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TECHNOLOGY AND MANPOWER IN DESIGN AND DRAFTING 1965-75.
MANPOWER RESEARCH BULLETIN NUMBER 12.
OFFICE OF MANPOWER POLICY, EVALUATION AND RES.(DOL

PUB DATE OCT 66

EDRS PRICE MF-$0.25 HC-$1.88 45P.

DESCRIPTORS- *TECHNOLOGICAL ADVANCEMENT, *ENGINEERING GRAPHICS, *ENGINEERS, DRAFTSMEN, OCCUPATIONAL INFORMATION, EMPLOYMENT STATISTICS, EMPLOYMENT OPPORTUNITIES, EMPLOYMENT TRENDS, EDUCATIONAL NEEDS, DESIGN TECHNOLOGY, DRAFTING TECHNOLOGY,

AS PART OF AN EXPERIMENTAL AND DEMONSTRATION PROJECT LAUNCHED BY THE DEPARTMENT OF LABOR IN 1965 TO EMPHASIZE LIKELY FUTURE TECHNOLOGICAL AND MANPOWER CHANGES, THIS STUDY OF THE DESIGN AND DRAFTING PROCESS AIMED TO IDENTIFY THE MAJOR TECHNOLOGICAL CHANGES IN THE NEXT 10 YEARS, TO DETERMINE THE EXTENT AND RATE OF DIFFUSION OF THESE CHANGES, AND TO ASSESS THEIR EFFECTS. THE MAJOR TECHNOLOGICAL CHANGES EXPECTED WILL UTILIZE COMPUTER BASED SYSTEMS TO PERFORM DESIGN COMPUTATIONS, PROCESS DESIGN INFORMATION, AND CARRY OUT, OR ASSIST IN CARRYING OUT, THE STEPS IN DESIGN ITSELF. THE INTERACTION OF THE FACTORS OF EQUIPMENT, METHODS OF USING THE EQUIPMENT, AND THE DESIGN AND DRAFTING PROCESS ITSELF WILL DETERMINE THE RATE AND DIRECTION OF CHANGE. THE EFFECTS OF TECHNOLOGICAL CHANGES ON THE TOTAL REQUIREMENTS FOR DRAFTSMEN DURING THE PERIOD ARE EXPECTED TO BE MODERATE. THE USE OF TIME-SHARED GRAPHICS SYSTEMS MAY SUBSTANTIALLY REDUCE THE DEMAND FOR DRAFTSMEN AFTER 1975, HOWEVER. THE EFFECTS OF TECHNOLOGICAL CHANGES UPON ENGINEERS ARE DIFFICULT TO ISOLATE, BUT CLERICAL-TYPE ROUTINE ACTIVITIES ARE BEING REDUCED, THUS FREEING MANY ENGINEERING MAN HOURS. INDUSTRIES ACTIVE IN INTRODUCING TECHNOLOGICAL CHANGE INTO DESIGN AND DRAFTING ARE EXPECTED TO CONTINUE IN THE FOREFRONT TO 1975. THIS DOCUMENT IS AVAILABLE FROM MANPOWER ADMINISTRATION, OFFICE OF MANPOWER POLICY, EVALUATION, AND RESEARCH, U.S. DEPARTMENT OF LABOR, 14TH STREET AND CONSTITUTION AVE., N.W., WASHINGTON, D.C. 20210. (EM)

MANPOWER RESEARCH BULLETIN

NUMBER 12 • OCTOBER 1966

Technology and Manpower In

DESIGN and DRAFTING

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DEPARTMENT OF LABOR • UNITED STATES OF AMERICA

U.S. DEPARTMENT OF LABOR: W. Willard Wirtz, Secretary

Manpower Administration

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MANPOWER ADMINISTRATION
Office of Manpower Policy, Evaluation, and Research
Curtis C. Aller, Director

Technology and Manpower In

DESIGN AND DRAFTING

1965–75

U.S. DEPARTMENT OF LABOR: W. WILLARD WIRTZ, Secretary
MANPOWER ADMINISTRATION

Preface

Technological, social, political, and cultural changes are continually reshaping the economic structure of the United States. Significant for more than a century, the influence of technology has been especially important in the last two decades. The technological advances made during World War II established the foundation for many entirely new products and industries. More recently, Government military and space research expenditures combined with greatly increased industrial spending for research and development have produced an abundance of technological advancements which promise to have an even greater influence on our economy.

Technological change affects the labor force. Existing occupations are eliminated, others decline in importance; totally new occupations come into existence, job content changes and new skills are required. Although a wide variety of mechanisms is available to facilitate manpower adjustment to technological change, the need for information lies at the core of each. The U.S. Department of Labor has for many years recognized in its research program the need to provide advance information on the potential impact of technology.

In early 1965, an experimental and demonstration project was launched within the Department of Labor as part of its continuing efforts to refine and improve its research methods. This project was designed to emphasize likely future technological and manpower changes. Close industry contact was stressed and many interviews were held with persons in companies, labor unions, research organizations, and trade and professional organizations as a means of gaining the insight needed to project specific occupational, skill, and manpower requirements at the industry level. It was expected that this approach would provide information useful for program and policy development within the Department of Labor and other Government agencies as well as to union and management personnel, the general public, legislators, and local communities that must deal with specific problems relating to present and future conditions.

On a demonstration basis, three industries and functional areas in which technology is expected to have important manpower ramifications were selected and studied. They are the design and drafting function, the health service industry, and the telephone communications industry. (*Technology and Manpower in the Health Service Industry, 1965–75* and *Technology and Manpower in the Telephone Industry, 1965–75* are now in process.)

The research for this project was completed in December 1965.

This report was prepared by Ann Marie Lamb under the supervision of Peter E. Haase, project director, and the general direction of Curtis C. Aller, director, Office of Manpower Policy, Evaluation, and Research.

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2. TECHNOLOGICAL CHANGE—Continued

Introduction

"We are on the threshold of a complete revolution in design and drafting . . ." "In the future the only familiar item in the design and drafting areas will be the engineers . . ." "Conventional drafting practices will be completely outmoded . . ." Statements similar to these are increasingly appearing in both technical journals and popular magazines. They have focused attention on technological change in design and drafting, a process found in whole or in part in many diverse segments of industry and government.

Before construction of a road in California begins, highway department engineers have considered hundreds of design details and draftsmen have prepared the many necessary drawings. Before manufacturing next year's automobile begins in Michigan, many thousands of man-hours will have been spent on designing and detailing each of the more than 3,000 body parts which must be manufactured.

Although no two design/drafting processes are identical, the end purpose is the same: To provide to those who will manufacture or construct the product all of the information needed to translate its concept into actuality.

In the case of the road, this may involve selection of the optimum route possible considering such factors as the relationship to other roads, the cost of acquiring the rights of way, as well as the technical problems of construction.

In the case of the automobile, the artistic designers use specifications obtained from product planning and market research groups to aid in producing a clay model. This model is then used by engineering design groups to implement a body design in full detail.

In each case, graphic representation is the means of expressing design ideas and detail at every stage in the process. Graphic representation includes the rough sketches used by the engineers and designers to assist them in developing early ideas, as well as the detail drawings of each part produced by the draftsman and used in manufacturing.

Changing Design Methods

The design/drafting process is undergoing change. The use of computers within the process is being extended through the development of both special programs and new equipment such as time-shared-systems, and graphical display devices. The use of numerically controlled drafting machines and microfilm equipment is also growing. The application of these techniques and equipment is coming about slowly, but the changes are affecting manpower requirements for draftsmen and engineers.

In 1963, about 199,000 draftsmen were employed in industry in the United States. While no data are available to indicate exactly how many of these are involved in design/drafting as opposed to research and manufacturing, the vast majority are believed to be directly associated with design/drafting. This is particularly true of manufacturing, which employs 120,000 or approximately 60 percent of all draftsmen, and of engineering and architectural services, which accounts for about 43,000 or approximately 22 percent.

In addition, many of industry's 684,000 engineers are concerned with design and drafting. Although it was not possible within the frame of reference of this study to determine what percentage of engineers are directly involved in design, a conservative estimate would be at least 20 percent or approximately 137,000.

The Study Approach

The purposes of this study are to identify the major technological changes which will affect the design/drafting process in the next 10 years; to determine the extent and rate of diffusion of these changes; and to assess the effects of these changes on manpower needs during the next 10 years.

The analysis of the changes affecting the design/drafting process is, however, complicated by the diversity of industries, processes, and products which incorporate design and drafting, and by a lack of meaningful statistical data. The design/drafting process is involved in the design of such diverse products as automobiles, office buildings, chemical process plants, toys, missile systems, and highways to name only a few. In spite of such a wide scope of application, many similarities exist in the design steps taken and in the basic requirements of the process. Without these similarities, of course, it would be impossible to reach any general conclusions about the impact of new technological innovations on this industry function.

This study of the design/drafting function is, therefore, based upon three working hypotheses:

1. The design/drafting process has common elements and common manpower requirements, regardless of the industry in which the process functions or the product which is being designed.
2. The same technological changes which apply to the design/drafting process in one industry or for one product will apply to the process in other industries or for other products;
3. These technological changes will have similar effects on manpower in different design/drafting processes.

Because some of the new design/drafting technology examined in this report is still in the early stages, and because of the lack of pertinent statistical data and the extremely small number of interviews possible within any single industry or product category, quantitative manpower estimates are extremely difficult to develop. Estimates made in this report are presented in broad ranges—more specific estimates are not possible at this time.

Overview

The design and drafting process is an important segment of a wide cross-section of American industry. Within this functional area, which comes between research and manufacturing or construction, design ideas are developed and refined, and the detailed information necessary to build future products or structures is produced. These design/drafting activities provide employment for a majority of industry's 199,000 draftsmen and probably more than 20 percent of its 684,000 engineers.

Although technological change is not new to design/drafting, recent developments in data processing, graphics communication, and reproduction are expanding both the number and the range of applications of advanced technology being introduced into the process. The equipment which will be used to implement technological changes in the next 10 years includes the electronic computer, manually and automatically controlled drafting machines, cathode ray tube scanners and recorders, microfilm devices, and graphic man-machine consoles.

The major technological changes expected before 1975 will utilize computer-based systems to perform design computations, process design information, and carry out, or assist in carrying out, the steps in the design itself—including the preparation of necessary drawings. Many systems that utilize presently available equipment and techniques to process applications similar to these, are already in operation today in a variety of industries. Systems and applications like the present ones will continue to diffuse over the next 10 years.

In addition, major new developments in time-shared computer systems which include graphic input-out capabilities are expected to move from experimental to operational use in design/drafting within 10 years. By 1975, only a few large firms and possibly some service bureaus will have these systems installed and performing extensive production operations. However, the use of these systems is expected to diffuse rapidly between 1975 and 1985.

