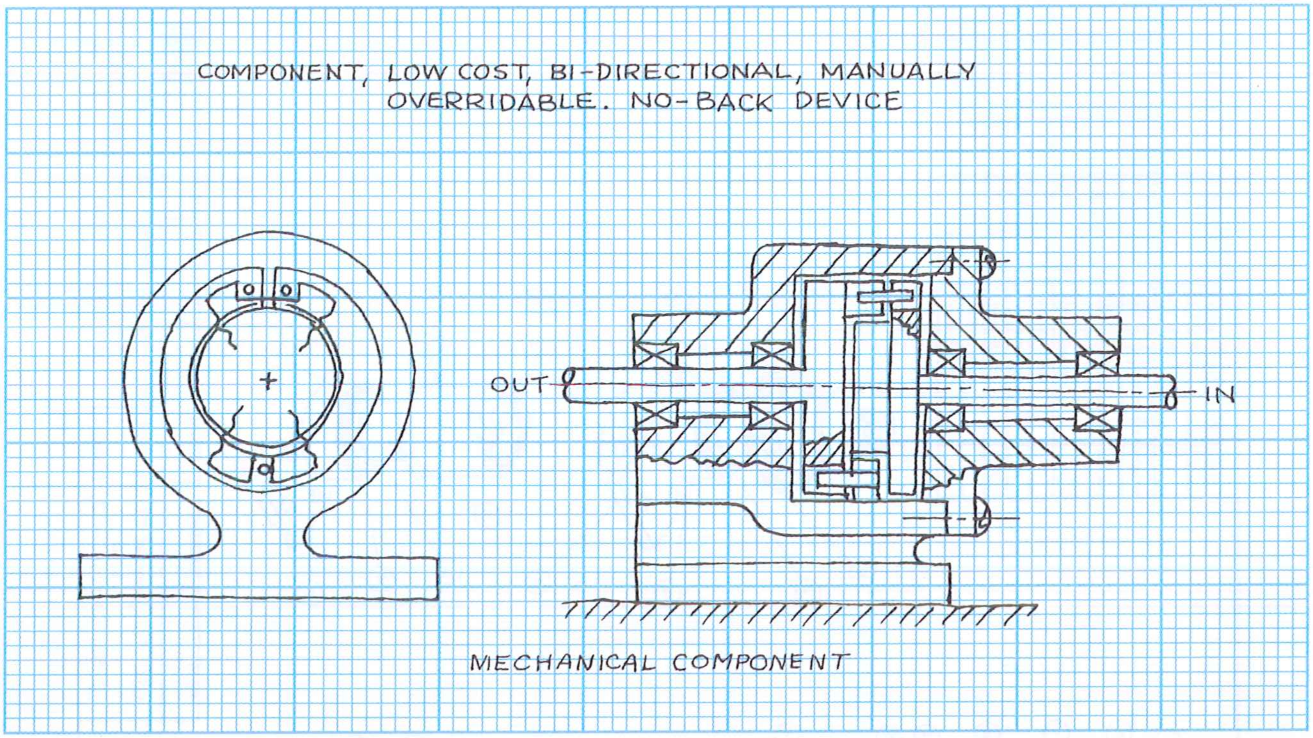



**Figure 1-3**. Design engineers use preliminary sketches to get their ideas on paper. (Sperry Flight Systems Div.)

## Sets of Drawings

Sets of drawings are commonly used in manufacturing and construction projects. Instead of one specific drawing, a group of drawings is used to communicate the complete product or idea. At this level, the idea has been refined still further from a sketch. Evaluation of the design has been completed, details have been added, and costs figured. Instructions for the production of the item are included. A set of drawings generally contains all of the information required for production, **Figure 1-4**.

## Presentation Drawings

***Presentation drawings*** normally consist of several drawings and other information combined together, **Figure 1-5**. Drawings and technical descriptions of products are usually combined with other forms of communication for presentation to the prospective buyer, client, financier, or management. Verbal descriptions of the basic features or specifications are accompanied by pictorial drawings of the product. The purpose of the presentation is typically to secure acceptance of the proposed product. The goal is to provide a true-to-life image of the finished object that highlights the primary features and specifications.

## Other Types of Technical Drawings

Each technical drawing, from a sketch to a pictorial, plays a significant role in the development, manufacture, and sale of products. Other specialized or unique forms of technical drawings are sometimes needed as well. For example, patent drawings, reference drawings, advertising drawings, technical literature drawings, and maintenance and repair drawings may also be required, **Figure 1-6**. However, the main purpose of all of these drawings is to communicate ideas.

# Drafting as a Problem-Solving Tool

***Problem solving*** is the process of seeking practical solutions to a problem. A ***problem*** is a situation, question, or matter requiring choices and action for a solution. Problem-solving methods vary depending on the type and complexity

