GRAPHICAL COMMUNICATION PRINCIPLES: A PRELUDE TO CAD

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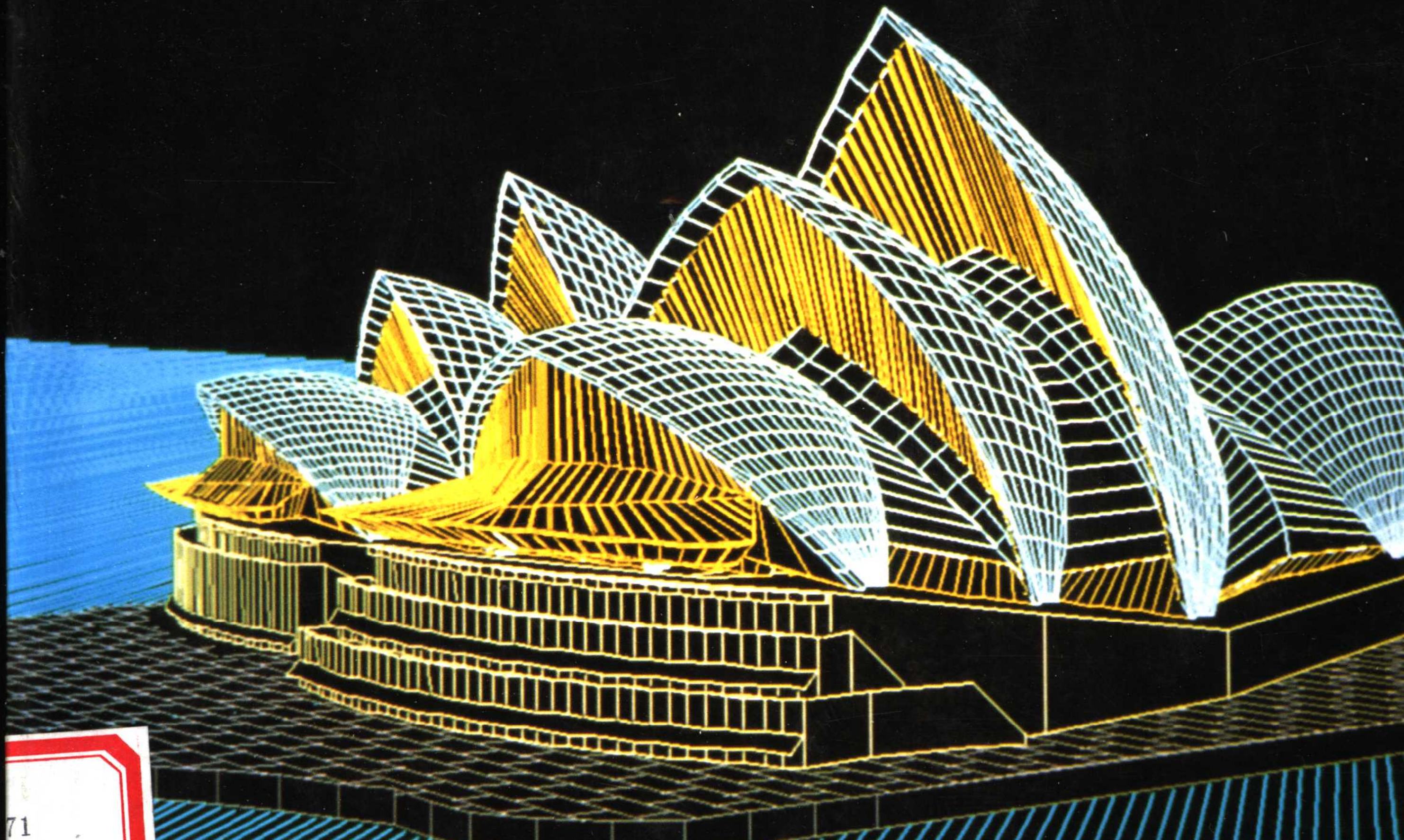

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Pennsylvania State University

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Professor Foster's interests are teaching engineering graphics and studies of student retention. He has published several articles in these areas. He is the author of two McGraw-Hill texts—*Graphic Science and Design,* 4th ed. (French, Vierck, Foster) and *Engineering Drawing & Graphics Technology,* 13th ed. (French, Vierck, Foster).

Hugh F. Rogers is currently an associate professor of engineering graphics at The Pennsylvania State University. He has taught machine and technical drafting design, technical illustration, architectural graphics, nomography, and related subjects for thirty-three years at the college level.

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Richard F. Devon is an associate professor of engineering graphics at the University Park Campus of The Pennsylvania State University. He has taught first-year engineering courses there for the past eight years. His particular responsibility has been in generating computer curricula in programming, CAD, and computer graphics.

Professor Devon has three year's experience in industry as a civil engineer, including a brief period on the site of the Sydney Opera House. He is author and coauthor of two small books on programming and of a number of articles on engineering education and the social context of technology.

PREFACE

This text represents a bridge between the traditional large graphics books and direct application of software for computer-aided drafting (CAD). It is generally accepted that a person about to use a CAD system needs to have basic knowledge about graphical concepts and relationships. One needs to know about orthographic projection systems, dimensioning procedures, and three-dimensional relationships among other basics. One does not need to know about extensive hand lettering, inking, and intricate intersections of solids, for example, to successfully operate a CAD system.

