Fundamentals of Graphics Communication, 3/e
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CHAPTER 1

Introduction to Graphics Communication and Sketching

Chapter 1 is an introduction to the graphic language and tools of the engineer and technologist. The chapter explains why technical drawing is an effective way to communicate engineering concepts, relating past developments to modern practices, and examines current industry trends, showing why engineers and technologists today have an even greater need to master graphics communications. Concepts and terms important to understanding technical drawing are explained and defined, and an overview of the tools, underlying principles, standards, and conventions of engineering graphics is included. In addition, this chapter introduces you to sketching and the use of sketching for lettering. These techniques are expanded on in later chapters.

Technical drawings are created using a variety of instruments, ranging from traditional tools, such as pencils, compass, and triangles, to the computer. Drawing tools are used to make accurate and legible drawings and models. Traditional drawing instruments are still important, especially for sketching; today, however, the computer can be used for most drawing and modeling requirements. This chapter is an introduction to: computer-aided design/drafting (CAD) systems, including the related hardware, software, and peripheral devices; and the traditional equipment normally used by engineers and technologists to create technical drawing models.

In engineering, 92 percent of the design process is graphically based. The other 8 percent is divided between mathematics, and written and verbal communications. Why? Because graphics serves as the primary means of communication for the design process.

Drafting and documentation, along with design modeling, comprise over 50 percent of the engineer's time and are purely visual and graphical activities. Engineering analysis depends largely on reading engineering graphics, and manufacturing engineering and functional design also require the production and reading of graphics.

Engineering graphics can also communicate solutions to technical problems. Such engineering graphics are produced according to certain standards and conventions so they can be read and accurately interpreted by anyone who has learned those standards and conventions.

A designer has to think about the many features of an object that cannot be communicated with verbal descriptions. Technical drawings are a nonverbal method of communicating information.

Engineers are creative people who use technical means to solve problems. They design products, systems, devices, and structures to improve our living conditions. **Technologists** assist engineers and are concerned with the practical aspects of engineering in planning and production. Both engineers and technologists are finding that sharing technical information through graphical means is becoming more important as more nontechnical people become involved in the design/manufacturing process.

THE IMPORTANCE OF ENGINEERING GRAPHICS

Engineering graphics is a real and complete language used in the design process for:

1. Communicating
2. Solving problems
3. Quickly and accurately visualizing objects.
4. Conducting analyses.

A drawing is a graphical representation of objects and structures and is done using freehand, mechanical, or computer methods. Drawings may be abstract, such as the multiview drawings shown in, or more concrete, such as the very sophisticated computer model shown in.

Technical drawing is used to represent complex technical ideas with sufficient precision for the product to be mass-produced and the parts to be easily interchanged.

THE DESIGN PROCESS

A engineering drawing is used for documentation. These types of drawings are used in manufacture, for planning, fabrication, and assembly.

The traditional design process involves organizing the creative and analytical processes used to satisfy a need or solve a problem. It is a sequential process that can be grouped into six major activities, beginning with identification of the problem and ending with documentation of the design.

This finite element model of a crane hook is used in the analysis of a part to determine where maximum stress and strain occurs when a part is placed under various load conditions.

CHANGES IN THE ENGINEERING DESIGN PROCESS

The design process in U.S. industry is shifting from a linear, segmented activity to a team activity, involving all areas of business and using computers as the prominent tool. This new way of designing, with its integrated team approach, is called concurrent engineering. **Concurrent engineering** involves coordination of the technical and nontechnical functions of design and manufacturing within a business. Engineers must be able to work in teams. They must be able to design, analyze, and communicate using powerful CAD systems, and they must possess a well-developed ability to visualize, as well as the ability to communicate those visions to nontechnical personnel.

Geometric modeling is the process of creating computer graphics to communicate, document, analyze, and visualize the design process. There are various applications for a CAD database in the production of a product, using concurrent engineering practices.

STANDARDS AND CONVENTIONS

Conventions are commonly accepted practices, rules, or methods used in technical drawing.

Standards are sets of rules that govern how technical drawings are represented. Standards allow for the clear communication of technical ideas. In the United States, the **American National Standards Institute (ANSI)** is the governing body that sets the standards used for engineering and technical drawings. Other professional organizations, such as the American Society for Mechanical Engineering (ASM), assist ANSI in developing technical graphics standards.