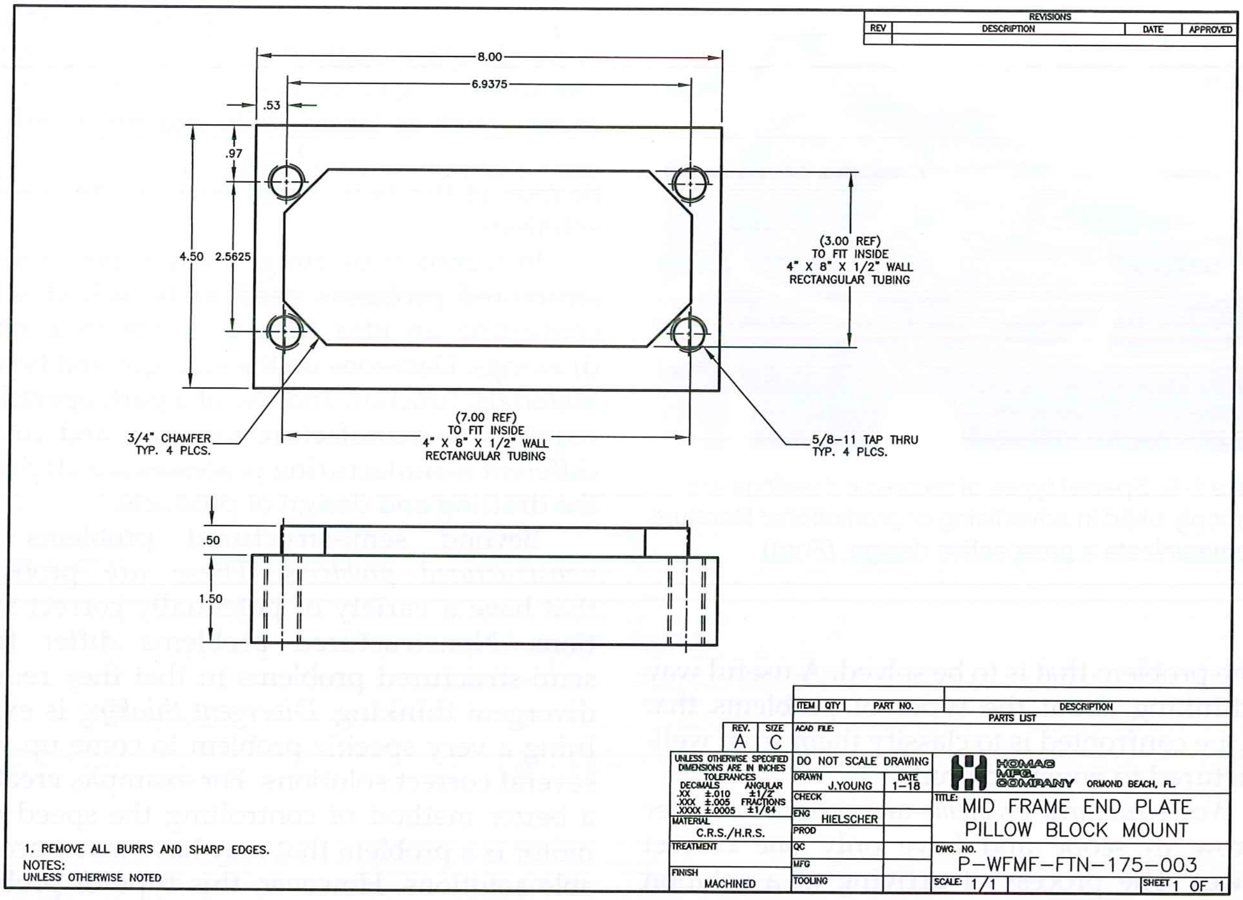



**Figure 1-4**. A set of drawings may contain many different types of drawings and views, such as this detail drawing for a welding fixture assembly. (Autodesk, Inc.)

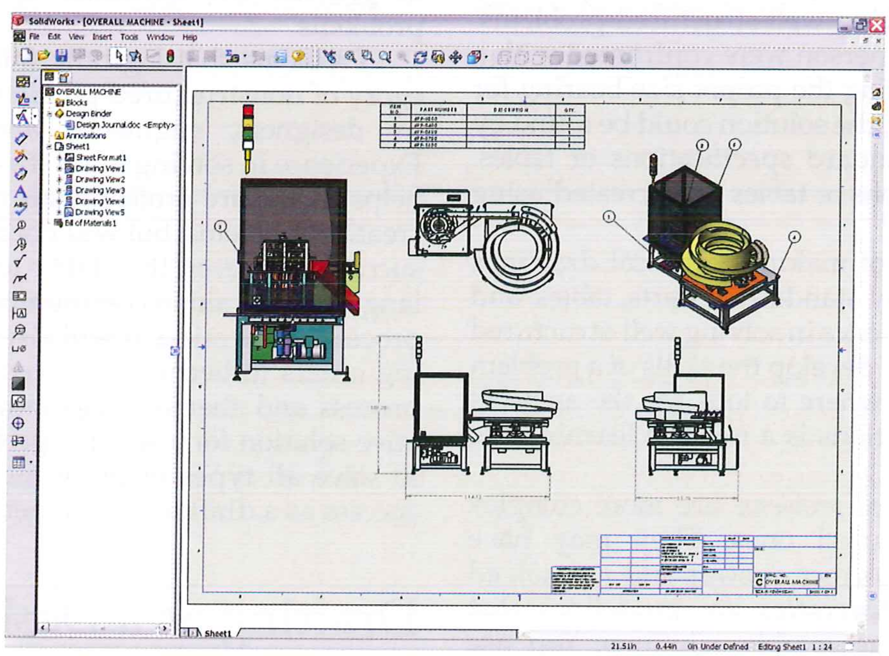



**Figure 1-5**. Several types of presentation drawings are sometimes combined to describe the various components of a product. Shown are CAD-generated views of a machine assembly. (Image courtesy of SolidWorks Corporation)

**Figure 1-6**. Special types of technical drawings are commonly used in advertising or promotional literature to communicate a prospective design. (Ford)

of the problem that is to be solved. A useful way of thinking about the types of problems that may be confronted is to classify them from well-structured to nonstructured.

*Well-structured problems* are generally rather narrow in scope and have only one correct answer. The process of arriving at a solution for a well-structured problem is usually accomplished through *convergent thinking*. This is where the situation is examined to arrive at the one best solution. ***Algorithms*** (mathematical equations) are useful in solving well-structured problems. For example, if a person were confronted with a problem of selecting the proper size bearing for a particular shaft, the solution could be found by simply using standard specifications or tables. These specifications or tables were created using algorithms.

The process of making technical drawings involves the use of standards, charts, tables, and references. Experience in solving well-structured problems helps to develop the skills of a problem solver. Knowing where to look for the answers to technical questions is a must in learning the graphic language.

*Semi-structured problems* are more complex than well-structured ones. They may have more than one correct answer and are solved by heuristics. ***Heuristics*** are guidelines that usually lead to acceptable solutions. You use heuristics in your everyday life without really thinking much about it. An example might be to perform a set of tasks in order of importance. Another might be to perform a group of manufacturing processes in a logical successive order—such as locate, drill, and ream. Solving semi-structured problems requires the identification of the factors that bear on the possible solutions.

In technical drafting, many types of semi-structured problems need to be solved when converting an idea from a sketch to a set of drawings. Decisions on the strength and type of materials, function and use of a part, operations required to manufacture the part, and cost of different manufacturing processes are all part of the drafting and design of products.

Beyond semi-structured problems are *nonstructured problems*. These are problems that have a variety of potentially correct solutions. Nonstructured problems differ from semi-structured problems in that they require divergent thinking. *Divergent thinking* is examining a very specific problem to come up with several correct solutions. For example, creating a better method of controlling the speed of a motor is a problem that may have many acceptable solutions. However, this type of problem is seldom solved by referring to an algorithm or applying heuristics to produce an acceptable solution. Creative problem solving is required to provide the solutions to these types of problems.

Problems that logically fall within the category of nonstructured problems are dealt with by designers, engineers, and technologists. Experience in solving more structured problems helps to prepare professionals to solve the more creative problems, but will not necessarily mean success. However, the ability to use the graphic language will aid in communicating the creative process of the mind. It will also aid in encouraging others to become involved in the thinking process and thereby help move toward a creative solution for a specific problem. The ability to solve all types of problems is necessary for success as a drafter or designer.

## Drafting as a Design Tool

Engineers, industrial designers, and drafters make extensive use of the *design method* in arriving at a final solution to a design problem. An example of a final solution in sketched form is shown in **Figure 1-7**. From basic sketches come the machines and products of our technological age.

Space vehicles such as the Mars Exploration Rover were first created by designers using the design method. The various components of the design were developed through the use of sketches and renderings, **Figure 1-8**. Then a prototype of the vehicle was constructed and tested. In **Figure 1-9**, a photograph of the Spirit Rover on the Martian surface is shown.

## Using the Design Method

The ***design method*** is a systematic procedure for approaching a design problem and arriving at a solution. The method consists of four steps. These are problem definition, development of preliminary solutions, preliminary solution refinement, and decision and implementation.

As used in this text, ***design*** is the result of creative imagination that forms ideas as preliminary solutions to problems. Evaluation of these ideas provides functional solutions to problems.