Industries active in introducing technological change into design/drafting today are expected to continue in the forefront to 1975. Within manufacturing, these industries are electrical equipment, nonelectrical machinery, transportation equipment, ordnance, petroleum refining, chemicals, primary metals, fabricated metals, and instruments. Outside of manufacturing, significant activity is found in contract construction and engineering services. Small firms will continue to lag considerably behind larger ones in the introduction of technological changes.

The effects of technological changes on the total requirements for draftsmen during the 1965–75 period are expected to be moderate. The growth rate for the occupation in the next 10 years will be slowed somewhat but because of economic growth the absolute number of draftsmen will continue to rise. The expected reduction in growth will be spaced over the entire period, but as much as two-thirds of the drop may occur between 1970 and 1975.

The impact upon numbers of draftsmen required will vary substantially among industries and types of drafting activities. The greatest effects from technological changes will occur in two industry groups.—The first includes medium and large establishments in industry classifications where technological change will have a perceptible, but not extensive, effect. The second includes medium and large establishments in industries in which the impact from technological changes is expected to be most significant. The former group employs 28.2 percent of all draftsmen, the latter, 29.1 percent of the same type of workers.

Within these groups, maximum reductions from technological changes of 10 percent and 25 percent respectively will be more than offset by expected growth in demand for drafting services. Employment in these two groups can be expected to grow from the present 114,300 to at least 173,300 by 1975. The group of draftsmen working on dimensioned drawings, such as those required in complex mechanical design, will be least affected within this 10-year period.

The use of time-shared graphics systems will have a significant impact upon the number of draftsmen required. The effects from these systems will still be numerically small by 1975, but their rapid diffusion after 1975 may substantially reduce the demand for draftsmen between 1975 and 1985.

The effects of technological changes in design/drafting upon engineers are much more difficult to isolate because of the greater diversity of the engineers' functions within various design processes. However, new methods in design/drafting

Glossary of Technological Advances

Time-shared computer systems: Allow the man with the problem to communicate directly with the computer. Service more than one man at a time and use their free time to process other jobs.

Equipment to reproduce and store drawings: Accurately records the content of drawings and stores them conveniently and compactly.

Numerically-controlled plotters and drafting machines: Produce drawings using instructions and data from previously prepared tape or directly from the computer.

Cathode ray tube recorders: Interpret instructions and assemble the required picture on the face of the cathode ray tube. Then the information is photographed and printed.

Photo-composition devices: An operator composes the drawing by mechanically selecting the proper symbols. When the symbols are properly positioned on the viewing screen, they are photographed.

Cathode ray tube scanners: Scan information contained in a microfilm frame and convert it to a form the computer can use.

Digitizing machine: A finished drawing is traced under manual control and the required coordinate positions are recorded on magnetic tape or punched on cards or paper tape. The tape or cards can then be processed by a computer.

Man-machine consoles: Permit the man with the problem to communicate directly with the machine. Handle alphabetic, numeric, or graphic information depending upon the particular devices used.

are reducing clerical-type, routine activities which presently require many engineering man-hours. At the same time, these methods are opening new avenues for creative engineering. Many experts predict that the coupling of man and machine through the use of time-shared computer and graphic systems will result in a new era in engineering design.

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The Design/Drafting Process and Its Manpower

The Design/Drafting Process

The design/drafting process is a study in contrasts and similarities. If the steps taken in the design of a jet engine and a vacuum cleaner are studied in detail, little appears to be the same. However, viewed from a broader perspective, unifying elements and characteristics are identifiable.

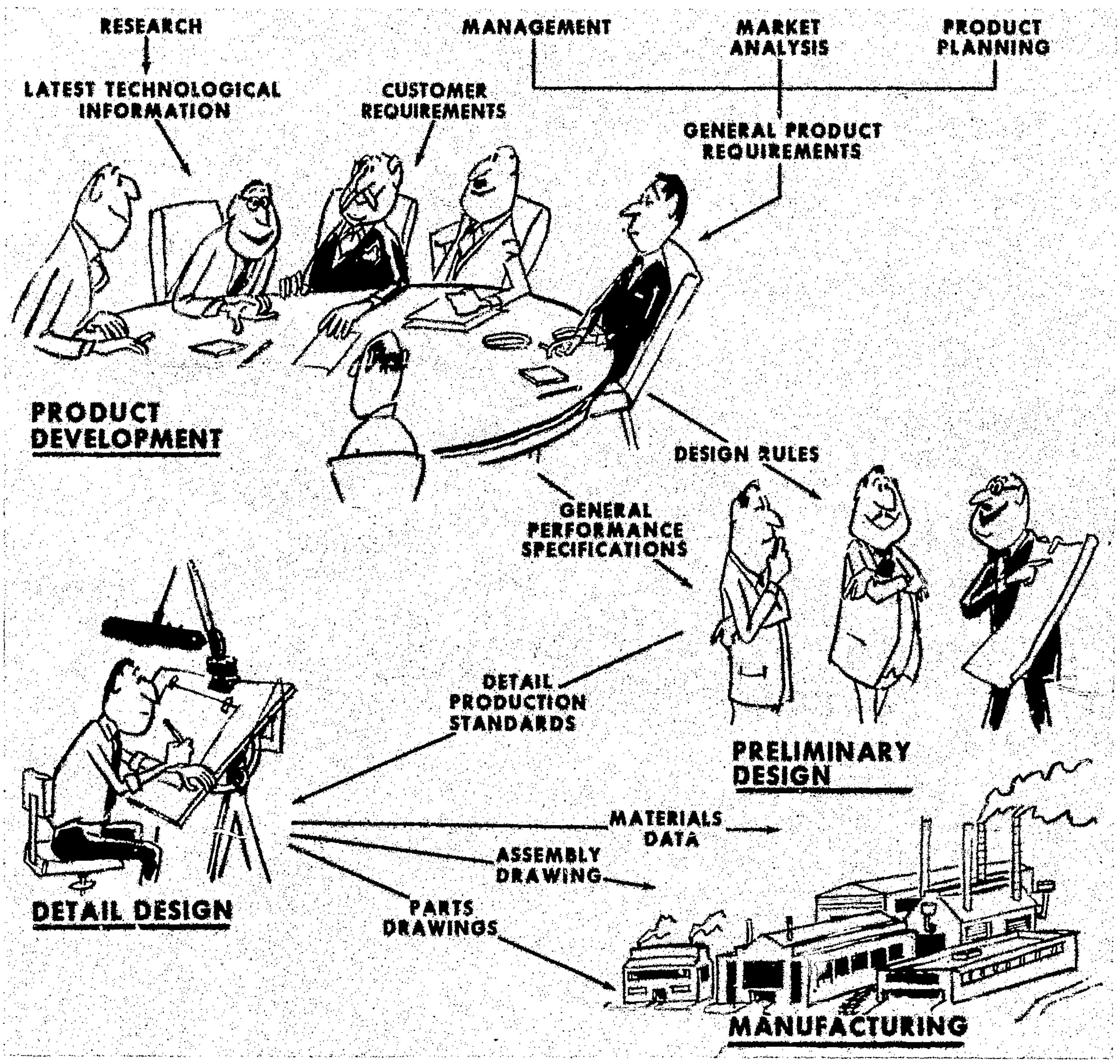
The total design process is concerned with the creation of systems, devices, or processes which will serve a human need. It must be possible to build such systems and they must have utility to consumers at an appropriate cost. Although there is no universally accepted definition of this complex and diversified process, the general sequence of events to bring a product from concept to production can be described. While this description is formed as an amalgamation of processes taking place in a variety of actual design situations, it does contain representative elements of a complex new product design in a manufacturing industry.

Steps in Design

For the purposes of this study, the design process can be described as the steps which take place between research on the one end and manufacturing on the other. The process which takes place between these two points will be called design/drafting and further segmented into product development, preliminary design and detailed product design. (See chart 1.)

Product Development. The first phase in the design process, product development, determines the validity of the product design. It begins at that point at which it is known that a particular new product is to be produced. At this point, the needs for this product and its general requirements are supplied to product development from

CHART 1 **DESIGN STARTS WITH ABSTRACTIONS, ENDS WITH PRODUCT PLAN**



other organizations such as product planning, management and market research, or in some cases direct customer specifications. On the basis of this information, the engineers begin to look for possible solutions to the problem as defined. To aid in seeking solutions, the engineers make use of the latest technological data coming from the research areas. They also rely heavily on past experience which may be codified in the form of technology handbooks and corporate engineering standards. Through combinations of creative activity, analysis, test, simulation, and evaluation the performance specifications for the product and the design rules and feasible solutions to the design problems are developed. In some cases, prototype models are prepared to prove the technical feasibility of some components or parts of the product. This information is then passed on to the preliminary design stage.

Preliminary Design. Preliminary design is concerned with the development of the specific requirements and specifications for the product.

The general requirements and characteristics are refined and made more specific, and the preferred solutions to the various engineering problems are selected. The engineers apply their own knowledge and use the information from prior designs of similar products and company specification handbooks to advance the design from the abstract to the concrete. At the completion of this phase of the process, specific product specifications are completed and the concepts are translated into preliminary graphic or mathematical terms.

Detail Design. During detail design, the design concept is documented and the complete detail necessary to manufacturing is developed. This includes preliminary master layout drawings which convey overall outlines and features of the product. From these master layout drawings progressively more detailed drawings are added until each of the parts in the final product has a complete drawing. In addition to the parts drawings, engineering must supply additional data on materials required for manufacture and must provide assembly drawings indicating how the parts will be assembled during manufacture.

The design process is repeated for each component and subcomponent within the total product. For example, an aircraft is composed of various subsystems including the frame or structure, the engine, the electrical system, and the electronic systems. After the overall performance requirements of the composite system have been established, then the design process goes forward for each of these major subsystems. Within each of the subsystems, the process is further repeated for the components within this system.

Characteristics of the Process

Some additional characteristics are important for an understanding of the design process. They are the constant iterations and changes which take place, the requirements for information handling, and the contrasts between the early and later design/drafting stages.