ALPHABET OF LINES

The **alphabet of lines** is a set of standard linetypes established by the American National Standards Institute (ANSI) for technical drawing. The alphabet of lines, and the approximate dimensions used to create different linetypes, which are referred to as **linestyles** when used with CAD. Listed below are the standard linetypes and their applications in technical drawings:

Center lines are used to represent symmetry and paths of motion, and to mark the centers of circles and the axes of symmetrical parts, such as cylinders and bolts.

Break lines are freehand lines used to show where an object is broken to reveal interior features.

Dimension and **extension lines** are used to indicate the sizes of features on a drawing.

Section lines are used in section views to represent surfaces of an object cut by a cutting plane.

Cutting plane lines are used in section drawings to show the location of a cutting plane.

Visible lines are used to represent features that can be seen in the current view.

Hidden lines are used to represent features that cannot be seen in the current view.

Phantom lines are used to represent a moveable feature in its different positions.

CAD software provides different linestyles for creating standard technical drawings.

SPECIALISTS AND TECHNICAL DRAWINGS

Over the years, specialized technical and engineering fields have developed to meet the needs of different industries and professions. Many of these specialized areas have also developed their own types of technical drawings.

TRADITIONAL TOOLS

Traditional mechanical drawing tools are still used in some places for the creation of traditional working drawings, but more often for sketching and informal drawing purposes. Traditional equipment includes:

1. Wood and mechanical pencils.
2. Instrument set, including compass and dividers.
3. 45- and 30/60-degree triangles.
4. Scales.
5. Irregular curves.
6. Protractors.
7. Erasers and erasing shields.
8. Drawing paper.
9. Circle templates.
10. Isometric templates.

Mechanical pencils used for engineering drawings come in different lead sizes for drawing the different thicknesses of lines required on technical drawings.

Line weight refers to the relative darkness of the line. Uniform thickness means that the line should not vary.

Media are the surfaces upon which an engineer or technologist communicates graphical information. The media used for technical drawings are different types or grades of paper such as tracing paper, vellum, and polyester film.

Pencils are graded by lead hardness, from 9H to 7B: 9H is the hardest, and 7B is the softest.

Preprinted standard borders and title blocks on drafting paper are commonly used in industry.

Scales are used to measure distances on technical drawings. They are used to translate the size of real objects to dimensions that can comfortably fit on a sheet of paper.

The **civil engineer's scale** is a decimal scale divided into multiple units of 10 and is called a fully divided scale.

A **combination** scale is one that has engineering, metric, and architectural components on a single scale.

The **mechanical engineer's scale** is used to draw mechanical parts and is either fractionally divided into 1/16 or 1/32, or decimally divided into 0.1 or 0.02.

The lead in a compass is sharpened to a bevel using sandpaper.

The **compass** is used to draw circles and arcs of varying diameters.

A circle is drawn with a compass by first locating the center point, placing the needle at this point, and then leaning the compass in the direction you draw the circle.

A **divider** is used to transfer measurements. Unlike a compass, it has needles on both ends.

Templates are devices used to assist in the drawing of repetitive features, such as circles, ellipses, threaded fasteners, and architectural symbols.

TECHNICAL AND COMPUTER-AIDED DRAWING TOOLS

A **CAD system** consists of hardware devices used in combination with specific software. The hardware for a CAD system consists of the physical devices used to support the CAD software.

FUTURE TRENDS

Future trends in technical and engineering graphics include the use of increased realism in graphic images through the use of high resolution displays, animation and simulation, 3-D stereo, holographic, and other virtual reality techniques.

A general discussion can be had about the uses of visualization techniques in other areas. Many of your students may have had experience with computer/video/arcade games that make use of stereoscopic displays or other virtual reality (VR) techniques. Emphasize that advanced visualization techniques are important in a wide range of technical and scientific fields.

An important concept to get across to students is that 3-D models created on the computer are meant to be **virtual models** of real world objects. **Virtual reality** is simply technology which strives to make this model and its surrounding environment as realistic as possible. The two main factors in the success of this experience are the *fidelity* and *responsiveness* of the virtual environment. Together, these two factors create a sense of **immersion**.