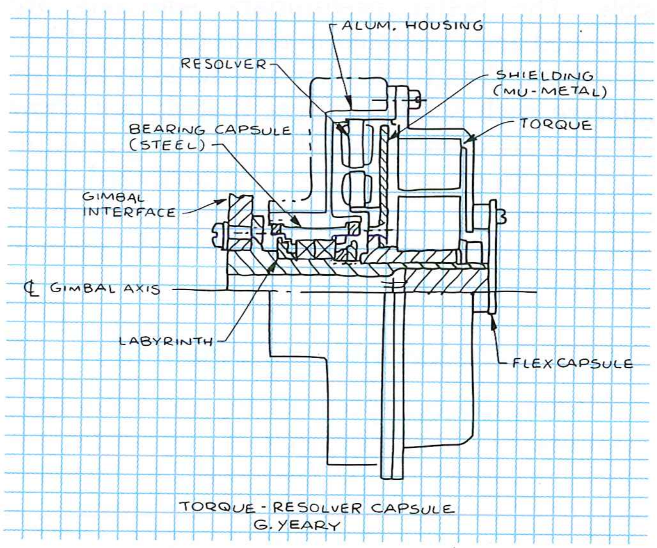



**Figure 1-7**. Sketching is one of the most useful techniques to a designer in "thinking through" a solution to a problem.

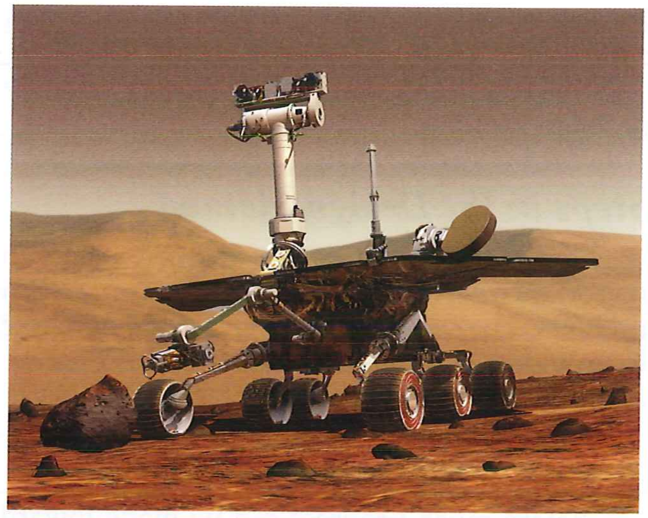


**Figure 1-8**. An artist's rendition of a Mars Exploration Rover helps communicate the idea to the public. The vehicle has the ability to function as a robotic geologist. (NASA)

Many of the problems you will solve as a student of design drafting will have a clearly stated approach and solution. For example, you will be asked to supply the third view when two views are given. All that is left for you to do is solve for the missing view. While these problems are necessary in learning the basics of drafting

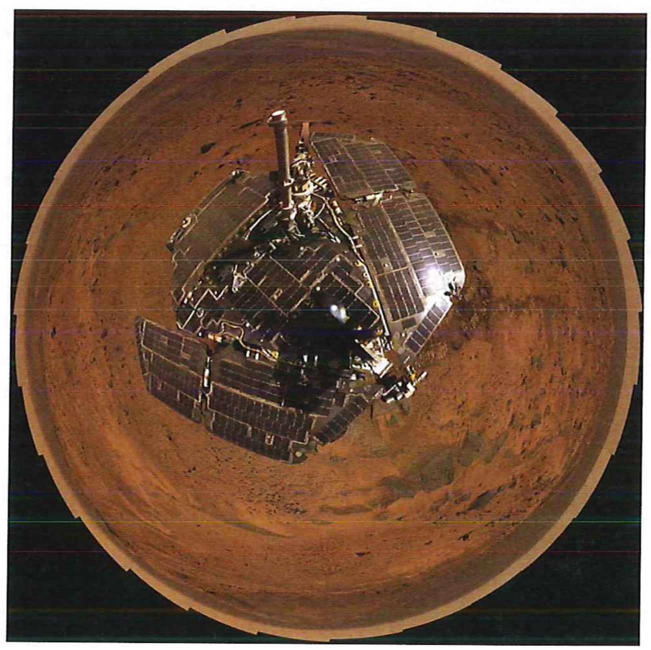


**Figure 1-9**. A panoramic photo of the Mars Spirit Rover taken by the spacecraft itself on the Columbia Hills range inside Mars' Gusev Crater. (NASA)

and other subjects, there are other problems you will need to solve that are not clearly identified. Solving these problems will require creative problem solving.

## Steps in the Design Method

Each step in the design method plays an important role in developing a solution to a design problem. The steps are listed and explained here to provide a clear understanding of their nature and use.

### Step 1: Problem definition

Before much progress can be made toward the solution of a problem, the problem must be clearly defined. This step is divided into four parts:

- **Statement**. The statement of the problem should be clear. It should describe the need that is the basis of the problem. In the problem statement, there should be no stated requirements or limitations such as quantity or size.
- **Requirements**. The requirements of the problem should be listed. The requirements include items such as needed and desired features.
- **Limitations or restrictions**. The limitations or restrictions on the design should be specified. For example, it may be necessary to describe limiting physical factors (such as size, weight, and materials) and limiting monetary factors.
- **Research**. The research of the problem should further aid in defining the problem. Information must be gathered relative to the number and size of items to be included and other factors, such as safety. Questions need to be asked in order to reveal the various requirements of the problem statement.

Answers for these questions are obtained from previous experience, actual measurements, research in technical publications, and discussions with knowledgeable sources.

### Step 2: Preliminary solutions

The second step in the design method is the most creative and will be influenced by the backgrounds (experiences and personal knowledge) of the designers. If the designers have had considerable experience with similar problems, and if the problem has been carefully researched, they will be able to develop more creative and useful solutions.

There are two methods by which this step may be developed—individual methods and group methods. An individual may work alone and list all of the solutions that come to mind, no matter how unconventional they may seem. The designer should try to think of unique uses of existing items for possible solutions as well as standard or customary ways of solving the problem.

Small groups (up to 10 or 12 individuals) can also work effectively in the above manner by brainstorming. ***Brainstorming*** is a means of working with others to develop creative solutions to problems. Each person makes suggestions as they come to mind. New and unusual solutions often come forward as various individuals are stimulated by the suggestions of others.

It is important to get as many preliminary solutions as possible. No attempt should be made during brainstorming to evaluate the various solutions suggested. Evaluation takes place in the next step.

### Step 3: Preliminary solution refinement

In this step, all preliminary ideas are combined or resolved into as few solutions as possible. The better preliminary solutions are reviewed and evaluated in terms of the problem definition. Rough sketches are made to further analyze each solution. Ideas that do not show promise are eliminated. The remaining preliminary solutions are refined and analyzed until only three or four are left. These remaining ideas are then evaluated in terms of the general problem statement.

### Step 4: Decision and implementation

When the best preliminary solutions have been selected, a decision chart is prepared showing comparison of the solutions on the main requirements and limitations of the problem. A rating system of weighing each factor for comparison on a scale of 1 to 3 may be used, with 1 being the best rating. Where two or more preliminary solutions seem equally desirable on a particular factor of comparison, an equal rating should be given. The solution is then determined from the best rating of the preliminary solutions considered. This solution is implemented by preparing a working drawing from sketches and building a model and/or prototype of the design solution, **Figure 1-10**.