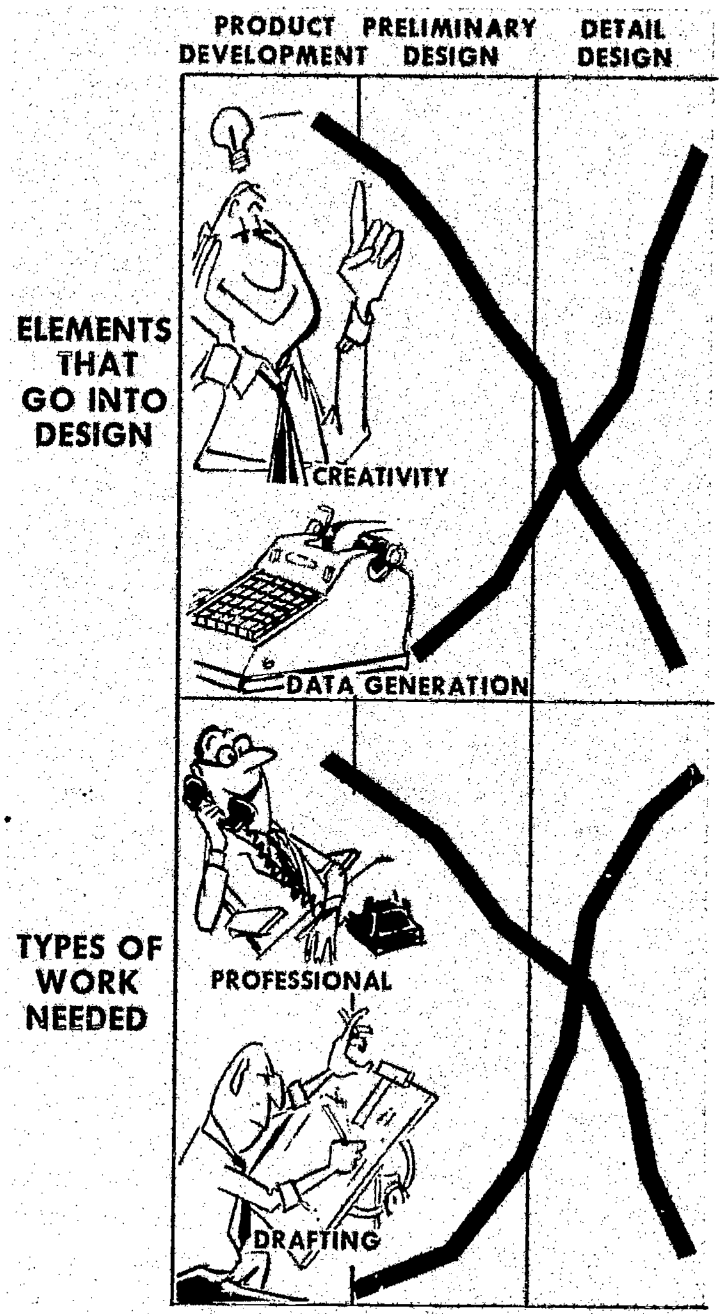
Constant Iterations and Change. Iteration and change are an integral part of the typical design process. A constant recycling takes place within, between, and among the various steps in the process. Some of these iterative loops are inherent in design: While the engineer is refining his approach to the solution of a problem, he makes assumptions, tests these assumptions and then modifies them on the basis of the results; or as more detailed information is developed, it sometimes becomes apparent that a better product would result if some of the original specifications of the product were modified. Frequently, however, the necessity for iterations in the process is caused by the pressures in many industries to minimize the total elapsed time between product conception and product manufacture. Because of these time pressures, it becomes necessary to operate segments of the total process in parallel, as for example when manufacturing tooling design begins before the part design is made final. Then both the number of changes and the number of places in which each change must be made increase.

Requirements for Information Handling. The pertinent evolving detail and the change information must be rapidly and accurately communicated within the design/drafting area and with other parts of the organization. The communication must take place vertically between the subsystems as well as horizontally within the subsystems. While some of the subsystems are relatively independent of changes occurring in the evolution of other subsystems, many of them are very closely interrelated. Any failures to coordinate the various elements of the total product during design can result in finding incompatabilities at a late stage in the process. The immensity of the information communication problem is illustrated most dramatically in missile systems, where the total number of parts may exceed a quarter of a million.

Since the basic language of the design/drafting process is graphical, the form for communication of information must permit the use of graphic representation.

Contrast Between Early and Later Stages. Creativity is concentrated in the early stages of the design process. While there is disagreement within the technical community as to what constitutes creativity in design, there is general agreement that as the design proceeds from a general idea to a specific design, the need or usefulness for creative thinking declines. In contrast to this, the amount of data which is developed and must be carried forward increases sharply as the design proceeds from the early to the later stages. This, as might be expected, results in shifts in manpower requirements. The need for professional level personnel (a level achieved either through education or equivalent experience) is high in the early stages of the process and decreases as the detail end of the process is reached. In contrast to this, the total number of manhours utilized follows the trend of the information curve. (See chart 2.)

CHART 2 CREATIVITY IS AT ITS HIGHEST LEVEL IN PRODUCT DEVELOPMENT



Common Design Elements

In spite of the diversity in the design process among industries and products, some common elements can be found. During the design process, the logical design path which is followed requires computations to take place at various points in the design, requires the referencing of various types of information during the process, and creates various types of data during the process. Some of these data must be recorded so that they can be transmitted on to a later stage in the design process itself or back to an earlier stage as part of an iteration. In other cases, information must be recorded for use outside the design area itself.

These activities, common among all design processes, can be classified under three headings: Computation, information handling, and design logic.

Computation. The need for computation occurs at scattered points in almost all design processes. In connection with one product design these computations may include making a few simple calculations with a slide rule and solving complex sets of mathematical equations.

Information Handling. The information handling element consists of two parts. On one hand are the sources of data that the engineer must call upon as he proceeds through his phase of the design. These data may come from within the design organization or from without—from within might come notification of changes which will affect his work and from without cost data on materials supplied by the purchasing department. The information may come in a highly structured form, such as a company manual containing approved standards, or it may be in an extremely informal form, such as previous personal knowledge confirmed by discussion with a colleague.

On the other hand, the information handling element consists of the information which must be passed on as a result of the engineer's work.

Again, this output may be highly structured or formalized, such as a notice of change order, or it may be as informal as a discussion. The structuring of this information handling varies drastically, first because of differences in the kinds of information. Other important differences include those in individual corporate policies and in the size of the design activity, and the resulting lengths of the lines of communication. The complexity of the product with respect to the number of parts and variables also affects information handling requirements.

Design Logic. Another underlying element of similarity in the design process among industries and products is the design logic. In a very broad sense, the design logic is the step-by-step guide to the design of a particular part. Theoretically at least, if the complete design logic for a particular product were written out, any person or group of persons with the necessary subject matter knowledge could accomplish a successful design by following the instructions. These instructions would indicate, for example: At what point in the process particular computation should be performed; how the results of these computations should be evaluated to determine what action to take next; when a search should be made in the standards catalogue; and what exact criteria should be applied to the selection of the proper standard.

While it is true that a complete design logic must exist for every product being designed, in practice it may be very difficult to follow the detail threads of the logic. In some cases, this may be because individuals who participate in the process are supplying whole segments of the process creatively or from experience without consciously going through the successive steps. In some situations, the number of parameters in the product design are so extensive that it is difficult to identify the procedures in detail. For these and similar reasons, in many instances it is not an easy task to discern the exact design logic which is controlling the details of the process. The variations in the ease with which the design logic can be detailed are found not only from one type of product to another but also within different subcomponents of the same product.

Manpower in the Design/Drafting Process

The primary categories of manpower found in the design/drafting function are engineers and draftsmen. While other significant groups, such as technicians, mathematicians, and clerical personnel support the process and are inseparable from it, this study is confined to seeking information relevant only to engineers and draftsmen.

In general, engineers are found in the early stages of design and draftsmen concentrated in the later stages. Information becomes more rigid and specific as the later stages in design are reached. Because of this, methods and procedures followed become increasingly more concrete and specific. Consequently, in the later stages of the design process there is much less variation from industry to industry or product to product.

The duties and functions of draftsmen are well defined across industry while the specific jobs performed by engineers are much more diverse and influenced greatly by the industry and product.

Draftsmen

The unifying theme within the drafting function is the description and presentation of ideas and information in graphic form. The variety in the kinds of drawings produced and knowledge needed by the draftsmen to produce these drawings is tremendous. The common denominator in the family of jobs making up the drafting occupation is the man at work on the drafting board who is first of all skilled and knowledgeable in the techniques of drafting.

Job Categories. The job categories within the family of drafting jobs tend to remain consistent across industry although there are many differences in job titles, organization structure, and the content of the individual jobs. The structure of typical jobs for a mechanical product design is used for illustration here. These jobs form a normal progression for promotion.

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Tracer. The lowest level draftsman is the tracer. This is a job which has already become obsolete in many instances because of changes in methods of reproducing and preparing drawings. In the past, the tracer performed such routine tasks as copying drawings in a better form, making minor changes in drawings, and preparing charts and graphs. When hired, he needed limited drafting experience. This job also served as a training ground for the next job up, that of a junior detailer.

Detail Draftsman. In practice, the lowest level job is now that of the detailer. His primary function is to prepare the final detail drawings which will be released to manufacturing. These may include parts drawings, assembly drawings or catalog drawings. In addition to preparing original parts drawings, working from the layout drawings, he may also correct and revise drawings. The detailer should be an expert in depicting and/or dimensioning. Although he may make simple decisions, he generally receives explicit work instructions.

The minimum requirements for this type of job vary among companies. In some cases, high school courses in drafting are considered sufficient, although in most cases, some experience or education beyond the high school level is required. In most companies, there are several levels of detail draftsmen differentiated by years of experience.

Layout Draftsman. The layout draftsman proves out the product design on paper. Taking prior layouts, sketches, models, and verbal instructions he prepares the layout drawings, or revises existing layouts. This may involve completing designs using knowledge of part fits and tolerances, algebra, geometry, or trigonometry.

These jobs generally require a 2-year technical school education or its equivalent, plus several years of experience in detailing drafting. Several levels of jobs are common within this category.

Senior Draftsman or Designer. At the top of the drafting caegory in the nonprofessional group is the senior draftsman or designer. This man draws upon his accumulated knowledge of drafting requirements, practices and know-how plus his knowledge of the product, its technology and characteristics. Using this combined knowledge he contributes to the design itself and not merely to the expression of the design in graphic form.

The designer must also have had at least 2 years of post-high school education or its equivalent, and many years of experience.

Checker. Many companies have an additional job classification—the checker. The checker is near the top of the progression and his job is to be sure that the characteristics of the design are being reflected accurately in the graphic representations at each successive stage. Even in those companies where separate classifications do not exist for checker, the checking function is present. Most checker jobs have requirements similar to those for senior draftsmen or designers.

Within these job categories from tracer to designer there appears to be substantial variation in the distribution of draftsmen from one organization to another and also at different times within the same organization. It is generally agreed that the levels usually form a pyramid with the designer at the apex. Average distribution of draftsmen ranges from one designer for every four layout and detail draftsmen to one designer to two layout draftsmen and six detail draftsmen. In actual practice, however, these averages may never be approached. Two of the several reasons for this are: First, the workload requirements tend to consist of peaks and valleys; in order to maintain a stable work force much of the detail routine work may be contracted out during peak periods. Second, in industries such as aerospace where layoffs frequently occur in drafting, the more experienced, senior personnel are retained and make the pyramid decidedly top heavy. Unfortunately, sufficient data to develop more specific information on the number of draftsmen at the various levels are not available.

The variety in the types of drawings required adds another dimension to the job categories existing within the drafting function. The drawings produced to describe a mechanical part are significally different from those describing an electrical circuit. While many subclasses undoubtedly exist, the major categories of drafting specialty identified are electrical, electronic, mechanical, and structural.

Within the framework of this study, it was not possible to obtain any estimates as to either the number of draftsmen currently employed by field of specialization or the probable distribution of workload among the various areas. However, technological trends within product types are causing a shift away from mechanical toward electromechanical and electronic design and drafting.