For most VR systems, immersiveness is achieved with the following features:

- Displays
- Tracking
- Tactile/audio feedback
- Response time

A distinction should be drawn between telepresence and VR. Typically, the VR system is uses an environment that is by and large synthetic. That is, it is created completely on the computer. Telepresence uses remote video equipment under the user's control to allow someone to experience a real environment that is in a remote location.

TECHNICAL SKETCHING

It is important to emphasize to the students the role that sketching plays in the engineering design process and how **technical sketching** differs from other types of sketching, such as those used in the fine arts. Many students have the mistaken impression that since sketching is less precise than manual drafting or CAD, it is less important. They don't realize that good sketching is an acquired skill and just because sketching is less precise doesn't mean that it should be sloppy or confusing. It may be worth noting that in many applications, technical sketches are required to follow the same graphics conventions that are imposed on formal drafted or CAD-produced drawings.

FREEHAND SKETCHING TOOLS

Note that though sketches can be created with any kind of drawing instrument on most any kind of paper, a good quality **pencil** and paper will help a beginning student. The instructor will have to decide their policy on the use of **grid paper**. Some feel it is a great way to support orthogonal and isometric line sketching in beginning (or advanced) students, but others feel it becomes a crutch which prevents them from becoming proficient on plain paper. The same decision goes for the use of **tracing paper**.

Another important issue is the use of straight edges. Students feel a tremendous need to produce that 'perfect' line. It is the opinion of this author that when you start using a straight edge, it is not longer a true sketch and you have lost much of the speed and flexibility advantage of sketching.

SKETCHING TECHNIQUE

Students will come to your class with a truly diverse abilities to mentally create and manipulate graphic imagery (**visualization**). Either through their life experiences or through innate ability, some students are simply better at visualization than others. This does not mean that those who don't come to your class with strong skills can't be taught many of the skills presented in the text. What it does mean is that it will be worth your while to try to informally assess your student's visualization abilities; either through exercises presented in this chapter, direct observation, or other methods. The ability level of your students may influence the level of instruction needed to get students to an appropriate level of proficiency.

It is important to emphasize the dynamic qualities of the visualization process. Not only can this dynamic process be taking place solely in one' head, but also between the mind, the eyes, and some physical stimulus such as a drawing or an object.

To apply these ideas in a more functional way, have your students experience this **feedback loop.** If you have already done some sketching exercises, then ask them to sketch a simple object in pictorial form. Now verbally describe changes you want them to make in their object (e.g. drill a hole through it, chamfer a corner, etc.). Ask them to first mentally imagine this operation and then sketch it. They can also do this completely on their own; have them start with a simple shape and then transform it into a common household object over a series of four or five sketches.

One of the most fundamental techniques in sketching is **contour sketching**. This technique defines the edges and contours of the object. The lines also define the boundary between the object and the surrounding space.

Variations on contour sketching include negative space sketching and upside-down sketching.

Encourage students to explore with different paper positions and body postures for drawing their lines. Emphasize the need to develop an appropriate balance of speed and accuracy in their linework. Encourage them not to look right at where the pencil is but to where the pencil is going. **Intermediate points** (especially for curved lines) can be of great help in creating lines that follow the marked path.

Get students comfortable with sketching out squares to guide circle and circular arc construction and rhomboids for elliptical curves. With the **guide boxes** in place, have students develop a feel for the proper curvature relative to the box. Trying to sketch without guide boxes is a common pitfall with beginning students and happens almost as often on small diameter circles as it does with large ones.

PROPORTIONS AND CONSTRUCTION LINES

A logical extension of the use of guide boxes for circles and ellipses is the use of bounding (guide) boxes for developing the **proportions** of the sketch. Emphasize the importance of their use since all but the most gifted students are unlikely to have the visualization skills necessary to control the sketch proportions 'on the fly'. Encourage them to not only make small hash marks to mark distances, but to draw complete construction lines. These lines subdivide regions of the sketch and help the student refine the object from a rough whole to a detailed sketch. This process goes hand in hand with developing a student's visualization skills of looking at objects at various levels of detail; from the overall shape of an object to the details of particular features to where these features are located on the overall object.

LETTERING

Lettering is certainly one area where CAD has definitively increased the speed and accuracy of engineering and technical drawing. On the other hand, sketching done by hand cannot take advantage of the computer. For that reason, lettering has been placed in the chapter on sketching. In addition, this section also introduces many of the text variables you have at your disposal when using a CAD system. If you have not introduced CAD yet in your course, you may want to come back and review portions of this section when you do.