## Models

The use of models in the design process plays an important role in industry. Two important advantages in using models are improved communication between technical personnel and greater visualization of problems and their solution by nontechnical and management personnel.

Models are also used extensively in the presentation and promotion of a product or design solution. In addition, they are useful in training programs for personnel who will use the equipment. The term ***model*** is used to refer to three-dimensional scale replicas, mockups, and prototypes.

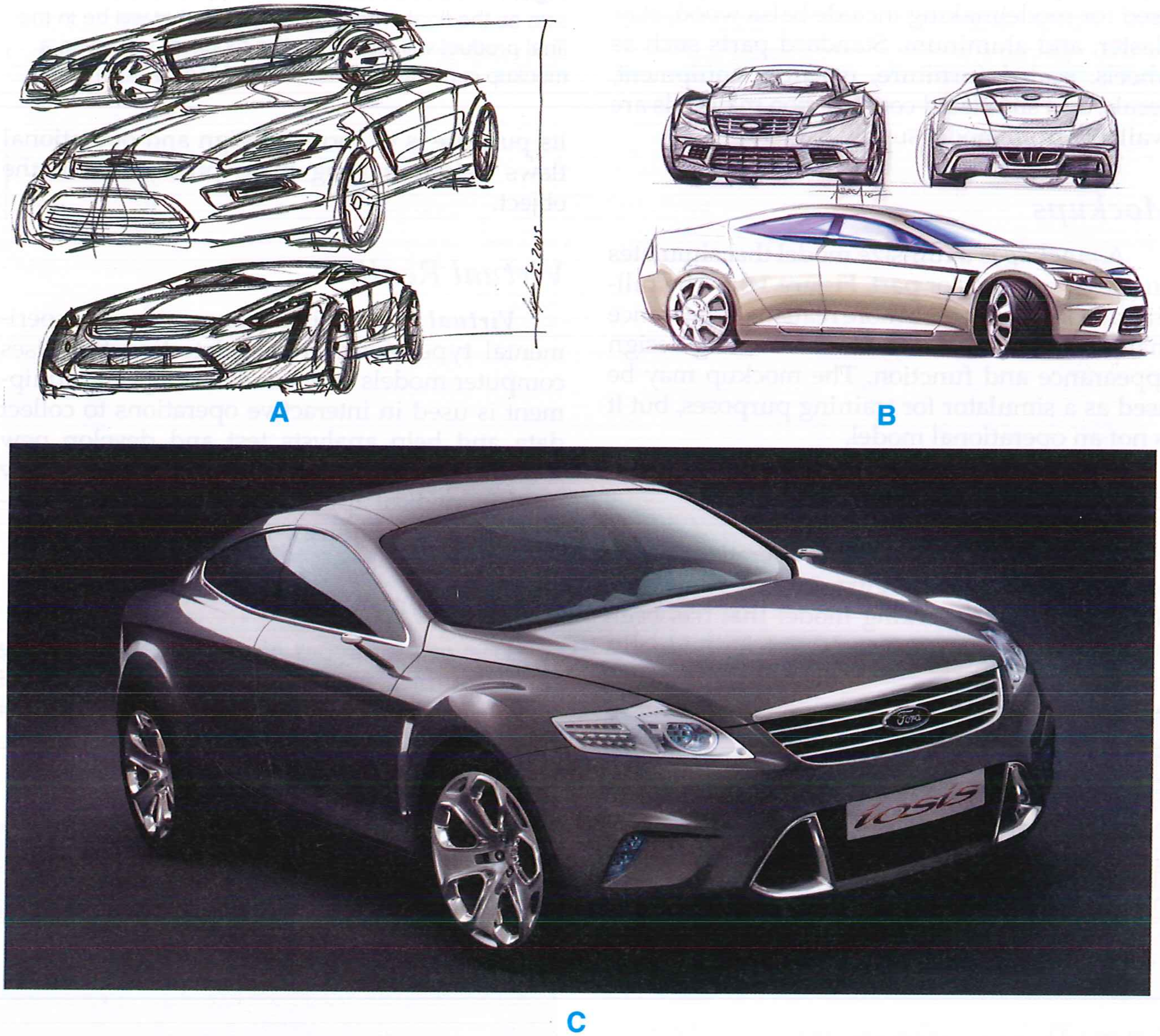



**Figure 1-10**. Design solutions evolve from the development of sketches and more advanced representations. A—Thumbnail sketches of a new concept car design. B—Renderings showing different views of the concept car. C—A prototype model of the car. (Ford)

## Scale Models

A ***scale model*** is a replica of the actual, or proposed, object. It is made smaller or larger to show proper proportion, relative size of parts, and general overall appearance. Some scale models are working models used to aid engineers and designers in their analysis of the function and value of certain design features, **Figure 1-11**. The size, or scale, of models may vary depending on the size of the actual object and the purpose of the model.

Construction of models in industry is the work of professional modelmakers. Materials used for modelmaking include balsa wood, clay, plaster, and aluminum. Standard parts such as wheels, scaled furniture, machine equipment, decals, and simulated construction materials are available from model supply dealers.

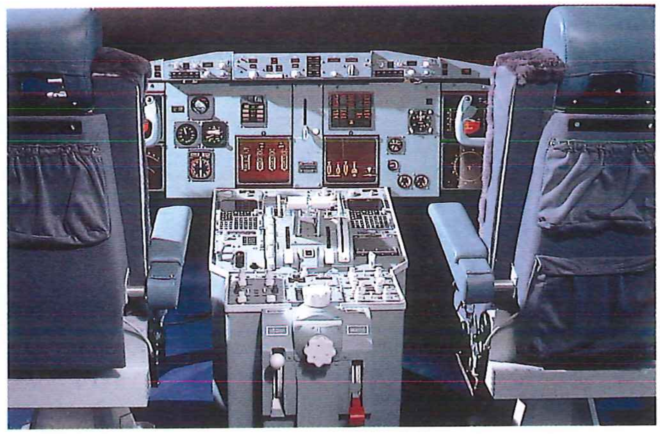


**Figure 1-12**. Full-size mockups appear the same size as the final product. Everything that will be in the final product will also be in the mockup. However, a mockup is not functional. (Scale Models Unlimited)

## Mockups

A ***mockup*** is a full-size model that simulates an actual machine or part, **Figure 1-12**. The full-size mockup presents a more realistic appearance than a scale model and aids in checking design appearance and function. The mockup may be used as a simulator for training purposes, but it is not an operational model.

## Prototypes

A ***prototype*** is a full-size operating model of the actual object, **Figure 1-13**. It is usually the first full-size working model that has been constructed by making each part individually. Its purpose is to correct design and operational flaws before starting mass production of the object.