The intent of the text is to present in a concise, streamlined manner with clear illustrations those topics of graphics most needed by beginning CAD operators. The text leaves to other sources, such as CAD reference manuals, exploration of techniques of operating a particular CAD software package. The many software systems are best learned with instruction from specific literature devoted exclusively to that software.

Note that all CAD software formats assume that the reader is familiar with basic concepts of graphics. Hence one must know where a left-side view appears, where a half-section is to be placed, or where dimensioning should be properly located. This text provides a full but CAD-tailored background in graphical concepts to support CAD users.

The text is organized into five parts, Parts A to E, respectively: Tools and Techniques of Manual Graphics, Representation of the Three-Dimensional World, Clarification of Shapes and Sizes, Spatial Analysis, and Visual Techniques to Communicate and Analyze Data. Each part is fully illustrated. Representative problems are found at the end of each chapter.

Part A, Tools and Techniques of Manual Graphics, includes Chaps. 2 through 4. Use of basic instruments, such as the compass and dividers, is covered so that a CAD user will be comfortable doing simple initial trial layouts prior to starting a CAD project. Lettering techniques available in CAD software are discussed. Also tangencies and other basic geometric relationships are described.

Part B, Representation of the Three-Dimensional World, stresses x, y, z axis systems and visualization of objects in 3-D space. Chapters 5 through 7 take the reader carefully through the conversion from 3-D formats to the 2-D orthographic system. There is emphasis on sketching ability.

Part C, Clarification of Shapes and Sizes, utilizes Chaps. 8 through 10 to convey information on sectioning, dimensioning, and tolerancing. These topics are vital to the intelligent use of a CAD system.

Part D, Spatial Analysis, uses Chaps. 11 and 12 to guide the reader through an understanding of auxiliary views so that later effective use can be made of such facilities on a CAD system. The basic concepts are covered, such as the true length of a line, edge view, true surface of a plane, and relationships among lines and planes. Artwork is largely new and intended for ease of understanding.

Part E, Visual Techniques to Communicate and Analyze Data, is a one-chapter section to aid the reader in presentation graphics and analysis of data. The design of effective charts and graphs of lower-order curves is also discussed.

A new workbook by Professor Hugh F. Rogers has been developed to supplement the text material. The plates are carefully designed to allow one to sketch the solutions or to use traditional hand instruments. A facility in sketching is a valuable asset to a CAD user. One often needs to think while using a pencil and perhaps a straightedge. A basic sketch for the problem approach desired on a CAD system can save time and minimize idle time while one is sitting at the CAD console.

A supplement entitled *Technical Drawing with AUTOCAD* by Leendert Kersten (University of Nebraska, Lincoln) is available from McGraw-Hill. This paperback will teach a student the skill of using AutoCAD, while explaining the concepts.

The authors seek comments from users of this text. This is a new endeavor that grows out of the rich legacy of traditional graphics but aiming toward CAD use. Therefore the text strives to include that graphical background which is needed prior to beginning with a CAD system. A coupling of this text with a specific CAD-software manual should be of maximum benefit to the CAD user. Please provide feedback from your experiences.

McGraw-Hill and the authors would like to thank the following reviewers for their many helpful comments and suggestions: Russell M. Echols, Texas A&M University; Frederick T. Fink, Michigan State University; Leendert Kersten, University of Nebraska, Lincoln; Michael B. McGrath, Colorado School of Mines; and Manjula B. Waldron, Ohio State University.

In addition, the authors wish to acknowledge and thank the estate of Charles J. Vierck for permitting the use of certain Vierck-based illustrations within this text. Prof. Vierck was of the team French and Vierck which authored the well known graphics texts, beginning with Thomas E. French's, *Engineering Drawing* in 1911. Illustrations have been incorporated from the French, Vierck, Foster texts, *Engineering Design Graphics*, 4th edition, and from *Engineering Drawing and Graphic Technology*, 13th edition. In each case, Prof. Foster was the sole revising author and McGraw-Hill Book Company was the publisher. Their inclusion has enahnced the quality of this book.

Robert J. Foster
Hugh F. Rogers
Richard F. Devon

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CHAPTER 1

INTRODUCTION

1. NEED FOR GRAPHICAL COMMUNICATION

We live in a world of graphical symbols and pictures. If we traveled about the world in a car, we would often see the symbol in Fig. 1. We would be expected to know what it means. Our travel comfort could be affected by understanding that symbol.

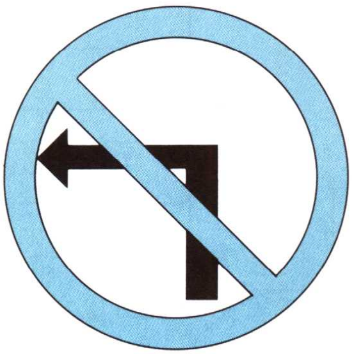

Figure 1
A symbol important to travelers.

Very often people communicate with one another in a graphical mode. Each day we see pictures on TV and in magazines. We absorb them almost automatically. If we did not, in a sense we would be illiterate. Some pictures simply entertain, of course. Others instruct us in some way. If we are going to drive an unfamiliar car, we look for symbols for the lights, windshield washer, and seat adjustment, for example.