Present Supply. Maintaining an adequate supply of draftsmen is not considered a serious problem nationally. Some difficulties are encountered from time to time in particular locations and industries. [Ed. Note: Since research for this study was completed, the draftsman category has become a shortage category nationally.] Employment service data for January–July 1965 indicate that during this period "the demand-supply relationships for draftsmen in the 30 major reporting areas became tighter than at any time in the 7-year history of the survey." [1] However, most firms can generally fill their needs without relaxing rigid hiring specifications. There are, of course, wide variations among firms in hiring patterns for draftsmen. For example, in some cases within the same geographic area there may be several firms with fluctuating requirements for draftsmen depending upon current contract commitments. In effect, this may create a local labor pool and shortages develop only if all of the firms need to staff up for major contracts at the same time.

Other firms in situations with more consistent workloads may rarely need to hire experienced senior personnel because they can depend upon internal promotions to fill vacancies that develop. Hiring difficulties are encountered only in the rare instances when upper level people are needed. Because the draftsman contributes more than the mere ability to place lines on paper, the higher up on the scale the draftsman is, the more significant the differences in specialization and industry become. Frequently, only draftsmen with experience in the same industry and the same specialization are able to satisfy the employer's needs.

Training. The trend in the last 10 years toward education for draftsmen in post-high school technical schools or junior colleges has had a substantial impact. Now many firms rarely hire people with just a high school background and in many others the percentage of those hired with only a high school diploma has dropped. Where educational institutions are supplying draftsmen equipped to perform the employer's work almost immediately, the number and extent of company internal training programs have been reduced.

This reduction in internal training programs, however, is not universal because of the increased specialization required in some industries and for some products. One firm reported it found the same amount of internal training was required for high school graduates and those with more advanced education. This led the firm to reduce its minimum hiring requirements from 2 years of college to a high school diploma.

In the past, the schools have been slow to keep up with changes in industry practices. However, the pattern is changing. In some geographic areas the schools are now quite responsive to industry needs and are supplying highly qualified people. As in many other fields, each side of the broad-versus-the-specialized-drafting curriculum question has staunch supporters.

Engineers

In contrast to the draftsmen, the engineering categories are extremely heterogeneous and the functions which engineers perform are much more diversified within the broad design boundaries.

Draftsmen do have a variation in subject matter specialty, but there is the unifying theme of the "man-on-the-board" running constantly throughout their occupation. In contrast to this, it was not possible to find a more definitive theme for engineers in design/drafting than "the participation in the creation of total product specification through the application of engineering principles and practices."

[1] *The Current Employment Market for Engineers, Scientists and Technicians* (Washington: U.S. Department of Labor, Bureau of Employment Security, October 1965), p. 1.

The industry and product variations are much more significant in determining engineering manpower requirements and structure. In combination with the primary field distinctions such as mechanical, civil, or electronic engineering these industry-product variations result in literally thousands of jobs which differ in actual content.

Within the scope of this study, no attempt was made to deal in detail with individual categories of engineering, but rather to seek information on what kinds of changes in engineering requirements might be attributed directly to technological changes in the methods of design/drafting. This is, of course, but one facet of the technological changes affecting engineering, because it does not encompass the effects of changes in the products and the technologies themselves.

2

Technological Change

The major technological changes expected to affect the design/drafting process in the next 10 years are related to the use of the electronic computer. The computer is not new to the design process; engineering computations were among the first applications of the computer in the early 1950's. With the recent additions of time-shared systems and graphic data processing, however, the scope of the applications can be expanded considerably. The drafting area which previously had been almost untouched by technological change is beginning to feel its effects.

Since the primary concern of this study is in translating the effects of technological changes into meaningful manpower terms, only those developments with potential manpower significance are considered. With this peculiar perspective, some developments which are considered significant technological breakthroughs are relegated to a minor place while others, which are insignificant technically assume a major importance. The scope of the study is also narrowed to include only those currently known developments which will affect the core of the design/drafting process. Developments, such as photogrammetry, which are related to specific types of design are not even considered.

Reasons for Introducing Change

In sharp contrast to the situation in many other segments of industry, in most cases technological change is not introduced to the design/drafting function to reduce labor costs. Reduction of and changes in manpower requirements can certainly result, but this is usually a peripheral effect.

A major reason for introducing technological change into design/drafting is a hoped-for reduction in leadtime. Time after time, experts in the design/drafting field cite this as the cause for the high levels of interest and activity in changing present methods. If an automobile manufacturer can reduce the time from the conception of a new model to its production, this can be worth many millions of dollars in this highly competitive industry. If an aerospace corporation can offer an earlier completion date than its competitors on a major bid, this can be the deciding factor in the award of the contract. In addition to any immediate competitive advantage, the increased flexibility brought about by decreased leadtime has widespread ramifications.

Interwoven with the reduction of leadtime is, of course, the requirement to produce the most advanced product at the least cost. This includes such specific aims as improving the communication of design information; decreasing the number of design changes; reducing the number of errors; allowing more investigation of alternative design possibilities; and improving the interaction between design and manufacturing.

It is important to understand the forces behind the introduction of change. First, because of the variety of applications for which the equipment is used, identical or even similar manpower changes do not necessarily result from the installation of identical items of equipment. To analyze these primarily indirect manpower changes, it is necessary to identify and follow the patterns of change which are developing within the design/drafting process itself rather than to focus on the amount of equipment which is being installed. Second, expected results from computer-based applications are expressed in such terms as days saved, or changes eliminated. Even for those intimately involved in the design/drafting process, it is difficult to translate these results into quantitative manpower equivalents.

Factors Controlling Change

The interaction of three controlling factors will determine the rate and direction of technological change in design/drafting. *The first of these factors is the equipment*—the basic hardware tools for implementing the change. In this category are the computers, the automatic drafting machines and the microfilm recorders. *The second includes the methods for using this equipment.* In this category are the techniques of systems analysis, the computer programs or software developments—the intellectual tools for implementing the change. And *the third is the design/drafting process itself from concept stage through to the boundary with manufacturing*—the field against which the combination of hardware and intellectual tools is to be applied. The interaction of these three elements determines the rate and direction of changes in design/drafting and each evolves in relation to the other two.

The relative importance of each of these three factors in a particular situation depends upon the specific objectives of the user. For example, if the desired result in one instance is to improve the operation of a particular segment of the design process, then the user's first question is, "Is there equipment presently available with capabilities which can assist in solving this problem at a feasible cost?" If the answer is "yes," then the next questions is: "Are the systems techniques and software tools needed to implement this change available, or can they be developed at a cost which will permit us to solve this problem more efficiently?"

If in another situation the desired result is to utilize available time on an existing computer system, then this user's first question is: "Given that this type of equipment is available with these capabilities at this cost, to what scope of the design/drafting process can this equipment be profitably applied?" Followed by: "Are the intellectual tools available, or can they be developed at a cost which will permit implementing this segment of the process now?"

Because of the close interdependence of these three factors, an analysis of the evolution of technological change in design/drafting must relate technical advances within one factor to the current status of development in the other two. The integrated status of the three factors then determines the technological "state of the art." Which of the three is the limiting factor may vary from one stage of total development to the next.

Equipment Developments

The equipment described in this section performs three major functions—computation and data processing, graphics communication, and reproduction. In some cases, the same item of equipment may combine more than one of these functions. In some instances an item of equipment may be capable of operating independently, in others it must perform as part of a larger equipment system.

General Purpose Computer

The general purpose electronic computer is the most important development and the major catalyst to significant technological changes in the design/drafting function. With but a few exceptions, it is an integral part of all recent changes in methods. It is considered an essential in formulating plans for changes to come.

Standard computers of all sizes and costs are currently used in a wide range of applications within the design/drafting area. Small desk-size machines are used by individual engineers as big slide rules. Large room-sized machines are used to simulate the product performance. Thousands of computers are presently being used to aid in design throughout industry and Government. The present trends toward constantly increasing the capabilities of these machines without raising the cost is expected to continue.

Two central computer system developments have particular significance to this study. The first is the storage capacity of the system. How many digits or characters of information can be stored within the system so that the computer can locate a specific item of information rapidly whenever it is required in processing? What does this cost per item of information? The general trend has been toward substantially increasing the storage capacity while at the same time lowering the cost per character. A continuation of this trend is likely, with big jumps being made from time to time.

The second development is the one popularly known as the time-shared system. In traditional computer installations, all the instructions necessary to process a given job are detailed in advance by the programer. When the data are available, they are fed to the computer and it carries out the instructions using the data. One job is processed completely before the next is begun.

Under the time-shared concept several things change. The man with the problem is permitted to communicate directly with the machine through a console. If his problem is not well enough defined so that a program can be written in advance, he can work it out using the assistance of a large powerful computer as he goes along. Since it would not be economically feasible to restrict a large computer to the speed of one man, the computer must be able to service more than one man at a time and to use its free time to process other jobs. While in actuality the computer is doing only one thing at a time and rotating among the various problems, because of its tremendous speed it appears to the users that many jobs are being performed simultaneously.

At the present time more than a dozen time-shared systems are in operation. These are primarily classed as experimental and are using modified conventional computers. The major computer manufacturers have announced and are now delivering new models which are specifically designed for time-shared operation.

The major problems to be solved in implementing systems of this type are not hardware but software and systems technique problems. Expert opinion varies as to the time and cost involved in meeting these problems, but there is general agreement that the development of the time-sharing concept is central to any evaluation of technological change in design and drafting.

Equipment to Reproduce and Store Drawings

One of the few major developments taking place almost completely independent of the computer is the change in the methods of reproducing and storing drawings. Developments, particularly in microfilming and reproduction techniques, such as xerography, have led to equipment which can accurately record the contents of drawings, store them in a convenient and very compact form, assist in referencing the drawings, and produce quick and accurate copies to required size.

Most of the organizations interviewed have already implemented systems of this type for their drawing files. These developments are itemized separately here because, although they are already widely diffused, they form a necessary backdrop for some of the later topics.

MAN-MACHINE CONSOLE: An engineer uses a CRT display and light pen in designing an electronic circuit.