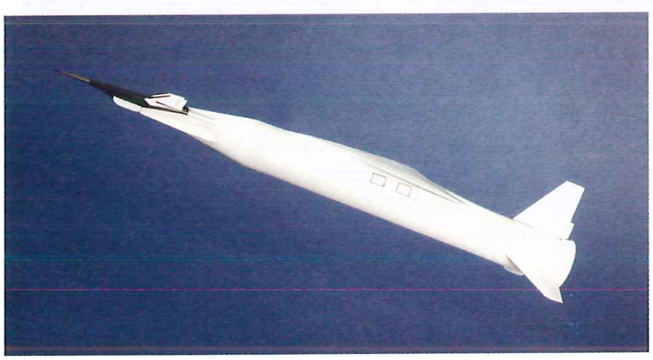


**Figure 1-11**. Scale models are frequently useful in aerospace engineering. Shown is a 3-foot-long model of the Hyper-X flight vehicle used in research for developing hypersonic aircraft. (NASA)

## Virtual Reality

***Virtual reality*** is a very modern, experimental type of research and testing that uses computer models and simulators. Special equipment is used in interactive operations to collect data and help analysts test and develop new technologies. Virtual reality testing is commonly used in medical applications and space exploration programs, **Figure 1-14**.

## Stereolithography

Design prototypes of complex parts can be produced in a few hours by a process called ***stereolithography***. This process produces a hard plastic model that can be studied to determine whether changes need to be made to the part.

**Figure 1-13**. An automotive prototype is a full-size operating model of a new product idea. (Ford)

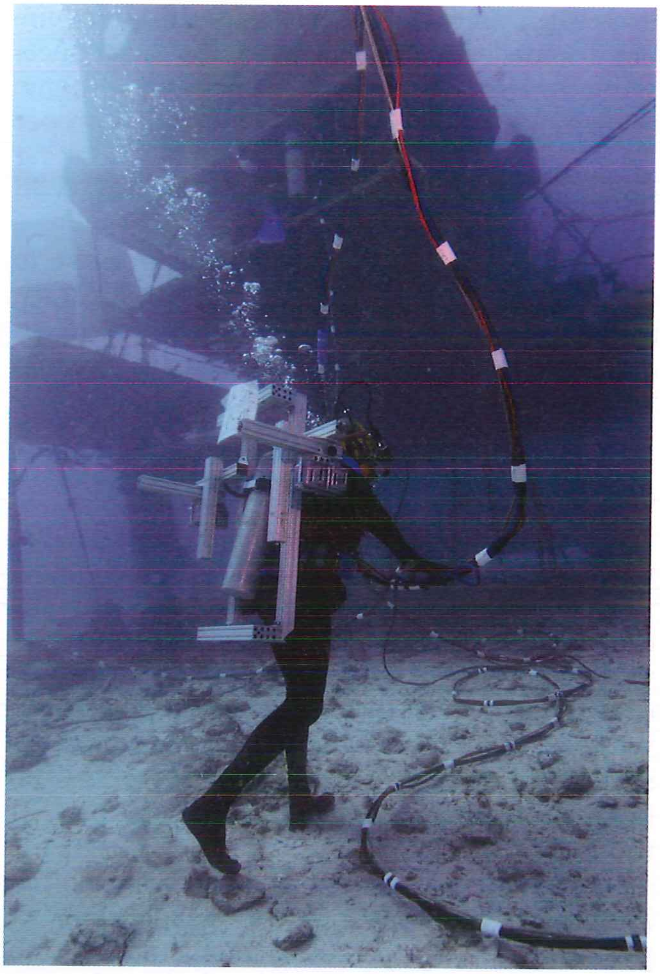


**Figure 1-14**. A crew member using special backpack equipment to conduct a simulated moonwalk in the Aquarius Underwater Laboratory during the NASA Extreme Environment Mission Operations (NEEMO) project. The project used virtual reality methods to test concepts for future space exploration, including the practice of remote health care procedures on patient simulators. (NASA)

Design data created on a CAD system supply the necessary information to guide the operation of the stereolithography machine. The operation is similar to that of a CNC machine tool. A low-power laser beam is used to harden a liquid photocurable polymer plastic in the shape defined by the computer. This is accomplished by curing thin layers of the polymer to form the desired shape. Construction begins at the bottom of the object and progresses layer by layer until the object is completed. Ultraviolet curing is required to complete the process.

# Careers in Drafting

There are many careers and opportunities available in the field of drafting. Job titles and duties vary from industry to industry, and the nature of activities may vary among industries under the same general classification. However, the career areas discussed in this chapter are typical for the job levels and industries described.

As you develop drawing skills and progress in your drafting studies, it is important to remember that the fundamentals of drafting are the same, regardless of the type of drawing discipline. The symbols used, the lettering styles, and the general arrangement of the drawing may vary from mechanical to electronic drafting or from architectural to map drafting. However, the standards used and the fundamental processes involved in producing, checking, and reproducing finished drawings are much the same. Once the basics of drafting are understood, a person with a continuing interest in drafting may select an area of specialization to gain additional experience.

The career fields discussed in this section do not require a college degree. However, preparation in a technical school or community college will give you skills that may be advantageous. This discussion should be supplemented by researching career information about specific industries of your choice.

## *Drafting Trainee*

At the time of employment, a ***drafting trainee*** is expected to have a basic understanding of drafting instruments or software and skill in their use, a knowledge of procedures for representing views of objects, and the ability to produce neat freehand sketches and lettering. Generally, a trainee will work under the close supervision of senior drafting personnel.

Typical duties of a drafting trainee include revising drawings, redrawing or repairing damaged drawings, and gathering information from reference sources needed to detail components (for themselves or other drafters), **Figure 1-15**. The work-training program will involve drawing detail and section views, dimensioning and preparing tables, and developing working drawings. The trainee must become familiar with

**Figure 1-15.** Drafting trainees will gain experience in a number of drawing areas and activities. Later on in their careers, they will draw on this experience to solve many different problems presented to them.

the company's drafting standards, as expressed in its drafting room manual.

Taking courses in drafting, mathematics, science, electronics, metals, manufacturing, and architecture is recommended. Additionally, courses teaching the use of CAD are essential for work in most companies.

## Detail Drafter

A ***detail drafter*** is well-informed in the fundamentals of drafting, and has gained proficiency and speed in handling instruments or CAD software. A detail drafter usually works as a ***detailer*** in the preparation of working drawings for manufacturing or construction. Primarily, detail drafters will revise drawings and bills of material, prepare detail drawings, and work on simple assembly drawings, wiring or circuit diagrams, charts, and graphs.

Detail drafters should be thoroughly familiar with drafting standards and symbols, and must be able to make basic calculations in their area of drafting. They also should have a practical knowledge of either engineering or architectural materials and procedures.

## Layout Drafter

It is the job of the ***layout drafter*** to prove out the product design, using sketches and models and a scaled layout drawing. Design layout helps to determine the manufacturing feasibility of a product.

This is an exacting type of drafting, requiring a knowledge of the field and the products being drawn. It may include preparation of some original layouts and studies to determine proper fits or clearances. It also could involve making some changes in the design after consulting with the engineer in charge.

Since layout drafters may be required to make dimensional computations and allowances, a knowledge of machine shop practices and materials is essential. The ability to research reference manuals is also necessary.

## Design Drafter

The ***design drafter*** is a senior level drafter, representing the highest level of drafting skill. After acquiring considerable experience in the drafting field, a design drafter will do layout work and prepare complex detail and assembly drawings of machines, equipment, structures, wiring diagrams, piping diagrams, and construction drawings. A design drafter works from basic data supplied by architects, engineers, or industrial designers.