In addition to the ANSI standards, you may have other rules of thumb to convey to the students. Good and bad examples of lettering are always helpful in illustrating these principles.

Again, if the emphasis on your course is on CAD, you may want to only briefly touch on this section. By having all the students do a small amount of practice lettering in class, you can identify those needing help and have them do some remedial work out of class. If your primary interest in lettering is for use on sketches, you may not want to discuss lettering guides, since they slow down sketching much in the same way straight edges do.

Emphasize that guidelines (construction lines) are just as important in lettering as they are in sketching and drafting. You may decide, however, that those students who don't seem to be having too much trouble keeping their lettering aligned vertically, can skip putting in their vertical guidelines.

Cover not only the design style of each of the letters but also the numbers. There especially is a tendency to use non-standard designs for numbers among beginning students. Proper spacing is also something important to cover. Emphasize that the idea is to have uniform volume between the letters, not necessarily uniform distances between the nearest elements of the letters.

Though different companies and industries may use different computer lettering styles, Single Stroke Gothic is still the ANSI standard. (In AutoCAD, the closest equivalent is Roman Simplex). There can be a tendency among students to go a bit wild with their font choices (if given the opportunity) on a CAD system.

Within the same font, there are quite a few ways of varying the lettering, including plain, bold, slant, aspect, alignment (justification), etc. Point out times where it is appropriate to use these options. Explain to your students that the object is always drawn full scale in the CAD system, but that lettering may have to drawn at something other than the ANSI standard 3mm to account for print/plot scaling; that is, the 3mm standard is for the size on the printed/plotted page.

TEXT ON DRAWINGS

Examples from Chapter 10 on production drawings might to helpful in explaining the different areas where text is used on a drawing. Note that lettering within the drawing area should almost always conform to the ANSI standard 3mm, but that different sized and style text is often incorporated in other areas such as the titleblock.

If you can, point out examples of graphics that would clarified with the addition of a small amount of text and text notes that would be clarified by the addition of some graphic elements.

CHAPTER 2

Engineering Geometry

INTRODUCTION

Technical graphics is an integral part of the engineering design process through which engineers and drafters/designers generate new ideas and solve problems. Traditionally, engineering design consisted of closely related steps documented as paper graphics and text which flowed in a linear/sequential manner through an organization. In the face of increased global competition, many industries in the United States have a adopted a team-oriented concurrent approach using 3-D CAD model information as a primary means for communication. This chapter describes a modern approach to the engineering design process, so that you will have a better understanding of and appreciation for the role of engineering graphics in the design process.

DESIGN

Design is the process of conceiving or inventing ideas mentally and communicating these ideas to others in a form that is easily understood. Most often the communications tool is graphics.

Design is used for two primary purposes: personal expression, and product or process development.

Design for personal expression, usually associated with art, is divided into concrete (realistic) and abstract design and is often a source of beauty and interest.

When a design serves some useful purpose, such as the shape of a new automobile wheel, it is classified as a design for product or process development.

Aesthetic design is concerned with the look and feel of a product. **Functional design** is concerned with the function of a product or process. **Function** means that a product possesses a form related directly to the purpose of that product.

ENGINEERING DESIGN

Engineering design is a problem-solving process that uses knowledge, resources, and existing products to create new goods and processes. Engineering design has both aesthetic and functional elements and can be broken into two broad categories: product design and system design.

Product Design is the process used to create new products, such as a new automobile model, a new appliance, and a new type of wheelchair. Product design is a complex activity that includes market, production, sales, service, function, and profit analyses used to produce a product that meets the wants and needs of the consumer, is economically produced, is safe for the consumer and the environment, and is profitable to the company.

System design is the process used to create a new system or process. A system is an orderly arrangement of parts that are combined to serve one general function. Examples of the system designs are: the arrangement of the assembly process in a factory; the heating, ventilation, and air-conditioning (HVAC) system in a structure; and the electrical system in the automobile.