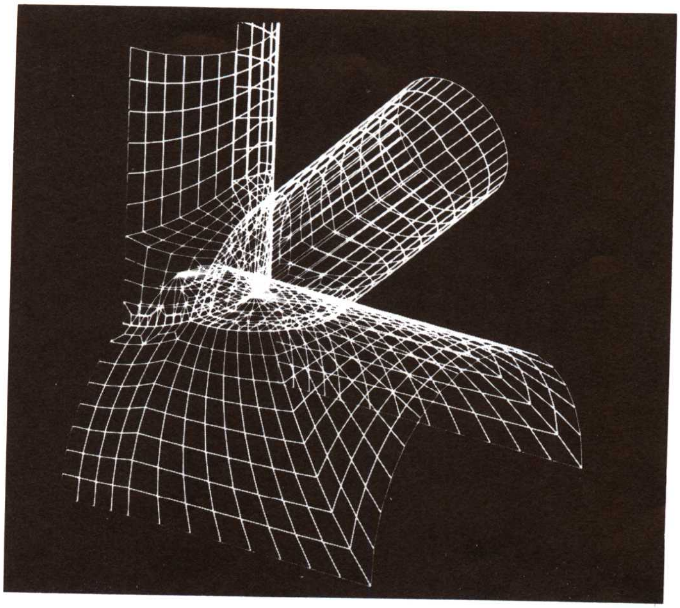

Figure 2
Abstract design from a computer.

People who design and build products use lots of graphical symbols and pictures. The builders receive their instructions from the designers through graphical means. Information may be abstract, as in the three-dimensional representation of intersecting surfaces in Fig. 2. This particular figure was computer-generated. Figure 3 shows more specific information for a hand-drawn part of a diesel engine. You are not expected to understand yet all that is implied in this two-view figure, but it transmits information to the informed builder. The rocker arm of Fig. 3 is shown half size; that is, 1 inch (in) on the drawing represents 2 actual inches. The scale

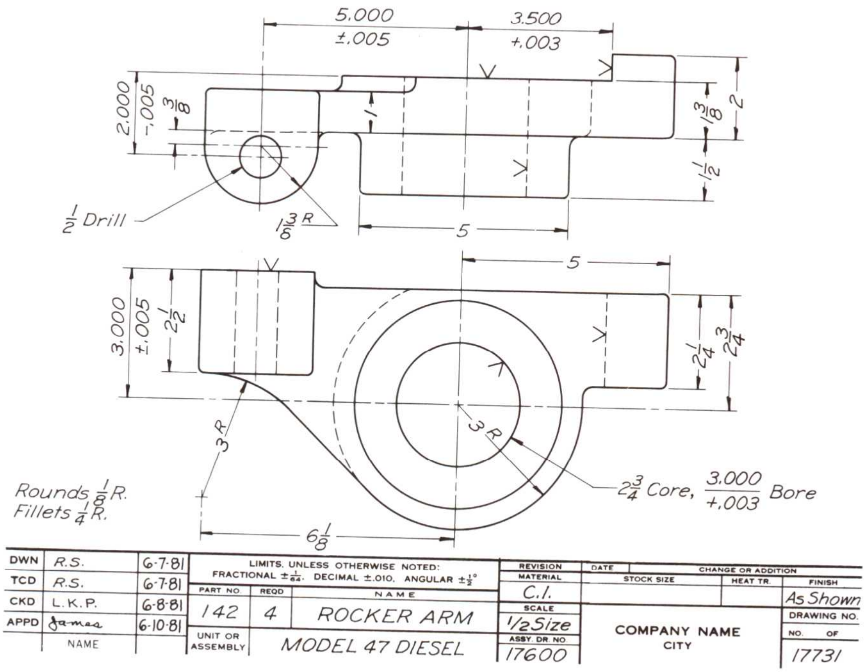

Figure 3
Hand-drawn engine part.