The design drafter must possess a sound knowledge of good engineering and drafting procedures, shop practices, mathematics, and science. He or she may make design changes when required, in consultation with the design engineer or architect. The drafter must then follow through on changes made to see that they are reflected on other drawings involved. The design drafter may prepare cost estimates based on the materials and parts list, according to the design problem. Instructing and supervising other drafters in assigned tasks or other related drawing problems is usually another responsibility of the design drafter.

## Checker

After a drawing is finished by a drafter, it must be reviewed for accuracy, completeness, clarity, and manufacturing feasibility. This examination is made by an experienced drafter called a ***checker***.

Checkers are drafters who understand manufacturing processes and are thoroughly familiar with both the drafting practices in their particular industry and standards set by

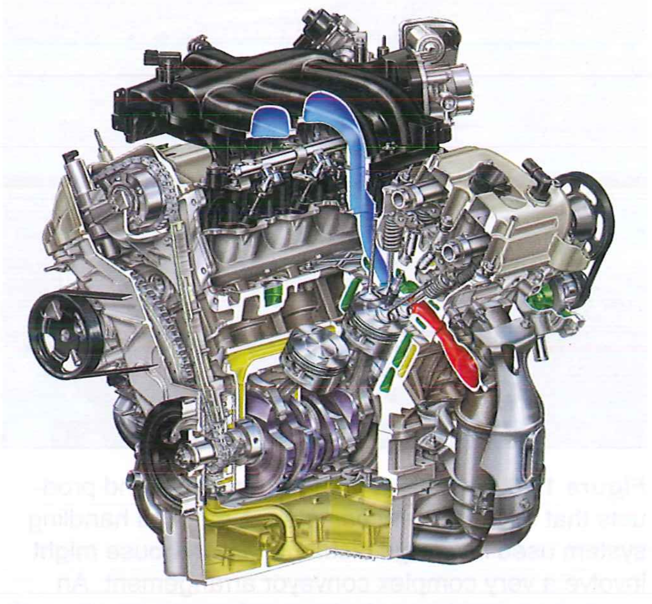


Figure 1-16. Technical illustrators present images of things that are more easily understood in pictorial views, such as the internal components of a four-cylinder, dual overhead cam automobile engine. (Ford)

ANSI. Usually, checkers have reached the level of design drafters. As such, they may suggest modifications in design or specifications, or other changes to facilitate production. The approval signature of a checker normally will appear in the title block of the drawing.

### Technical Illustrator

Technical illustration is the drawing of objects (usually machine parts, assemblies, or mechanisms) in pictorial form. These illustrations may be enhanced by line weight variations, shading, or colors to give them a more realistic appearance, **Figure 1-16.**

A ***technical illustrator*** should thoroughly understand drafting fundamentals, including the construction of pictorial views. The illustrator should be able to read and interpret working drawings and must have some background in art, industrial design, and manufacturing processes.

Technical illustrations are used in manufacturing and production to assist workers in interpreting the drawings. Such illustrations also aid workers who are unable to read blueprints, by helping them visualize the object and its construction. A more "artistic" type of technical illustration is often used in marketing and advertising literature.

## Careers Related to Drafting

There are a number of career opportunities related to the drafting field. All require a skilled background in drafting, since it is used on the job, as well as advanced CAD skills. Many of these related career fields require preparation at the college level.

### Architect

***Architects*** plan, design, and oversee the construction of residential, commercial, and industrial building projects. They often are involved in such fields as city planning and ***landscape architecture*** (the design of parks, golf courses, and other outdoor facilities). Because the field is so broad, architects tend to specialize in one type of structure, such as residences, churches, schools, factories, or office buildings.

The architect's duties begin with a study of the client's needs and desires. They then progress through preliminary plans and sketches, finished drawings, and often, presentation renderings and scale models, **Figure 1-17.** The architect also must develop cost estimates, prepare specifications, and supervise construction of the project.

Figure 1-17. Presentation renderings are commonly used by architects to help clients better understand a design. (Autodesk, Inc.)

Training for a career in architecture usually consists of four or five years of college, including drafting experience and CAD training. An architect should have a sound understanding of mathematics and science, as well as the arts and humanities.

## Industrial Designer

An ***industrial designer*** is concerned with the development of solutions to problems that involve esthetics, materials, manufacturing processes, human factors, and creativity. The industrial designer's task is working to develop scientific ideas and discoveries into products and services that are useful for humans.

Products such as office machines, furniture, systems for controlling forest fires, and special equipment to enable handicapped persons to lead fuller and more productive lives are goals of the industrial designer's efforts, **Figure 1-18**.

There are two areas of emphasis in the four-year college preparatory program for this career. One is product design; the other is mechanical design.

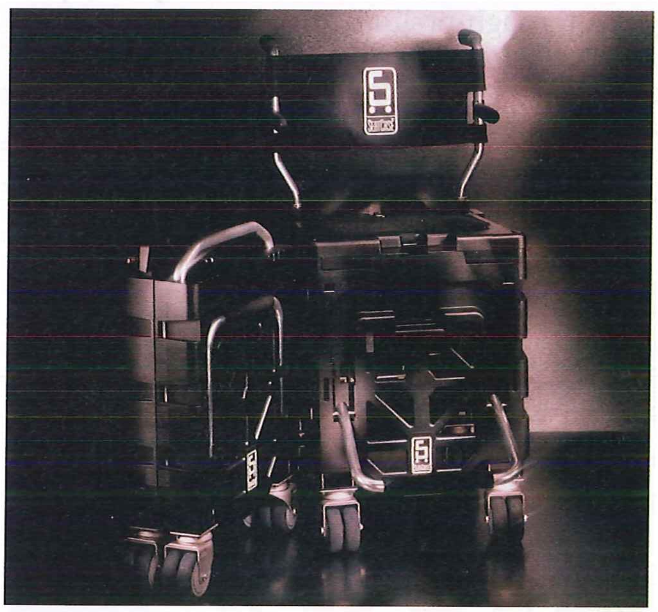


**Figure 1-18**. Industrial designers often develop products to make the lives of people easier or more satisfying. This folding travel wheelchair, designed to maneuver easily in airplane, train, or bus aisles, won a design excellence award from the Industrial Designers Society of America. It weighs only 16 pounds and folds down to briefcase size, as shown at left, for storage. (SEATCASE, Inc.)

**Figure 1-19**. Engineers deal with systems and products that might be very complex. A material handling system used in a large distribution warehouse might involve a very complex conveyor arrangement. An engineer is needed to design a solution to this type of problem. (SI Handling Systems, Inc.)

The product designer works primarily with problems where the user interacts with the product (such as the design of a telephone, automobile steering wheel, or furniture for a library). The mechanical designer addresses problems where there is a machine-to-machine relationship, and no direct human interaction is involved (such as the design of an automobile transmission or machine tool).

Although an industrial designer may not be working as a drafter, a good background in drafting, CAD, mathematics, and science is required. The designer should be creative and have a thorough understanding of problem-solving methods.

The design drafting process is not a one-person job. It involves a team of engineers, designers, and drafters.

## Engineer

Like industrial designers, professional engineers are also concerned with creative design solutions, **Figure 1-19**. They usually have a strong background in science and mathematics and computers, since they must be able to apply these principles in searching out practical problem solutions.