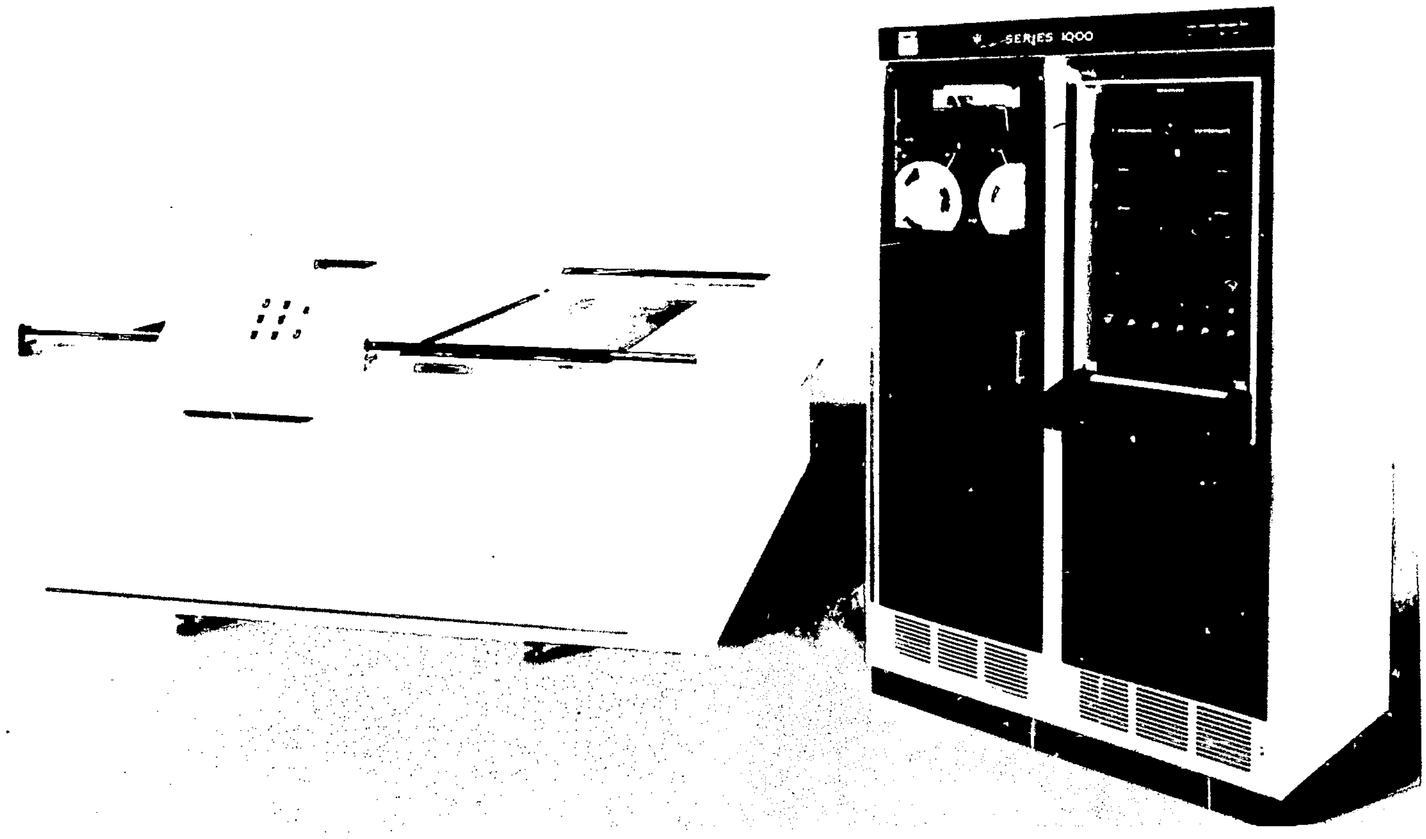
Equipment to Produce Drawings

Although the equipment described above can copy drawings, it causes no changes in the initial production of the drawings. The equipment described later actually assists in the initial preparation of the drawings. Some operate as independent units, while others depend upon a prior computer operation. Some can produce many kinds of drawing, while others are more limited in their capabilities.

Numerically Controlled Machines. The basic numerically controlled drafting machine consists of a drafting table with a turret mechanism which can be automatically positioned with high precision anywhere over the table. Mounted on this are the drawing instruments and in some cases a separate print wheel for alphabetic information. The types of drawing instruments may include pens, styli, and in some cases a photographic device to expose film. On some models multiple pens are mounted so that drawings can be done in various colors. The printing capabilities also vary. Some models offer more than one type style while others do not include a separate printer; alphabetic and numeric (alphanumeric) information is drawn with the pen.

A unit separate from the drafting table interprets the instructions and controls the drawing and printing of the proper lines and characters. The devices can work at tolerances measured in thousandths of an inch and at speeds of several hundred inches per minute. Complex engineering drawings can be produced in less than 20 minutes.

The instructions to this equipment can be provided directly from a computer or from a tape which has been prepared by the computer in advance. Taped instructions are normally used because of the time disparity between the elec-



AUTOMATIC DRAFTING MACHINE: Precision drawings are prepared using information from tape or from a computer directly.

tronic speed of the computer and the mechanical speed of the drafting machine.

Although a small number of these drafting machines are installed today, the majority are in experimental, rather than production use. The limitations on use at this time stem from broader systems problems rather than from hardware characteristics.

The plotting machines are quite similar in concept and operation to the drafting machines. The differences are primarily in the degree of accuracy and the quality of the drawings that can be produced. These simpler plotters are more widely used today than the drafting machines and are currently producing a variety of less complex, nonprecision drawings.

Although improvements certainly will continue to be made in this equipment over time, the rate of its use will depend on the solution of application, system, and software problems and not on hardware breakthroughs.

Cathode Ray Tube Recorders. Cathode ray tube recorders serve a purpose similar to that of the automatic drafting machines but operate from a completely different premise. The heart of these devices is a televisionlike cathode ray tube (CRT). The recorders interpret instructions and, in effect, assemble the required picture on the face of the CRT. When a complete picture is present, the image is recorded on microfilm. This equipment could, of course, be used as a printer for alpha-numeric information or for simple plotting as well as for drafting. Since the CRT is electronic, the speed at which the picture is assembled is measured in microseconds. Therefore, an entire drawing can be displayed in seconds compared to 15 minutes to an hour when the drafting machine is used.

These devices can also be operated directly from the computer or from magnetic tape. Because the speeds are more commensurate with computer speeds, there will be more instances where the on-line mode will be used. However, the main use at this time is off-line from tape.

A few devices of this type are presently being used in the design/drafting area, and several manufacturers are offering models as standard equipment. But as with the drafting machines, the future use will be determined by broader applications developments.

Photo-Composition Devices. These devices for producing drawings are substantially different from those discussed previously. An operator "composes" the drawing by mechanically selecting the proper symbols from a set available with the particular device. When the symbols have been properly positioned on the viewing screen they are photographed. These machines are completely independent of a computer system. The kinds of drawings which can be produced are determined by the symbolic set available to the operator.

Several devices of this type are commercially available today. They are used primarily to produce nondimensioned drawings such as electrical or electronic diagrams.

Equipment to Read Drawings

The need to produce drawings automatically is readily apparent in considering changing methods in design/drafting. The significance of the ability to read drawings automatically is perhaps less obvious. However, if a computer system with a drafting machine is to be used to produce new drawings, it will frequently need to refer to information contained in already existing drawings. It will therefore need to be able to read these existing drawings automatically into the system.

Cathode Ray Tube Scanner. The cathode ray tube scanner is representative of the types of equipment used to read drawings. This device performs the reverse operation from that performed by the CRT recorder equipment on output. That is, it scans information contained in a microfilm frame, and converts this information into a form that the computer can use.

Developments in this area are slightly behind those in the output area. However, several devices of this type are in experimental operation. Standard models are expected to be available in about a year.

At least in the early stages, these devices will require direct attachment to a computer so that the power of the computer can be used to aid in "reading" the drawings. The major technical problem remaining is to develop a technique which enables the computer to determine the meaning of the drawings—for example, to determine that four lines are, in fact, a square and not merely four lines. The solution of this problem will require specially developed computer programs. Generalized programs of this kind do not exist today and estimates are that they are several years away.

Digitizing Machine. Another approach to reading or digitizing drawings uses equipment similar in many respects to the numerically-controlled drafting machine described previously. A finished drawing is traced under manual control and the required coordinate positions are recorded on magnetic tape, or punched on cards or paper tape through the control unit. The tape or cards then can be processed by a computer.

Devices of this type are available, and some are currently being used in connection with preparing tapes for numerically controlled machine tools.

Man-Machine Consoles

Man-machine consoles permit the man with the problem to communicate directly with the computer and are an integral part of the time-shared systems concept. If the information which the man and machine wish to communicate is all alpha-numeric, then the standard types of typewriterlike keyboards can be used by the man for input. Simple typewriterlike printers can be used by the machine for output. Many devices adequate for this purpose are available today.

If it is necessary for the man to be able to communicate graphically with the machine, then a completely different set of conditions must be met. Of the several approaches being investigated, one utilizes a CRT display, a device called a light pen, and a set of pushbuttons. The light pen can be positioned anywhere on the face of the display tube. By pointing or, in some cases, drawing with the pen, the man can direct the computer to make changes in designated parts of the drawings on the CRT.

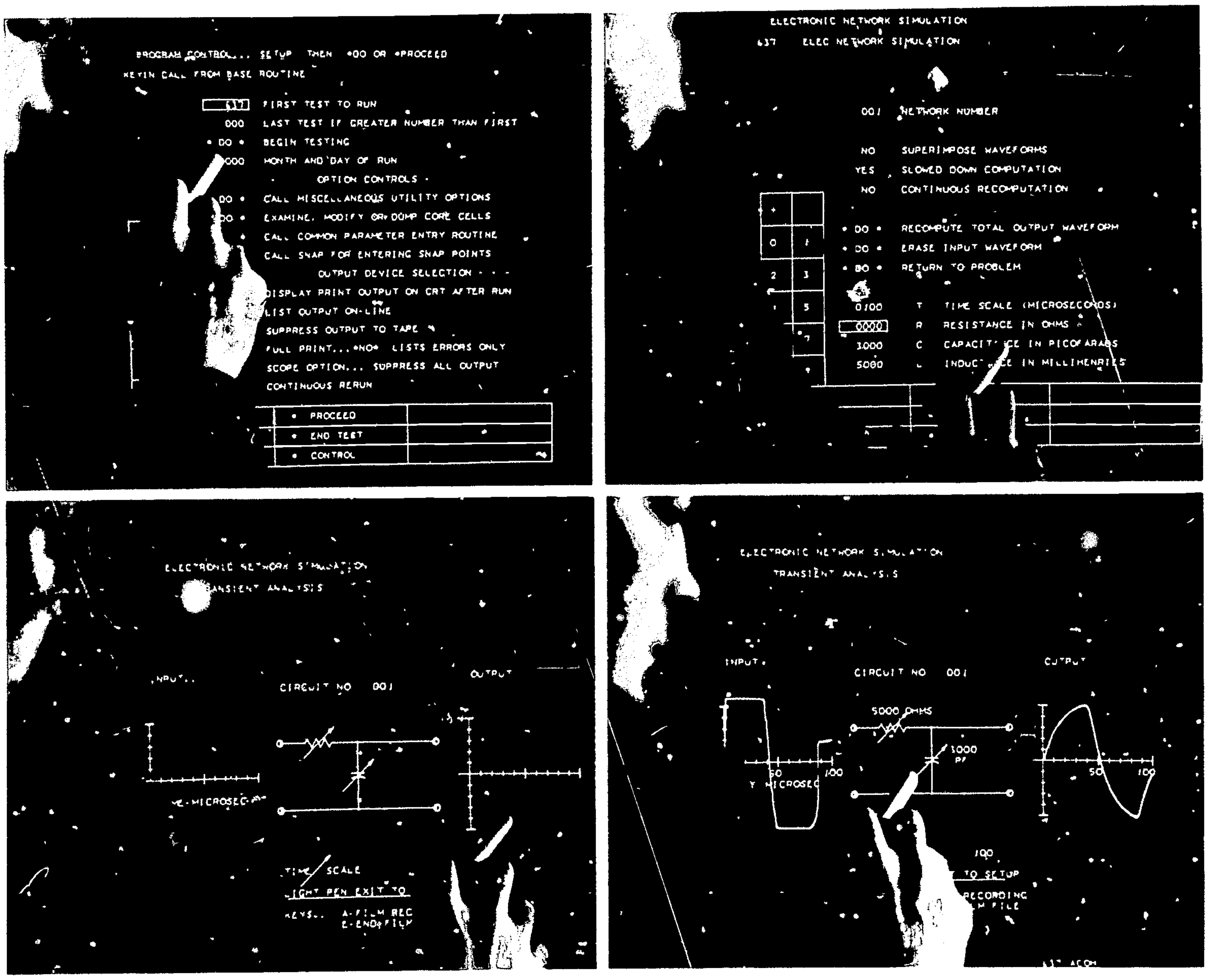
Because the computer's role in this man-machine communication is determined primarily by the programs provided and not by the hardware itself, the possibilities for extension of these techniques are unlimited. The computer can store, manipulate, and analyze the information it is receiving, in addition to providing a substitute for manual drawing.