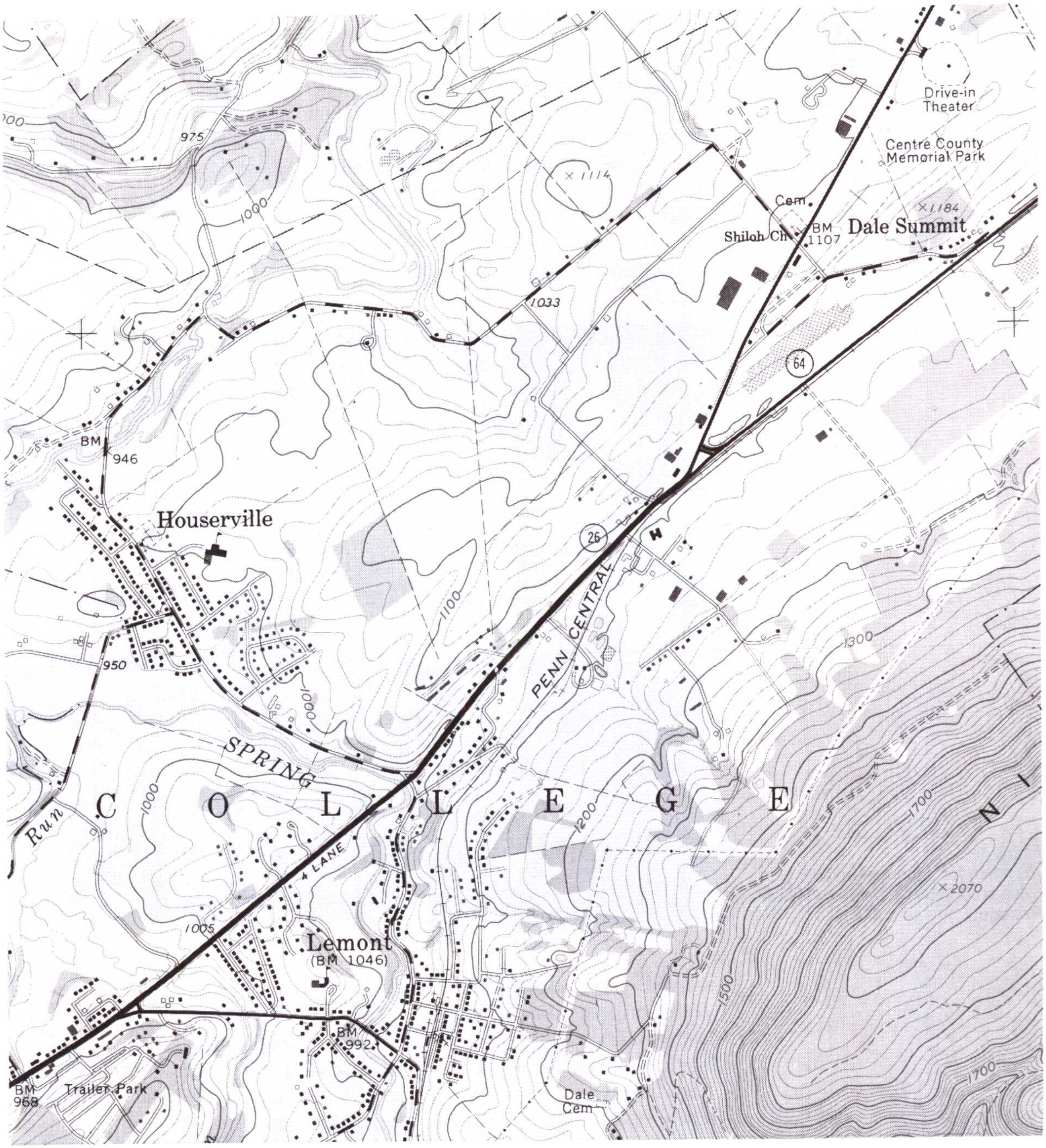

Figure 4
A portion of the United States geological survey map.

is thus 1 = 2. The map in Fig. 4 is a one-view drawing at a much smaller scale, where 1 in equals 1000 feet (ft). Figure 4 conveys very real but different information from the other figures.

In all the pictures seen so far, we would be expected to see or *visualize* what is being shown. A key factor in understanding any drawing is the ability to visualize. This book emphasizes visualization, often through freehand sketching.

2. PURPOSE OF OUR STUDY

Much drafting today is done by *computer-aided drafting* (CAD). A system such as that in Fig. 5 allows the user to generate drawings via the computer. The user gives input through means such as a keyboard, ''mouse,'' or graphics tablet. Output can be put on paper by means of pen plotters, laser printers, or dot-matrix printers, to name three. Computer-generated drawings offer speed and high-quality linework. However, CAD systems are really just sophisticated tools to create drawings. Any CAD system waits for commands to be inputted. The user must give proper commands, knowing what is desired in the way of a drawing.

Figure 5
A system for generating drawings using a computer. (Courtesy Hewlett-Packard.)

All CAD systems operate on specific software which provides a particular format for entering drafting commands. There are also commands for loading, editing, and saving drawings, plus numerous other manipulations. Each software package has its own unique commands, although all software allows the same basic operations to be done. For example, each software program will easily permit lines and circles to be drawn, combined, rescaled, moved, or copied.

Every CAD system has one feature in common: the human being needed to give information to the computer. This human being *must* understand basic graphical concepts in order to input intelligent information to the CAD system. For example, where does a top view properly go, how should the sectioned view look, and what is proper dimensioning technique? A person illiterate in graphical concepts cannot operate a CAD system with any degree of efficiency or competence.

The purpose of our study is to provide clear, concise knowledge of graphical concepts so that you may then use a CAD system with confidence. This book gives background which allows you to use *any* CAD system when supplemented by specific information for a specific CAD system. Each software company, whether it offers AUTOCAD, CADKEY, VERSACAD, or other graphics software, provides complete, thorough manuals on the operation of its software. An operator of a CAD system should always make good use of company information. Also a number of excellent references are available which assume that users know the principles underlying graphics. These books go immediately into useful details of a particular software.

Our study therefore explains the principles of graphic communication which have universal application. Applications can be for CAD as well as hand-drawn manual uses, including both freehand sketching and instrument drawing. In this book, however, we do not dwell on graphical aspects unrelated to CAD, such as instruction in the creation of hand-inked drawings.

In addition, we emphasize the understanding of principles needed for computer-aided *drafting* as opposed to computer-aided *design*. The term *CAD* may mean different things to different people, because the letter D can stand for either *drafting* or *design*. Sometimes we see the term *CADD,* which means computer-aided drafting and design.