The engineer's field of interest and knowledge is broad, even though many engineers specialize in one particular area. A good understanding of drafting procedures is needed so that the engineer can communicate with other members of the technical team. The chief means of expressing ideas to others is by original freehand sketches. Engineers also review drawings prepared by drafters and make suggestions for their alteration.

There are a number of areas of specialization within the broad field of engineering, but all require four to five years of college education. Some of the better-known areas are presented here.

## Aerospace engineering

This specialization deals with the design and development of all types of conventional and experimental aircraft and aerospace vehicles. An ***aerospace engineer*** usually concentrates on one area, such as aerodynamics, propulsion systems, structures, instrumentation, or manufacturing.

## Agricultural engineering

The problems of production, handling, and processing of food and fiber for the benefit of society is the province of the ***agricultural engineer***. More specifically, the agricultural engineer's specialty is the design and development of farm machinery, farm structures, processing equipment, and the control and conservation of water resources.

## Ceramic engineering

A ***ceramic engineer*** is concerned with the design and development of nonmetallic materials into useful products. Examples are as widely varied as glassware, joint replacement in humans, electrical insulators, and the fusing of refractory materials as protective coatings for metals. Ceramic engineers have developed coating materials for metal signs, cooking utensils, and sinks.

## Chemical engineering

Chemical engineering is the branch of engineering that processes materials to undergo chemical change. A ***chemical engineer*** designs and develop the processes and equipment that convert raw materials into useful products such as petrochemicals, plastics, synthetic fibers, and medicines.

## Civil engineering

The design and development of transportation systems, including highways, railroads, and airports, is done by the ***civil engineer***. This field of engineering also includes the design and construction of water systems, waste disposal systems, marine harbors, pipelines, buildings, dams, and bridges, **Figure 1-20**. Computer expertise is essential in this field.

## Electrical engineering

The field of electrical engineering has three major branches: electrical power, electronics, and computer engineering. The electrical power field involves the generation, transmission, and utilization of electrical energy. An ***electrical engineer*** specializing in this field designs major projects, such as power transmission lines or the electrical distribution systems for large buildings or industries. Electrical engineers are also involved in the design of equipment such as electrical generators and motors, **Figure 1-21**.

Engineers working in electronics are concerned with communication systems, especially

**Figure 1-20.** One of the greatest civil engineering projects in history was the building of the Panama Canal to connect the Atlantic and Pacific oceans. There are six locks on the 51-mile long waterway. To accomplish construction, many civil engineers had to solve a variety of problems that this task presented. (Panama Canal Commission)

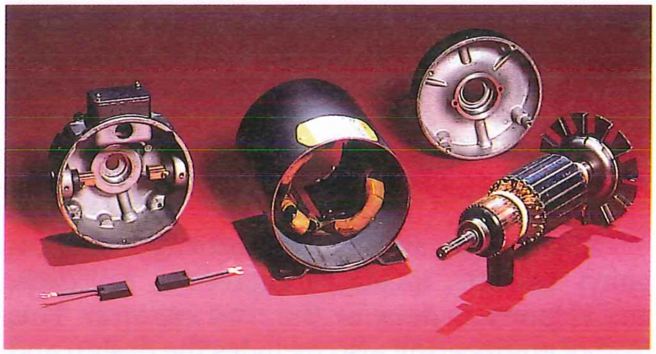


**Figure 1-21.** Electrical engineers design and develop a wide range of devices and systems, from huge power plants to small DC wound-field motors. Electrical engineers also work in the electronics and computer fields. (Baldor)

in radio and television broadcasting. They also work with industrial electronics, designing automated control systems for processing equipment.

Engineers working in the field of computer engineering design computers to control equipment and devices, such as automobiles, aerospace vehicles, and manufacturing machinery.

## Industrial engineering

Industrial engineering is concerned with the design, operation, and management of systems. An ***industrial engineer*** designs plant layouts and devises improved methods of manufacturing and processing. Industrial engineers also work with quality control, production control, and cost analysis. To develop and coordinate these systems, industrial engineers work with engineers in other areas of specialization and with personnel managers.

## Mechanical engineering

The design and development of mechanical devices ranging from extremely small machine components to large earthmoving equipment is carried out in mechanical engineering, **Figure 1-22.** A ***mechanical engineer*** will usually specialize in a given area, such as machinery, automobiles, ships, turbines, jet engines, or manufacturing facilities.

## Metallurgical engineering

The ***metallurgical engineer*** is involved in the location, extraction, and refining of metals. A metallurgical engineer may specialize in one general area of the total field, such as mining and extraction, refining, or the welding of metals. An engineer's responsibilities, for example, could include altering the structure of a metal through alloying or other processes to produce a material with certain characteristics to perform a special purpose.

## Nuclear engineering

Research, design, and development in the field of nuclear energy is the responsibility of the ***nuclear engineer.*** This type of engineering includes the design and operation of nuclear-fueled electrical generating plants used in ships, submarines, or locomotives. This field of engineering offers many challenges in the area of power systems, as well as in chemistry, biology, and medicine.

## Petroleum engineering

The ***petroleum engineer*** is involved in the location and recovery of petroleum resources and the development and transportation of petroleum products. Considerable research has been done on the use and conservation of petroleum resources, since petroleum-based products are in greater demand each year. New sources of petroleum and gases need to be located by petroleum engineers while the search for substitute materials continues.

**Figure 1-22.** Earthmoving equipment must be designed and engineered to withstand rough and heavy work. (Jack Klasey)

## Chapter Summary

The universal language of drafting is essential in solving problems, creating designs, and communicating ideas. Drafting is the process of creating technical drawings. A technical drawing is a graphic representation of an idea, an object, a process, or a system.

Graphic representation has evolved along two directions according to purpose: artistic and technical. Artistic and technical drawings allow abstract concepts to be communicated in ways that people can understand.

The primary purpose of drafting is to explain an idea, plan, or object. The process also serves as a problem-solving experience, a design tool, and a method of recording acceptable solutions.

There are many types of technical drawings. Each type, from a sketch to a pictorial, plays a role in the development, manufacture, and sale of products.

Freehand sketches are useful in communicating undeveloped ideas. They may be detailed or schematic in form. Mechanical drawings show an idea or product in a more refined or improved state than sketches. Size, shape, and form are shown to provide a scaled representation of the object.

Sets of drawings are used for manufacturing or construction communication. A set of drawings is a group of drawings that communicate the complete product or idea. These drawings represent the final stage of refinement.

Presentation drawings (or models) are frequently used as communication devices for the prospective buyer, client, financier, or management. The main purpose is usually to secure acceptance of the proposed product.

Once the basics of drafting are understood, a person may select an area of specialization and pursue a career in drafting. Job titles and duties vary from industry to industry. However, typical drafting careers include employment as a drafting trainee, detail drafter, layout drafter, design drafter, checker, and technical illustrator. Additionally, there are numerous career paths related to drafting. These include architecture, industrial design, and engineering.