Engineering design is one of the processes normally associated with the entire business or enterprise, from receipt of the order or product idea, to maintenance of the product, and all stages in between. An engineering design involves both a process and a product. A **process** is a series of continuous actions ending in a particular result. A **product** is anything produced as a result of some process. Graphics is an extremely important part of the engineering design process, which uses graphics as a tool to visualize possible solutions and to document the design for communications purposes.

Traditional engineering design is a linear approach divided into a number of steps. For example, a six-step process might be divided into: problem identification, preliminary ideas, refinement, analysis, documentation, and implementation. The design process moves through each step in a sequential manner; however, if problems are encountered, the process may return to a previous step. This repetitive action is called **iteration** or looping.

Concurrent engineering is a nonlinear team approach to design that brings together the input, processes, and output elements necessary to produce a product.

The concurrent engineering model shows how every area in an enterprise is related, and the CAD database is the common thread of information between each area.

The engineering design process consists of three overlapping areas: ideation, refinement, and implementation which all share the same CAD database.

Collaborative engineering has evolved from concurrent engineering into a true enterprise-wide integrated product development process. It creates an organizational environment where teams can effectively collaborate with shared product information databases. Collaborative engineering is based on empowered, cross-functional teams and low-level decision-making.

Collaborative engineering is highly dependent on computer-based tools, including those that support **virtual product representation.** Tools in this category include shaded CAD models, large assembly visualizations, and dynamic simulations for design and manufacturing.

Prototyping encompasses the creation of physical representations of the proposed design using traditional machining or rapid prototyping technology.

Productivity tools support the engineering design process. They include e-mail, word processing, and spreadsheet software.

Product Data Management (PDM) is the name given to specific computer-based tools and processes used to manage engineering and technical data associated with the product development process. **Enterprise Data Management (EDM)** describes similar systems used to manage information at the enterprise level.

Modern data networks are used to both manage the product development process within a company (using **Intranets**) and support sales and support of the product in the field (using **Extranets**). The use of Internet for conducting business is often called **e-Business**.

The actual members of a design team will vary according to the complexity and type of product being designed and the stage of the design process. The size of the design team may vary from one, to three, to many dozen. Coordination of the design team is critical to the success of the design and meeting deadlines. As mentioned earlier, design teams are an integral part of concurrent engineering.

Members of the design team include:

- product design engineer
- product manager
- mechanical engineer
- electrical engineer
- manufacturing engineer
- software engineer
- detailer/drafter
- materials engineer
- quality control engineer
- industrial designer
- vendor representatives

IDEATION

Ideation is a structured approach to thinking for the purpose of solving a problem. The ideation process consists of three important steps: problem identification, preliminary ideas, and preliminary design.

PROBLEM IDENTIFICATION

Problem identification is an ideation process in which the parameters of the design project are set before an attempt is made to find a solution to the design. Problem identification includes the following elements:

Problem statement summarizes the problem to be solved.

Research gathers relevant information useful to the design team.

Data gathering, sometimes called feasibility study determines: market needs, benchmarking with the competition, and rough physical measurements, such as weight and size.

Objectives list the things to be accomplished by the team.

Limitations list the factors in the design specifications.

Scheduling organizes activities into a sequence.

Engineering design problems must be clearly defined before the design process can begin. The problem definition requires input from customers, marketing, management, and engineering.

Data to determine consumer needs is gathered through surveys, such as personal or telephone interviews, mail questionnaires, and focus groups.

After all the data is gathered, the information is shared with the team before preliminary ideas are developed. Presentation graphics are a tool used to display the data in the form of charts and graphs, and are thus an important element in the information-sharing process.

Scheduling of the design activities is one of the last stages in problem identification. Objectives specifically state what is to be accomplished during the design process.

PRELIMINARY IDEAS STATEMENT

After the problem identification is complete, the design team begins to develop preliminary ideas for solving the problem.

Brainstorming is the process of identifying as many solutions to a problem as possible.

PRELIMINARY DESIGN

In the ideation phase, rough sketches and conceptual computer models, called ideation drawings or models are produced. **Ideation drawings** communicate new ideas through the use of rough sketches and computer models.

Inventive or creative ideas can come from a number of sources. Both personal sources and outside sources — such as surveys, competition reviews, library reference material, and vendor catalogues — can be used for inspiration.

A **design notebook** should be used to record all ideas, no matter how insignificant they seem at the time. A well-documented notebook is critical for recording ideas for later synthesis and to provide legal groundwork for patents and other proof of intellectual ownership.