All of the installations currently using this type of equipment are classed as experimental. Standard products in this category have been announced and some deliveries have been made. Once again, software considerations are expected to be the determining factor in controlling the rate of diffusion.

Several general observations can be made in summarizing the hardware component. With the exception of the standard microfilm-xerography equipment and the photo-composition type drafting equipment, the hardware categories which are expected to contribute toward major technological changes in design/drafting operations in the next 10 years are all components of computer-based systems. Numerous computer systems not requiring time-shared or graphical input-output capabilities are now used in various phases of design/drafting.

A few additional computer systems using graphic output only are in production operations today. Other systems of this type are being tested prior to their use for production purposes.

Time-sharing and man-machine consoles are inseparable. The present time-sharing systems are mostly experimental, but there is some limited



ELECTRONIC COMPUTER: Computers were first used for computation in design/drafting in the early 1950's.

operational usage with nongraphic consoles today. Graphic consoles and CRT type readers are still several years away from general operational usage.

While system techniques and software factors are always important to computer systems, they are particularly significant for advanced developments such as time-shared systems, and graphic communication equipment. The availability of pertinent general purpose software to support each hardware development will lag somewhat behind the availability of equipment.

Present Applications

Many technological changes utilizing the types of equipment just described have already been introduced into production operations in design/drafting processes. The majority of these applications can be classified by relating them to the three design/drafting elements of computation, data handling, and design logic. In addition, there are some specialized applications which do not lend themselves to simple classification.

The scope of the design/drafting applications in productive operation today is limited by three major factors: (1) The computers process each job serially to completion and all the instructions to process a particular problem must be written into a program in advance; (2) machines providing quick reference to large amounts of storage capacity for program and data are expensive; and (3) direct graphic capabilities are not available for input.

On the software side, the user can make use of the large reservoir of techniques and programs developed for general data processing use. Just emerging are the generalized programs for handling graphic output, and special types programing languages tailored especially for design/drafting applications.

The broadest and by far the largest use of computer systems in design/drafting today is for mathematical computations. This was the earliest major use of computers in design dating back to the mid-1950's. It undoubtedly will continue to be the largest for many years. The requirements to perform computations are scattered throughout the design process, but in a sense each one covers only a very small span out of the continuum of design.

Design/drafting applications for routine data processing such as maintenance of parts lists information also began in the mid-1950's and have spread rapidly. Pure applications of this type tend to reduce routine clerical activity and improve communications within design/drafting and with other groups such as manufacturing or procurement, but they do not improve on the design process itself.

Computation and data handling as independent applications may be extended with the advent of time-shared systems. However, the real advantage will come from the ability to integrate these areas with other parts of the design process through the use of time-shared systems.

These two types of applications are dispersed widely throughout many industries and many types of product design today. The other present operational systems to be discussed are much more restricted in the extent of their use.

In the third major category of applications the scope of the design process covered is extended to include segments of the design logic. The computer programs that are written tell the computer how to follow the same logical steps an engineer would take in producing a segment of the design. The programs give the computer detailed instructions for making any decisions required in the process. If computations are required in the course of the design steps, the computer performs them. If the engineers would consult a materials catalog in the process, then the equivalent of the catalog is placed in the computer's storage and the computer is told how to look up the needed information.

Systems of this type are currently in use for detailing circuits for complex electronic systems, for detailing the structure of pipes needed for a new processing plant, and for designing cams for electromechanical equipment.

The largest group of users of this type of system fall into the customized product category. Within this category, the basic design remains constant but each product produced is customized to meet the individual requirements of the customer. Here it is frequently possible to detail the design decisions in advance. These types of products include motors, pumps, switchgear, generators, transformers, instruments, communications gear, and heat exchangers.

The output supplied by the computer varies considerably among design logic applications. In one of the transformer design cases the computer supplies only alpha-numeric printouts. In piping detailing, all the drawings needed for construction are produced by the computer system. In the electronic circuit design the computer provides the output which can go directly to a numerically-controlled manufacturing machine which produces the part.

These applications which combine the computation, data handling, and design logic elements of the process do so in widely varying ways. Two illustrations of typical applications, although insufficient to show the variety of possible applications, do demonstrate the basic techniques used and advantages to be gained from computer design systems. These cases are representative of several categories of applications and indicate typical manpower implications. These are based on information from published reports and conference papers. (See exhibits 1 and 2.)

Exhibit 1 illustrates the use of a computer system without graphic output in the design of a customized product—in this case transformers. Over 90 percent of the required transformer designs can be handled by the new system; order processing time has been cut by nearly 85 percent; and substantial engineering time has been saved.

Exhibit 1—Transformer Design [1,2]

Problem: An electrical equipment manufacturer produces, among other items, power and distribution transformers. These transformers are a customized product; although the basic design is stable, some of the characteristics of the product must be varied to conform to each customer's specific requirements.

Previously, the engineers received the performance data supplied by the customer such as the high and low voltage requirements. Using their past experience, standards, and previous design solutions, they either found a previous solution to the same problem or selected initial variables, performed calculations using these variables, evaluated the results, selected new variables, and repeated the process until an acceptable complete design was reached. Then the necessary documentation was prepared to submit to manufacturing.

Solution: To develop a computer-based system, the steps taken by the engineers are analyzed and the complete design logic is detailed. Computer programs are written. These enable the computer to do more than merely perform computations. By following the rules laid down for decisionmaking and analysis, the computer is able to duplicate the total design cycle followed by the engineer.

When the customer requirements are received, they are edited. The information is punched into cards and the cards are fed into a medium-sized computer with two large storage units. The computer prints out all the documentation needed for the product including the product characteristics, references to assembly drawings, and a bill of materials which gives the part number and quantity of each mechanical part needed.

The decision to implement the computer approach was reached approximately 3 months after the initial study of feasibility began. The first computer transformer design was produced approximately 7 months later. The system is expected to handle 90 to 95 percent of the transformers; the remaining ones are special cases which require large amounts of information not practical to store in the computer.

The equipment used in this installation is standard computer hardware with card input and printer output. It should be noted that the system itself requires no graphical capabilities. The data used by the machine are all alpha-numeric. It is not necessary to create the assembly drawings or parts drawings with the computer system. These drawings are already in existence. The computer merely supplies reference numbers which identify the drawings needed in manufacturing.

Results: The new system has resulted in substantial savings in time and cost. The computer requires approximately 30 minutes to compute and print out the necessary electrical and mechanical information. This has reduced the total time to process a customer order from a minimum of 6 days to 1 day. The number of drawings necessary for manufacture has also been reduced. The primary manpower effect is to reduce the engineering man-hours required per transformer design. The engineering staff is freed from routine mathematical work and allowed to concentrate on creative development work; at the same time the firm's capability is increased without adding engineering personnel.

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[1] Holstein, David, "Automated Design Engineering," *Datamation*, June 1964, pp. 28–34.

[2] Sweitzer, Kenyon, "Automated Design Engineering," *Data Processing for Science/Engineering*, January/February 1964, pp. 35–39.

Exhibit 2 illustrates the use of a computer system with graphic output to analyze the stresses and select the proper steel beams needed for a process plant. The computer programs include not only computation but also the complete steps and logical decisions necessary to arrive at a solution to the total problem. To satisfy the data-handling requirements, the computer has access to the equivalent of the standard steel beam catalog.

The use of these programs in plant design has reduced the time for this phase of the design for a small building from 3 or 4 days to 25 minutes. Although some drawings are produced automatically, the major effect is a reduction in engineering man-hours.

Considering the total number of products and structures designed in the United States, the present day list of examples of design logic applications is exceedingly small. These present applications have four factors in common: (1) A clear cut design logic, (2) a limited number of design variables, (3) an acceptable nongraphic representation for input data, and (4) a requirement for repeated use of the design programs. Each of these factors tends to limit the number of users who can utilize computer design methods today.

In each of the present applications, the steps in the design were sufficiently well known so that programs telling the computer exactly how to proceed could be written in advance. In many other situations, the design logic is much less clear cut and, although it might be possible through an extensive analysis to establish the detailed steps, the cost would be prohibitive. In still other instances, the engineers or designers are supplying creative elements and it is not possible to write computer programs to duplicate this creative activity.

Where major segments of the design logic cannot be detailed in advance, the man-machine interaction of the time-shared system will offer an alternative solution; the man will be able to work in conjunction with the machine to guide

Exhibit 2—Process Plant Design [3]

Problem: An analysis of the stresses which must be borne by the beams in the building is a problem that must be handled in designing a process plant. The loads which must be considered can result from such forces as winds or earthquakes as well as normal gravity loads. When the stresses have been determined, the proper members must be selected from a catalog of standard steel beams and erection diagrams must be prepared. This problem is faced by an engineering firm extensively involved in design and construction of process plants.

Solution: The input data to the computer systems consist of the number of bays in the north and east direction, the number of floors and the dimensions between the bays and floors. The computer generates member records for all members within the above described grid system. Additional members, such as floor framing may be added. Members may also be moved from the grid locations or may be removed. Next the loads to be applied to each bay are supplied. The computer distributes these loads to the members located within the bay. Unit loads for the various loading conditions are computed, the maximums are sought and recorded in the member record. The computer then searches a steel shape catalog to locate the most economical shape in accordance with code requirements. Information about the selected beams is printed out. Erection diagrams may be plotted with an X–Y plotter. These drawings require additional work before they can be considered finished drawings.