This book teaches drafting, not design. Design is indeed a very important aspect of technology in which knowledge is analyzed and integrated to create a product. Design is often learned in upper-level engineering courses or during on-the-job training. Drafting is a tool used to assist in design and is a necessary element of design. Drafting may be done via CAD or manual methods, depending on the situation. By knowing well the principles of good drafting, one can become a better designer. Proper use of drafting principles can lead to the development of complex designs, as seen in Fig. 6.

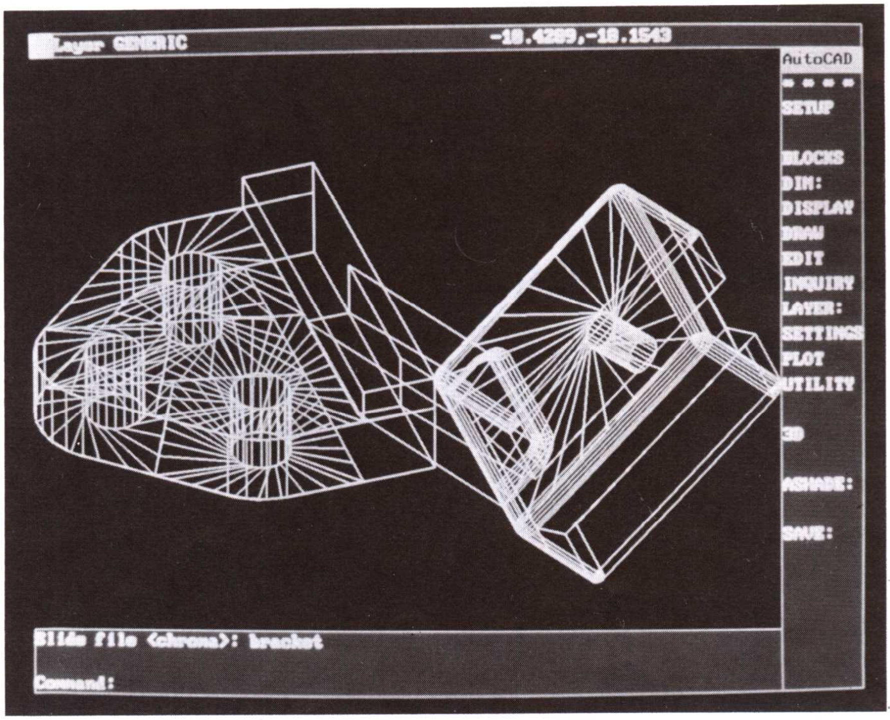

Figure 6
A complex shape seen on a computer screen. (Courtesy Autodesk, Inc.)

3. HOW CAD CAME TO BE

For centuries people have expressed their designs on paper by hand. Whether it is a freehand sketch, as in Fig. 7, or a drawing done by using manual instruments, as in Fig. 3, the human hand controlled its accuracy and quality. Computers had little commercial application until the late 1950s, when major corporations such as aircraft manufacturers began to use huge computers for complex calculations needed in design. These computers also were employed in *computer numerical control* (CNC) of machining operations. A computer could control the path of a cutting tool for a propeller, for example.