REFINEMENT

Refinement is a repetitive (iterative or cyclical) process used to test the preliminary design, make changes if necessary, and determine if the design meets the goals of the project.

The refinement stage normally begins with technicians using the rough sketches and computer models to create dimensionally accurate drawings and models. The refinement stage is heavily dependent on graphics to document, visualize, analyze, and communicate the design idea. **Refinement drawings** are technical drawings and models used to analyze preliminary design ideas.

MODELING

Modeling is the process of representing abstract ideas, words, and forms, through the orderly use of simplified text and images.

A **descriptive model** presents abstract ideas, products, or processes in a recognizable form.

A **predictive model** is one that can be used to understand and predict the behavior/performance of ideas, products or processes.

A **mathematical model** uses mathematical equations to represent system components.

A **scale model** is a physical model created to represent system components.

Rapid prototyping is a broad term used to describe several related processes that create real models directly from a 3-D CAD database.

Virtual reality (VR) systems offer a way to visualize a model more realistically than on a traditional computer display. By using the principals of human perception, a completely immersive environment in which the user experiences the model.

COMPUTER SIMULATION AND ANIMATION

Computer simulation is the precise modeling of complex situations that involve a time element. **Computer animation** is the imprecise modeling of complex situations that involve a time element. The major difference between simulation and animation is the degree of precision. An animation only approximately replicates a real situation; a simulation accurately replicates a real situation.

DESIGN ANALYSIS

Design analysis is the evaluation of a proposed design, based on the criteria established in the ideation phase. It is the second major area within the refinement process, and the whole design team is involved. Typical analyses performed on designs include:

Property analysis, which evaluates a design based on its physical properties.

Functional analysis, which determines if the design does what it is intended to do.

Human factors analysis, which evaluates a design to determine if the product serves the physical, emotional, quality, mental, and safety needs of the consumer.

Aesthetic analysis, which evaluates a design based on its aesthetic qualities.

Market analysis, which determines if the design meets the needs of the consumer, based on the results of surveys or focus groups.

Financial analysis, which determines if the price of the proposed design will be in the projected price range set during the ideation phase.

Finite element modeling (FEM) is an analytical tool used in solid mechanics to determine the static and dynamic responses of components under various conditions, such as different temperatures.

Discretization is the process that divides a solid model into smaller, discrete parts such as triangles and rectangles. Each corner of these elements is called a node.

After the finite element is created, the **boundary conditions**, such as temperature or load, are defined. The model is then analyzed by a computer.

Mechanism analysis is concerned with the calculation of motions and loads in mechanical systems comprised of rigid bodies connected by joints.

Assembly analysis is used to define the individual rigid bodies of the mechanism and to assemble them correctly, considering both geometry and velocities.

Kinematic analysis determines the motion of assemblies without regard to the loads.

Dynamic analysis determines the loads that drive or create the motion of a mechanism.

Functional analysis is a judgment process in which factors, such as cost, appearance, profitability, marketability, safety, and others, are used to determine the worth of a design.

Human factors analysis determines how a design interacts with the dimensions, range of motion, senses, and mental capabilities of the population that will use the product.

Aesthetic analysis is a process that evaluates a design based on aesthetic qualities. The look and feel of the product are analyzed by industrial designers, marketing personnel, environmental and human factors engineers, and the customer.

Market analysis determines the needs and wants of the customer so that the product produced is the product wanted by the consumer. **Financial analysis** determines the capital available for a project, the projected expenses to design, manufacture, assemble, market, and service a product. **Graphical analysis** is a process used in engineering analysis to display empirical data in the form of graphics.

DESIGN REVIEW MEETINGS

A design review is a formal meeting where the design team presents and defends their progress towards a solution to management. Graphic communication plays a key role in presenting the designs to meeting participants and providing a basis for discussion.

IMPLEMENTATION

Implementation is the third and final phase in concurrent engineering design and is the process used to change the final design from an idea into a product, process, or structure.

PLANNING

The **planning** process determines the most effective method of moving a product through the production cycle. Modern planning techniques include: **computer-aided process planning** (CAPP), **material requirement planning** (MRP), and **just-in-time** (JIT) scheduling.

CAPP uses the computer model of the design to determine which machines and processes should be used.