A small computer with two disc-type storage units is used. In addition to the standard card input and printer output, an X–Y plotter is also needed for output.

Results: With the computer system, the time from the geometric conception to the listing of selected members has decreased substantially. For a small building, stress analysis and beam selection which used to take 3 or 4 days of an engineer's time now take roughly 25 minutes with the computer system. Errors from communication failures among people have been reduced with the tightening up of communication lines. Better documentation of the project also results, since the methods used by the computer program are always consistent and provide detailed historical records. The major overall result is to permit the construction of the building to commence at an earlier date.

The use of the computer reduces the engineering man-hours required for this phase of the design. Some of the required drawings are also created directly from the information stored within the computer.

[3] Bathrust, L. L., "Automated Building Design," *SHARE Design Automation Workshop*, Atlantic City, N.J., June 1965.

it through the process.

In presently operating computer design systems the variables in the design are relatively small in number and the amount of information of the catalog type which must be available to the computer is slight. However, in many design areas vast amounts of data must be available at points in the design. Applications of this kind will probably have to wait for expanded storage capabilities at a lower cost and/or for the time-shared system capability to permit the man to continue to supply some of this information.

In all of the present installations, the original data supplied to the computer to use in the specific design work can be conveniently and economically expressed alpha-numerically in nongraphic form; none of these applications incorporates complex mechanical parts design into the work being done by the computer. Until graphics input equipment and software are available, it is doubtful whether much progress can be made in the design of mechanical parts on a broad scale.

All of the present users can make repeated use of the design programs. The electrical generator design system is used every time a customer orders a new machine. The electronic circuit programs are used many times for various circuits going into one final system product. For many types of product lines, most particularly standard mass-produced consumer products, the present computer development and operating costs far outweigh the usefulness of the end result. It is probable that the design process of these simple off-the-shelf types of products will be affected least by technological change within the next 10 years and for a considerable period thereafter.

In addition to the three major and relatively common applications in computation, data-handling, and design logic many specialized uses of computers are present within the design/drafting process. Although these uses will affect manpower requirements to some extent, their diversity and special purpose nature make it difficult to determine their impact and to evaluate their general applicability.

One of the more extensive specialized applications is described in exhibit 3. This example illustrates the problems associated with handling large amounts of graphic material without the availability of graphic input devices and also the extent of the software developments which can be required in a design/drafting application.

EXHIBIT 3—DETAIL DRAFTING [4]

Problem: A large aerospace company involved in complex prototype design must produce tens of thousands of detail drawings a year for electrical, mechanical, electronic and structural components. Because of the highly sophisticated nature of the product and the rapid changes in technology taking place within the product area itself, enormous numbers of changes must be made in these drawings These changes continue on through the life of the product. In addition to keeping the drawings themselves up to date, there is a tremendous communication and control problem.

Solution: The layout drawings are prepared in the conventional manner. Then, rather than preparing detail drawings as before, the draftsman uses a special drafting language to describe in symbolic form the data which would normally appear on a detail drawing. The draftsman not only translates the lines and the geometry of the drawing into symbols, he also performs his normal tasks of checking standards and adding information about items such as weights to the geometry. This information is also coded through the drafting language.

The coded information is read into a computer which stores the description of the drawing into the equivalent of a precision drawing file. These "drawings" then are available at any time to be drawn through the use of an automatic drafting machine or its equivalent.

When changes must be made in drawings existing in the computer file, the drafting symbolic language is used to indicate those segments of the drawing which should be changed. When these data are fed to the computer, it can make the required changes and produce a current drawing through the drafting machine. A complete history of the changes and the parts list information is also maintained by the computer.

This project is a joint development of the aerospace company and the computer manufacturer. The initial systems study required 6 months. During this time the specifications and a trial drafting language were developed. The systems development phase required

[4] Harris, H. R., and Smith, O. D., "Autodraft—A Language and Processor for Design and Drafting," *SHARE Design Automation Workshop,* Atlantic City, N.J., June 1965.

18 months. During this time the language was tested and revised and the computer programs were prepared.

This system requires special computer programs to handle the symbolic drafting language and to provide instructions for a variety of graphic output devices.

The systems development stage of this project has been completed and the applications development stage has begun. All types of draftsmen—electrical, mechanical, electronic, and structural—are being taught the language to begin implementing the system on a limited basis.

The equipment presently being used on this project includes a large computer and a cathode ray tube printer for the drawings. The alternative output device is a numerically-controlled drafting machine. However, one of the prime considerations in developing the system was to make it flexible so that it can be expanded or modified easily in the future to accommodate different hardware components as they become available.

Result: In contrast to the earlier examples, this system is primarily concerned with the drafting as opposed to design stage. It does not attempt to abolish the requirements for drawings or even to reduce the number of drawings needed *per se*. The objectives are to exercise more efficient control over the release of engineering drawings and to improve the communication of the detailed information.

The value of the computer approach stems not from the ability to replace the draftsmen as a producer of drawings but from the ability to coordinate and maintain large amounts of information and to cross reference and update this information efficiently.

In this application, the draftsmen must still go through the same process of planning and decision making but the method he uses to express his results has changed. Instead of placing the results on paper through drawings supported by alpha-numeric, and symbolic notations, he produces a coded description of these results.

This particular application of a computer system will probably be useful only for large firms designing complicated products with high rates of change to the drawing and therefore with severe communication and control problems. However, it does illustrate several important general factors. First, if the actual parts drawings used by manufacturing are to be prepared automatically by drafting or comparable equipment, then the instructions to these machines from the computer must be in numeric form. In this case this was done by having the draftsmen prepare the instructions in a special language. Then the computer translates this language into the form required by the graphics equipment.

In general, the data needed to prepare drawings must be able to be stored by the computer. This implies that the computer either must have sufficient storage to permit it to retain all pertinent drawing information within the system or must be able either to regenerate the information easily or to read it back as needed from a convenient source outside the machine.

In this application, the existing man-oriented programing languages were not suitable and it was necessary to develop a new language. (The drafting language was not totally new since it was based to some extent on the APT language used for programing for numerically controlled machine tools.) When new language developments are needed, this adds substantial development time and cost. New language developments may be deemed necessary either because standard languages are considered inadequate for the job or because it is felt that the language must be compatible with the user's normal methods of solving his problems. Once a user oriented language has been developed, the language can be used by others if the originating organization permits the use of its translation program.

This system, which is still in the final stages of test, is used to produce, control and maintain the detail drawings required for aerospace systems. It does not affect the design process as do the examples in exhibits 1 and 2. The engineers and draftsman still make all the decisions required in determining the content of the drawings; the computer system merely produces the drawings. Applications of this type are practical only for firms with extremely large volumes of detail drawings and with high rates of change.

Experimental Systems

In addition to present operational systems, several classes of experimental systems are in use today. While their purpose and activities are quite diverse, the results of these experimental projects will largely determine the operational developments in design/drafting to 1975.

The identification of present operational systems is quite clear cut. They are those systems actually doing productive work as a part of normal operations. Then it can be said that all other systems are experimental. However, many degrees are present within experimental systems. Some are experimental only because they are not yet ready for operational use. They are being developed using standard hardware and existing software applied to a real operational scope and as soon as the application programs are written and tested, the system will be converted to operational use. Others, such as the system described in exhibit 3, are being developed directly for operational use but the development phase assumes the construction of major new software tools or the arrival of standard but new equipment which has been announced but not yet delivered.

In addition to these are experimental systems used in research projects. These systems are not being developed for direct implementation in an actual operating situation. They are focused, rather, on developing better approaches to solving actual operating problems. When these techniques reach maturity, they lead to implementation of more advanced operational systems.

These experimental projects vary tremendously. One of the many reasons stems from their relationship to the three factors of hardware, software, and applications scope. Some of these projects start from an identification of a particular application scope and are focused on developing the needed software and perhaps even hardware to permit feasible use within this scope. Others may start with the present hardware and work toward developing generalized software which can extend the application scope to which this hardware can be applied economically.

Among the vast array of present experimental systems, two technological areas are particularly pertinent to the expansion of the application scope in design/drafting in the next 10 years. These are time-sharing and graphics communication.

Major projects combining both of these technological areas are underway in industry today in the aerospace and automobile industries in addition to the data processing industry itself. Considerable activity is also underway in universities and research organizations. Among this latter group, the most comprehensive projects are the time-sharing and computer aided design projects at Massachusetts Institute of Technology which are sponsored by the Advanced Research Projects Agency of the Department of Defense and the Manufacturing Technology Laboratory of the Department of the Air Force.

A major time-shared, graphics communication project underway in the automobile industry is described in exhibit 4. This system is using a conventional computer programed to operate as

EXHIBIT 4—MAN-MACHINE GRAPHICS COMMUNICATION [5,6]

In the late 1950's a major automobile manufacturer initiated a research project to investigate the potential role of computers in the graphical phase of design. The initial goals were to develop a combination of hardware and software techniques which would permit man-machine interaction for graphical communications and provide ease of use for experimentation. A system meeting these objectives has been in operation since early 1963. A large computer with large storage devices, an image processor and a graphic console are the major items of equipment. The graphics equipment was developed by a computer manufacturer to the specifications of the automotive firm.

The image processor is both an input and an output device. It can photograph drawings and in 30 seconds have the film ready for scanning by a cathode ray tube under computer control. Data can be sent from the computer to another cathode ray tube to be recorded on 35-mm. film. The graphic console permits direct graphic man-machine communication through the use of a display tube and a position-indicating pencil. After touching the pencil to a portion of the display, a man may instruct the computer to take action concerning this portion of the picture. The console also contains a keyboard, card reader, control keys and message lights to use in instructing the computer.

In using the system, the designer writes out statements describing a section of his total problem in a specially developed descriptive language. The statements are entered into computer storage. From the console, the designer tells the computer to carry out the instructions and normally to display the results. To assist in his analysis of the display the designer can request the computer to enlarge portions of the drawing or to display a view from another angle or perspective. If the solution is not satisfactory, he may make changes, such as adding or deleting lines, changing values in his statements or modify the statements.

[5] Design Augmented By Computers," *Search*, October 1964.

[6] Jacks, Edwin L., "A Laboratory for the Study of Graphical Man-Machine Communication," *Proceedings—Fall Joint Computer Conference* (San Francisco: Spartan Books Inc., October 1964), pp. 343–350.

If major changes in his problem solution are needed, he may resubmit an alternative approach to the computer at a later time. When the display is acceptable, the designer instructs the computer to produce a copy of the drawing. If the statements used by the designer contribute toward the solution of a recurring problem, then these statements can be added to a library of programs maintained within the computer. This library continues to grow and programs from it can be used by any of the designers.

In addition to the programs produced by the designers using the descriptive geometry language, others are necessary, for example, to direct the computer hardware and to provide the translation from the descriptive geometry language to the computer language. In all more than three-quarters of a million operating instructions have been written by the computer programers.