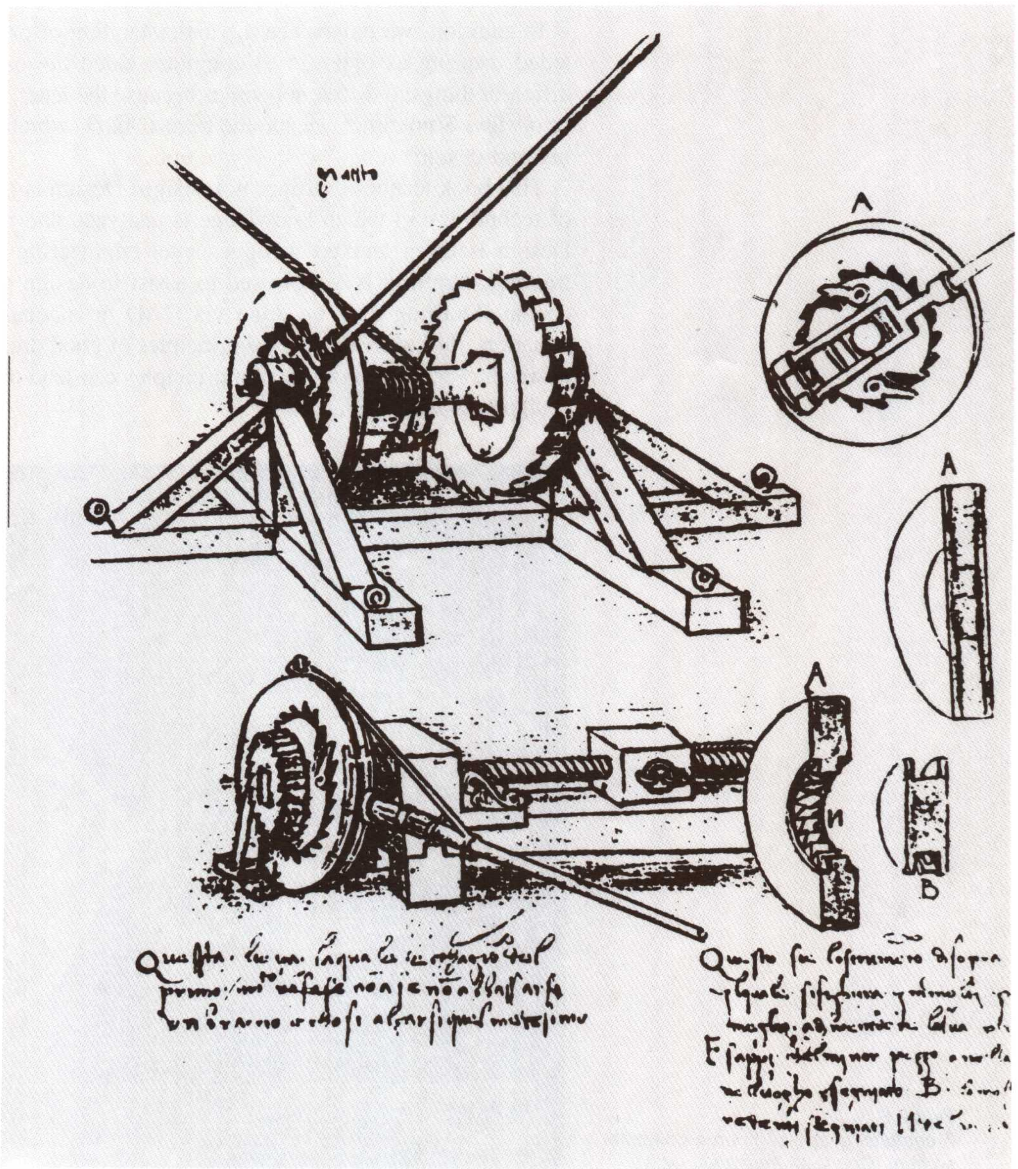

Figure 7
A historical sketch by Leonardo da Vinci (about 1500).

The use of CAD arrived by the 1960s. Large computers were still needed, but the CAD operator could interact with the drafting and design procedure, making revisions easily. This ease of design modification shown on a computer monitor screen was a great advantage over the tedious manual method of making changes.

Early CAD use was essentially limited to two-dimensional (2-D) layouts. Much good work could be done, but the computer memory needed for three-dimensional (3-D) work was still too costly for most applications. Large mainframe computers were still required for CAD work.

By the late 1970s, advances in computer technology had progressed so that memory capacities formerly reserved for mainframe computers could be incorporated into microcomputers. The resulting reduction in cost vastly widened the market. Many more drafters and designers could afford to use CAD. Software was still largely restricted to 2-D formats, but by the middle 1980s 3-D software was available and more cost-effective.

At present CAD systems can be afforded by even small companies. The range of hardware and software is extensive. The question for drafters becomes not whether a drawing can be done, but whether it *should* be done on a CAD system. Virtually all drafters now have the option of doing a drawing via CAD rather than manually.

4. PRESENTING GRAPHICAL INFORMATION

Graphical information can be defined as that information presented in the form of a picture, as opposed to mathematical equations or a written narrative. Our discussion relates to graphical material used primarily in a technological sense. The material includes freehand sketches, as in Fig. 8, and design drawings, as in Fig. 6. Also included are graphs, as in Figs. 9 and 10. The material typically does *not* include photographs, artwork, musical scores, or posters.

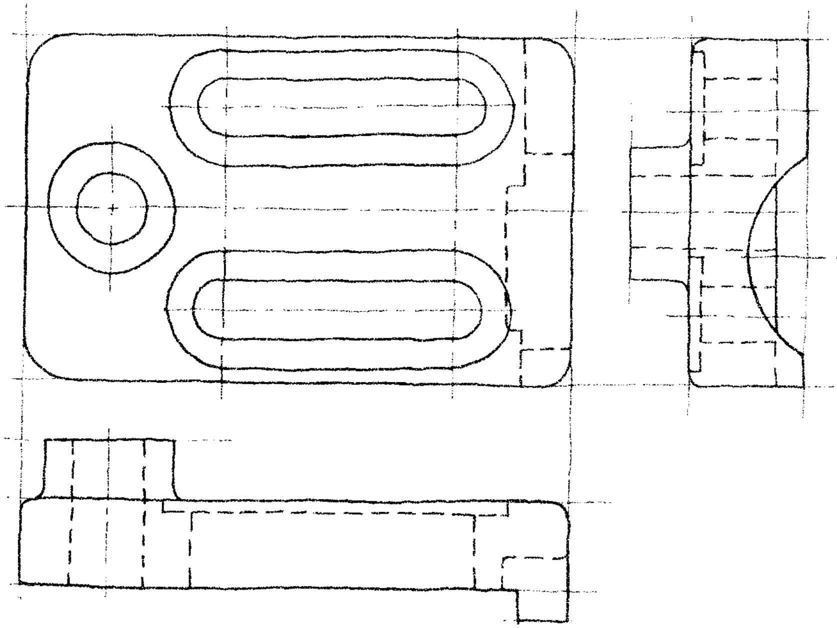

Figure 8
A freehand drawing.