## Additional Resources

### Publications

*ASME National Standards*
American Society of Mechanical Engineers (ASME)
www.asme.org

*Occupational Outlook Handbook*
US Bureau of Labor Statistics
www.bls.gov

### Resource Providers

American Design Drafting Association (ADDA)
www.adda.org

American National Standards Institute (ANSI)
www.ansi.org

Association for Career and Technical Education (ACTE)
www.acteonline.org

International Organization for Standardization (ISO)
www.iso.org

National Association of Industrial Technology (NAIT)
www.nait.org

SkillsUSA
www.skillsusa.org

## Review Questions

1. A _____ drawing is a graphic representation of a real thing—an idea, an object, a process, or a system.
2. _____ language is a basic and material form of communication that is universal and timeless.
3. What is the primary purpose of drafting?

4. Drafting standards developed by the _____ serve as the basic guide for technical drafting.
5. Name four types of technical drawings used to communicate ideas.
6. _____ are drawings that are very useful in communicating undeveloped ideas.
7. _____ drawings show an idea or product in a more refined or improved state than sketches.
8. Generally, what is the purpose of a presentation drawing?
9. Define *problem solving.*
10. What type of problem is generally rather narrow in scope and has only one correct answer?
11. _____ thinking is examining a very specific problem to come up with several correct solutions.
12. What is the *design method*?
13. Name the four steps of the design method.
14. Before much progress can be made toward the solution of a problem, the problem must be clearly _____.
15. _____ is a means of working with others to develop creative solutions to problems.
16. The term _____ is used to refer to three-dimensional scale replicas, mockups, and prototypes.
17. A _____ is a full-size model that simulates an actual machine or part.
18. What is a *prototype*?
19. Generally, a drafting trainee will work under the close supervision of _____ personnel.
20. It is the job of the _____ drafter to prove out the product design, using sketches and models and a scaled layout drawing.
21. The _____ drafter is a senior level drafter, representing the highest level of drafting skill.
22. Name three careers related to the drafting field.

## Problems and Activities

1. Collect examples of drawings that represent as many of the following types as possible. Be prepared to discuss with the rest of the class why you believe each drawing represents the category you designated.
   A. Idea sketch.
   B. Technical drawing.
   C. Manufacturing or construction drawing.
   D. Presentation drawing.
   E. Reference drawing.
   F. Patent drawing.
   G. Advertising drawing.
   H. Service or maintenance drawing.
2. Make a list of several problems for each of the following categories:
   A. Well-structured problems.
   B. Semi-structured problems.
   C. Nonstructured problems.
3. List as many useful items as you can that can be made from each of the following. Let your imagination be your guide. Include all items regardless of practicality for production.
   A. Bale of straw.
   B. One square yard of heavy canvas.
   C. Piece of white pine lumber 1″ × 10″ × 12′.
   D. Sheet of vinyl plastic .005″ in thickness and 10′ square.
   E. Unfinished interior flush panel door 2′6″ × 6′8″.
   F. Empty five-gallon bucket.
   G. Automobile radiator core.
   H. Sheet of window glass 30″ × 40″.
   I. Rubber garden hose 50′ long.
   J. Several glass bottles.
4. Creative thinking is a matter of developing the mind to be resourceful and imaginative. Test your creativity by listing as many

different ways you can think of to solve the following:

A. Paint a board 2″ × 10″ × 10″ on all surfaces.

B. Transfer a gallon of water to another location 10 feet away and 45° above its present location.

C. Make a 1″ square hole in the side of a tin can.

D. Design a clamping device for gluing wood edge-to-edge without the use of a threaded piece.

5. Make a list of six or more items not currently available on the market that you think have a market or use. Be sure the items can be produced by your class, using materials available to you commercially and using equipment at school or at home.

6. Select one item from Problem 5 and try to interest 3 to 5 members of your class in the design and production of the item. With the approval of your instructor, follow the project through the design stage and development of a prototype. Follow the steps outlined in this chapter on the design method and evaluate the design and production problems. Establish a selling price for which you could manufacture the item and make a reasonable profit.

7. Select any one of the following problems and develop a solution for it. Make use of the design method outlined in this chapter to solve the problem. Report your work and activities in proceeding through each of the steps. Develop sketches for at least two of the best possible solutions and a dimensioned drawing for the proposed final solution.

A. Portable shoe shine equipment with folding seat and storage space for tools and supplies.

B. A system for separating gravel (rock) into various sizes such as 1/2″, 1″, 1 1/2″, and 2″.

C. A study area that provides space and lighting for writing, reading, and storage for materials commonly used in the area.

D. A means of utilizing discarded plastic containers.

8. One of the most difficult types of problems to solve is one that calls for new uses or unique applications of commonly used items in ways they have not been used before. For example, a small gasoline engine is commonly used as a power unit for such items as lawn mowers, motorbikes, snowblowers, and tree saws.

How many ideas can you suggest for the small gasoline engine that would be useful and yet unique? Test your imagination and list some possible uses. You may add other pieces of equipment or material as needed.

9. Try the same approach used in Problem 8 with the following:

A. An electric motor from a cordless toothbrush, shaver, or hedge trimmer.

B. A spare tire and wheel from an automobile and a tire pump.

C. Bicycle wheels without tires or inner tubes.

D. The parts from several radios.

10. Ask your instructor, a member of your family, or an acquaintance to help you get in touch with an engineer or industrial designer. Make an appointment for an interview to find out all you can about the nature of the work and the design methods used to solve problems. Ask to be shown sketches used in the solution of problems. Report your findings to your class.

11. Select a famous creative inventor or designer and read his or her biography. See if you can identify things that caused the person to develop his or her creativity. Try to sum up these characteristics in two or three statements that could serve as a guide to others who want to develop their creative abilities. Report your findings to your class.

12. Review the local newspaper for news articles relating to a school or community need that could be solved using the design method. Take one such problem and develop a solution by applying the design method. Prepare a written report of each step in development of a solution.

*The following problems and activities are designed to help you understand the nature of drafting and its opportunities.*

13. Select an object around your home or school, such as window trim or the molding around a door, and write a description of it, using words alone.
14. Make a freehand sketch of the object you described in Question 13. Which description was easier to prepare? Which description conveys information with more clarity?
15. Review current issues of magazines, such as Aztlan, Ebony, Entrepreneur, Popular Mechanics, or Scientific American and prepare a report on an individual who is distinguished in a drafting career or a related career. Present your report to the class.
16. Use magazines, newspapers, and brochures to find as many different types and uses made of drafting as you can. These may include drawings, sketches, graphs, charts, or diagrams where drafting procedures were used. Mount your collection on notebook paper and be prepared to show it in class. Preserve the collection for later reference.
17. Interview an architect, industrial designer, drafter, or engineer on the nature and rewards of his or her work. Find out as much as you can about educational requirements and any specialized training needed, the pay compared to other types of work, and opportunities for employment and advancement.
18. Interview several persons not directly engaged in technical work. These might include your parents, neighbors, or the parents of your friends. Obtain their opinions on the value of drafting to the average citizen. Find out what activities they have done where a knowledge of drafting was (or would have been) helpful.
19. Try to obtain an actual print of a house plan or some manufactured machine part and bring it to class. Discuss its features and details with your classmates.
20. Select a person who has become well-known in a technical field related to drafting. Staff members at your school or community library can help you find candidates. Prepare a report on how that person became involved in this work and the contributions that they have made. Present your report to the class.