MRP calculates the raw materials needed to produce the product, and uses solid models to assist in these calculations.

Just-in-time (JIT) is an operational philosophy that tries to reduce cycle time while eliminating waste. A JIT system prevents waste by taking deliveries on orders only as they are needed.

PRODUCTION

Production is the process used to transform raw materials into finished products and structures, using labor, equipment, capital, and facilities.

MARKETING

The **marketing process** anticipates customer needs and directs the flow of goods from the producer to the consumer.

Computer models and technical drawings can be used as the basis to create the illustrations needed.

Motorola marketing example.

FINANCE

The **finance** process analyzes the feasibility of producing a product, relative to capital requirements and return on investment (ROI).

MANAGEMENT

Management is the logical organization of people, materials, energy, equipment, and procedures into work activities designed to produce a specified end result, such as a product.

Total quality management (TQM) is the process of managing the organization as a whole, such that it excels in all areas of production and service that are important to the customer. The key concepts are: (1) quality is applicable throughout the organization in everything it does; and (2) quality is defined by the customer.

Design qualitythe inherent value of the product in the marketplace.

SERVICE

Service is an activity which supports the installation, training, maintenance, and repair of a product or structure for the consumer. Service uses technical illustrations and reports to support its activities. Technical illustrations are typically assembly drawings which show how multiple parts fit together, pictorial drawings, rendered illustrations, and graphics showing the order of assembly, as well as the functionality, of the components of the product.

DOCUMENTATION

Documentation is a process used to formally record and communicate the final design solution.

Concurrent documentation is a process that creates documents at the same time that t he product design is being developed.

Design drawings and models are all the sketches, rough design layout drawings, and initial 3-D computer models created during the ideation and refinement phases.

Multiview dimensioned drawings and assembly drawings with a parts list are for production purposes. These multiview drawings are called **production drawings** because they are used as the communications medium between design and production or manufacturing.

If the design is modeled in 3-D by CAD, then multiview drawings can automatically be extracted from the model.

Another purpose for engineering drawings is **archiving**, which is a process used to create a permanent graphics record of the design in the form of drawings saved on vellum, microfiche, computer tape, or some other medium.

It is possible to create a product without the use of paper drawings by linking the entire business to computers.

Technical illustrations are developed and used throughout the concurrent engineering and documentation cycle, starting with the design database.

Animations are used in the documentation phase to support the marketing, training, production, and service activities.

Technical reports are in-depth accounts that chronicle the design process.

Presentation graphics are text, illustrations, and other visual aids used when making an oral report to a group.

A **patent** is the "right to exclude others from making, using, or selling ." The patenting process was developed to encourage the prompt disclosure of technical advances by granting a limited period of protection for the exclusive use of that advance. A patent is granted for a period of 17 years.

DRAWING CONTROL

Product data control involves managing all information associated with a product. PDM/EDM systems are central to this process.

Enterprise Document (or Data) Management (EDM) is a software system used to track all data generated by an enterprise, whether it is directly related to the design process or not. These databases are often linked to other database systems, including PDM systems.

Product Data Management (PDM) is the name given to specific computer-based tools and processes used to manage engineering and technical data associated with the product development process.

Networked computer systems are used to manage and distribute the PDM database information. Individuals working at CAD workstations (the clients) can access the database located on a central server through the network.

The client software allows the user to search for documents by database fields such as the part name, file name, who created the data, or the last date revised. The software usually provides a viewer for previewing the selected document.

The PDM system provides tools to update, manage, and secure engineering data. In addition, the system typically provides some means of managing the workflow of design information.

Wide area network tools on the Internet such as the World Wide Web are being used to distribute and manage engineering data among remote locations of global companies.

Even small organizations should have **file management** protocols in place. These include file naming conventions, saving, and backup procedures.

ISO 9000 is a set of quality standards that promote and facilitate international commerce. An important part of these standards is the documentation of all processes that affect the quality of service in your organization.

OTHER ENGINEERING DESIGN METHODS

Design for manufacturability (DFM) is a design technique in which the design is developed by a team, and the focus is on simplicity and functionality.

Knowledge-based engineering (KBE) systems complement CAD by adding the engineering knowledge necessary for a product's design.

Reverse engineering is a method of taking an existing product, accurately evaluating it, and putting the information into a CAD database.