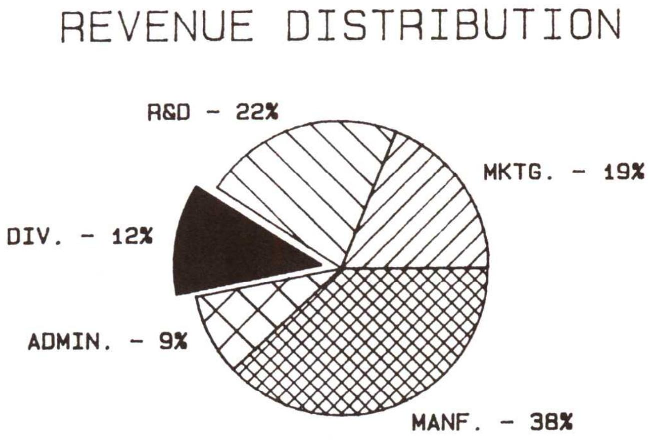

Figure 9
A pie chart as drawn on a computer-driven plotter. (Courtesy Hewett-Packard.)

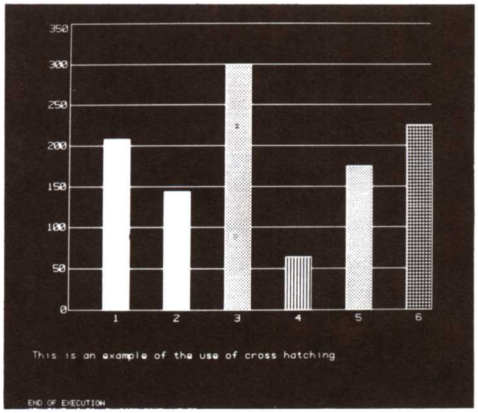

Figure 10
A bar chart with textured bars drawn by a computer program.

Graphical information can be presented manually, either by freehand sketching or by use of instruments. It can also be presented by using CAD. When would we use freehand sketching versus instrument drawings versus CAD? Each has its place, as we shall see.

a. The Case for Freehand Sketching

Sketching ability is valuable when you wish to jot down the general shape of an object or plot data quickly to note the trend of data in a graph. Sketching is quick and completely versatile. You can sketch on a mountaintop with a simple, lightweight pad and pencil, far removed from the need for electric power for a computer or a drafting table and instruments.

Also the brain interacts quickly with the human hand. Ideas flow from the mind through the hand to paper with a natural ease. Great concepts are often born with a modest sketch. We can also readily share ideas with others via sketches. Sketches can be great communicators of information. While sketches are not often the end-point of a design, they are often the beginning stage of a designed product.

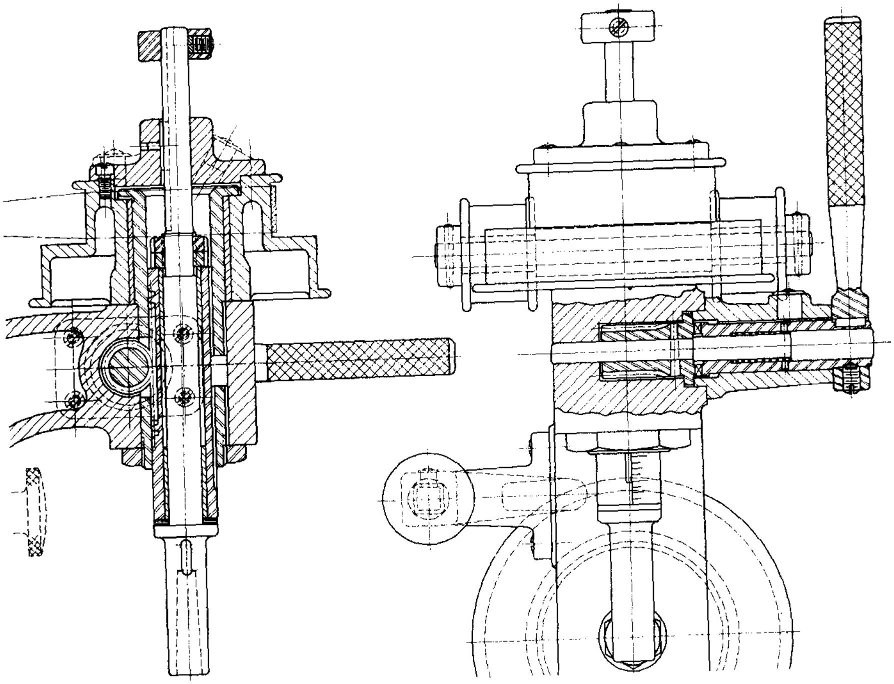

Figure 11
A portion of a design layout. Notes and specifications accompany the drawing.

b. The Case for Instrument Drawings

Sketches may be the beginning point of a design, but sketches in themselves go only so far. They express ideas well, but their accuracy is limited. Also for complex designs, such as that in Fig. 11, sketching becomes very tedious and difficult because of the intricate shapes and many assembled parts.

In that case, using hand-held instruments gives an advantage over sketching. Alignment between views is maintained, and good accuracy ensures a better understanding of the interrelationship of parts. In Chap. 2 we discuss many instruments, including the compass, dividers, and triangles. These instruments have existed for hundreds of years, evolving slowly as technical improvements have been made. Instruments were used in the design of the ships in which Columbus discovered the New World in 1492 and in shipbuilding today, for example.

Instruments are of real value when a drawing is to be done *once* for a product and is not expected to be revised frequently. On a personal level, if you were to design a dining room table for your home, using hand-held drafting instruments would be a natural choice.

c. The Case for Drawings by CAD

The last paragraph above gives a clue to at least one advantage of CAD drawings. Instrument drawings are well suited to drawings that are done *once* and are not expected to be revised often. But if drawings are to be *repeated* and *revised* often, CAD offers powerful advantages.

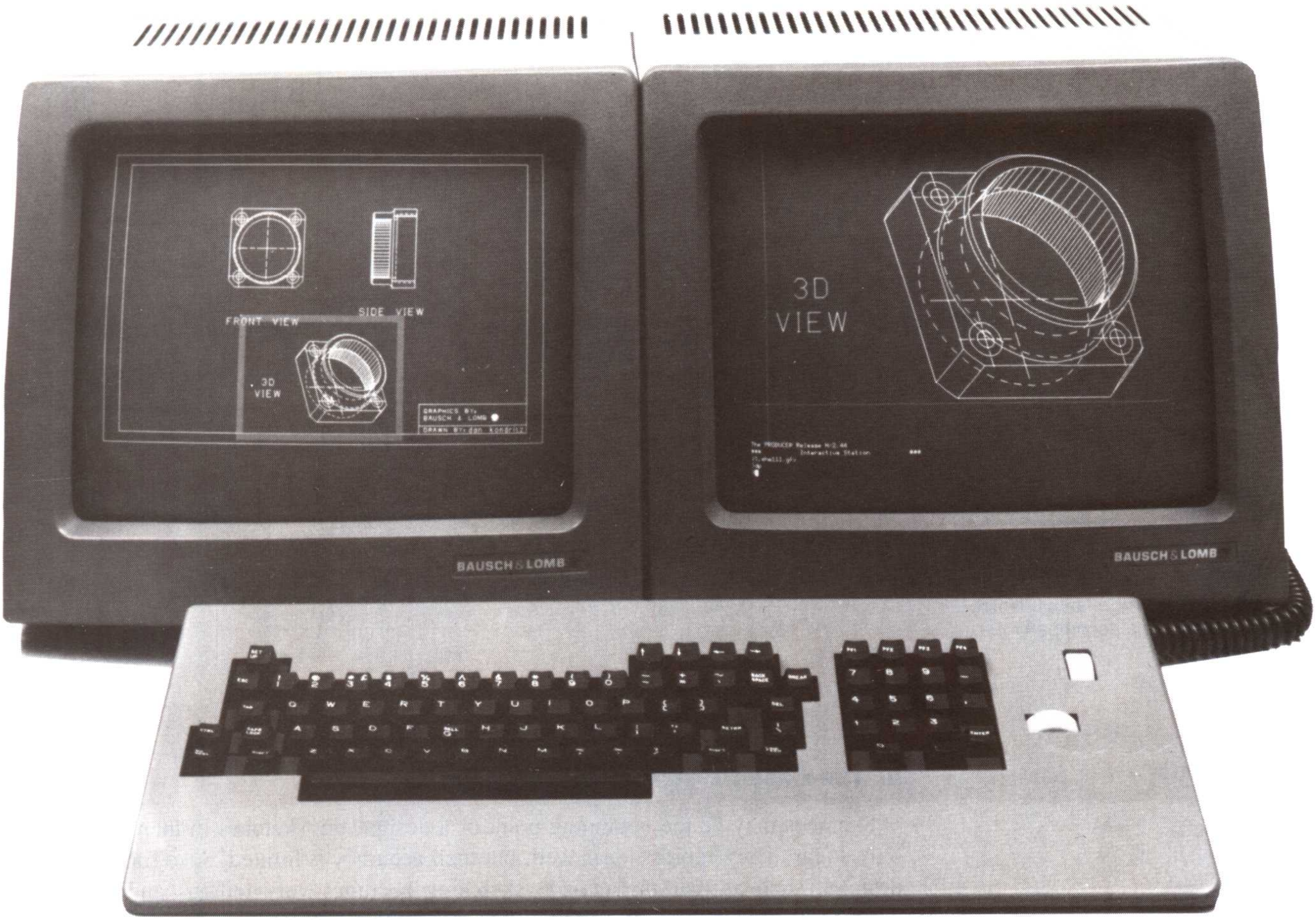

Figure 12
Both 2-D and 3-D drawings can be shown on this dual raster display. (Courtesy Interactive Graphics Division, Bausch & Lomb.)

Once data are entered into a computer, a CAD system can deliver fast, highly accurate variations of a basic drawing. Different views of an object can be created quickly in both 2-D and 3-D views, as in Fig. 12. Standard features can be repeated, modified, or deleted quickly, such as the size and number of windows on a given floor of an office building. Versatility, accuracy, and speed are virtues of CAD systems, once the basic data have been entered.

The data entered into CAD systems can also be used to help control manufacturing processes through computer-aided manufacturing (CAM). The database can be a powerful link between the design of a part and its production. Other texts discuss in depth the role of computer databases in production.

The intent of this book is to prepare you to use a CAD system intelligently from the standpoint of understanding the needed graphical principles of drawing layouts. Section 5 lists the various sections of the book and what they plan to accomplish.