One group of programs was developed to solve the basic problem caused by the different time scales in which the man and the computer operate within the man-machine partnership. The system is programed so that the computer can perform completely unrelated work until another request is made from the console. It is estimated that about 6 minutes of computer time are used for every hour of console time.

Because this is a constantly evolving laboratory project, the exact form that the system will take when it becomes feasible for production use is not yet known. Many man years of effort have gone into this project. The people involved have included many automotive designers, as well as computer hardware and software specialists.

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a time-shared system and specially developed graphics equipment including a man-machine console. Automotive designers and computer specialists are working with this laboratory project to develop methods for using systems of this type in the design of automobile bodies.

In addition to the projects combining both time-sharing and graphics communication, many projects are directed toward development of the time-shared concept. This concept for computer use has ramifications far transcending design/drafting. Much of the technique and software developments from these time-sharing projects will be applicable to design/drafting applications as a subclass within the total applications area.

The experimental projects in time-sharing and graphics communication have one common purpose: To permit the development of operational systems where the man supplies those elements in which he is strongest—imagination, creativity, and judgment—and the machine amplifies the man's abilities by supplying computational power, and speed and accuracy in carrying out routine repetitive tasks.

Future Operational Systems

The most significant future operational systems in design/drafting will be based on the two important concepts of man-machine interaction and direct graphical communication. With the addition of these concepts, it is possible to visualize a total systems approach to the design/drafting function beginning at the design concept stage and carrying through to the creation of the documentation for manufacturing, or where appropriate, of the tapes needed to run numerically controlled production equipment.

Selection of the equipment needed and desired for such a system can vary widely without exceeding the capabilities of existing and proposed equipment. Software and systems development projects already underway can technically remove any barriers to utilizing the equipment for greatly expanded segments of the total design/drafting process.

Thus systems can be designed which use the computer as a coordination center for the design process from product concept to manufacturing. While the details and exact nature of such a design process are not now known, the general outlines and trends seem well accepted.

The technical feasibility of such systems has been established, although considerable development work remains to be done. Determination of when the first systems will be introduced into design/drafting operations and who will be the first users depends upon an analysis of the costs involved and the ease with which these systems can be integrated into existing organizations.

Three major elements are involved in determining the cost of a proposed system: The cost of the equipment and personnel to operate and maintain the new system after it is in full operation; the cost to design the new system including analysis and programing; and the cost incurred in converting from the old to the new method.

Indirect as well as direct costs are implied here. For example, a 3-week reduction in leadtime might be assessed as permitting a 2-percent increase in sales.

While the equipment costs are relatively fixed over time, the development costs to a firm can vary tremendously depending upon how much the previous work of others can be utilized both in defining the approach and characteristics of the solution and in providing actual software tools to be used in implementing the solution.

Because the use of time-shared systems, man-machine interaction, and graphics communications is still in the early pioneering stage, most experts believe initial development costs for the first systems will run high.

Integration of total systems of this type into existing organizations is difficult and complex. As one man expressed it, "a system like this is not something which is developed and tested by the boys in the back room to be rolled out and plugged in some Monday morning." The impact of this type of system is not confined solely to the design/drafting part of the organization. It has a decided effect directly or indirectly upon the methods of operation in all phases of the business from manufacturing and research to procurement and marketing. The nature of this impact can range from as small an item as the requirement to change the layout of the engineering change order forms to as large an item as a major restructuring of the relationships between engineering and manufacturing.

Therefore, agreement is general that the path to a system of this type within a firm will have to be evolutionary not only with respect to the development of the system but also with respect to its implementation.

Two addenda to this position are worth noting. First, the rate at which the organization can adapt to change is a function of how used to change it is. Second, the extent of top management's commitment to the program largely determines the degree of difficulty in overcoming resistance to change.

Initial users of these systems will be large well-financed firms with complex and expensive design processes for sophisticated products. They will be firms which can afford and profit from expenditures on development running into the millions of dollars. They will be firms which can justify the installation of large-scale time-shared systems within their own organizations. They will be firms which have a history of widespread use of large-scale computers in both engineering and data processing and already are utilizing computers extensively in both operations and experimental projects relating to the design/drafting function.

There is presently little agreement about the type of firms that will adopt such systems after the first few large firms. This undoubtedly results partly from the increased distance into the future of the projections. However, the main cause appears to be the explosion in the number of assumptions which must be made and the number of variables which must be considered in determining the users after the first group.

For example, consider one of many possible categories remaining after the initial large firms: Smaller firms with design/drafting problems which require the capabilities of man-machine interaction and graphics communication but cannot support a time-shared system or underwrite the total development costs. Estimating how much time will elapse before these firms may be able to implement comparable systems raises a wide range of subsidiary assessments. How much of the software development for the first systems will be generalized so that it can be utilized by the smaller firms? Is the nature of these developments such that they will be made available or will they be considered proprietary by the original developers? Will time-shared systems be available on a service-bureau basis so that the using organization has only input-output equipment in his facility and rents the computer time on an "as-used" basis? Will these service bureaus provide generalized software or only hardware? Or will time-shared systems drop in price to the point where the smaller firm can have its own?

It is not possible to answer these and similar specific questions with any degree of confidence at this early stage in the development of total design systems. However, it does seem clear that once it begins, the trend toward adoption of systems of this type will continue until all design/drafting processes are affected.

Rate of Introduction and Diffusion to 1975

The rate of introduction and the diffusion of technological changes in design/drafting to 1975 can be discussed under two separate headings. The first deals with the probable status of the leading edge of advanced t chnology, i.e., the operational status of the most advanced types of man-machine, time-shared, graphic communication systems encompassing a broad application scope in the design/drafting process.

The second heading excludes these advance systems and deals with the probable status of all other technological changes in design/drafting.

Time-Shared Graphics System

Estimates of when man-machine time-shared graphic communications systems will be in operational use to develop the data to produce drawings or numerical control tapes for manufacturing range from 5 to 20 years; operation within 10 years seems to be most generally accepted.

The 5-year estimates are predicated on the development of generalized software for interpreting graphic input in 2 years, plus an additional 3 years for application development completion and conversion. Those who estimate more than 10 years emphasize development costs and the difficulties of integrating such systems into existing operations and organizations rather than any technical limitations.

Stemming from these differences on the time of implementation of the first systems are similar differences on the extent and rate of diffusion within 10 years. Those authorities with the earliest expectations for the first systems anticipate a faster rate of dispersion as well. The number of these systems expected to be in operation in 10 years ranges, accordingly, from 0 to over 100.

Many of those who expect early use of these systems also expect the early appearance of service bureaus which will make the capabilities of these systems available on a part-time basis to a variety of organizations. They therefore expect that the number of organizations using these systems will exceed the number of systems installed.

Firms installing these systems in the next 10 years are expected to be large or, as indicated above, organizations serving multiple users. Many experts believe that this first group will be widely scattered with respect to industry classifications. The only industries consistently mentioned by both their own representatives and others as likely to be among the first system installers are the aerospace industry and the computer industry itself. It is also expected that establishments in the engineering services industry will be among early users of service bureau type systems.

Because for large firms the path to installing these systems must be evolutionary, the first users wi also be active in expanding their use of conventional computer systems during the next 10 years. These users, therefore, come under the second as well as the first heading.

Other Technological Changes

Excluding time-shared graphics systems, the types of applications in design/drafting in 1975 will be quite similar to what they are today. And, as is the case today, the advanced applications which will have the greatest effects will be found in a large number of diverse industries. For example, applications in electronic systems design will continue to advance but these systems are found in many industries: Computers and office equipment, aircraft manufacture, communications equipment, and engineering services. Similarly, the customized product group which will continue to make extensive use of these systems includes parts of instruments, electrical equipment, and nonelectrical machinery. Advances also will continue to be made more quickly in electrical as opposed to mechanical design areas, but segments of each of these are found in many of the same industries.

Conclusions relating to future applications of technological changes cannot, therefore, be synthesized into a unified framework of industry classifications but hopefully can serve as guides to evaluate future trends.

Although the expected extent of application varies from one segment to the next within any single industry, the industries active in introducing technological changes into design/drafting today are expected to continue in the forefront to 1975. Within manufacturing, these industries are electrical equipment, nonelectrical machinery, transportation equipment, ordnance, petroleum refining, chemicals, primary metals, fabricated metals, and instruments. Outside of manufacturing, significant activity is found in contract construction and engineering services.

Within these industries activity in some smaller segments is particularly strong. These industry segments include distribution equipment, industrial apparatus, communications equipment, engines and turbines, computing equipment, motor vehicles, aircraft, and guided missles and space vehicles.

In all industries, size of firm is an important factor in determining the rate of introduction of computer-based systems in design/drafting. The proportion of small firms utilizing computer-based systems in design/drafting has been very small. While this proportion may increase somewhat in the next 10 years, small firms will continue to lag behind larger firms in introducing major technological changes into the design/drafting process.

The number of systems in each of the four categories of design/drafting applications—computation, data handling, design logic, and specialized applications—will continue to expand over the next 10 years.

Specialized applications are most likely to develop in large firms with sophisticated products such as aerospace systems. The extreme complexity of the problems makes it possible to justify the development of highly specialized applications such as that described in exhibit 3 for detail drawings. The directions of future extent of these specialized systems is, of course, extremely difficult to predict.

The area which will show the greatest increase in the number of new applications added will be data handling in support of the design process. Within 10 years, it is expected that most of the medium and large firms in these industries will be using computer systems to some extent to control and coordinate the flow of nongraphic data associated with design.

The rate of growth in pure computation applications will be slower than in the past few years because much of this work is already being performed by computers except in small firms.

When the design logic element is added to computation and data handling, predictions of diffusion are much more complex and the conclusions which can be drawn are difficult to synthesize. Design logic systems will be used universally by 1975 in the design of customized products such as transformers, generators, pumps, and some types of instruments. Products included in this class, however, represent a small percentage of the total products manufactured.

Design logic systems will probably not be used in designing standard consumer products within the next 10 years. These are products which are designed to satisfy the need of the market. While modifications may be made over the product life, these modifications are not introduced according to a preestablished schedule and are frequently cost improvement changes designed to reduce manufacturing cost. While there are a great number of these products, few draftsmen and engineers are involved in their design.

Few design logic systems will be used for products or segments of products which presently require complex dimensioned drawings such as those needed in much of mechanical design.

Design logic applications will be applied primarily to the design process of segments of products rather than complete products. These product segments will be widely scattered among industries and types of product. Although the number of design logic applications will increase significantly in the next 10 years, the effect on the total design processes in industry will be moderate.

3

Manpower Implications

Technological changes affect the design/drafting function in a variety of ways, depending upon the area of the process into which they are introduced. The manpower effects from these changes also depend upon the extent of the applications. Some of the applications of technological change affect either engineers or draftsmen. Others affect both groups.

Impact on Draftsmen

Traditionally, drawings have served as the primary medium for communication in the design process. This medium is used in the early stages to assist in capturing the ideas and concepts of the engineer. Then drawings are used to transfer these ideas in successive stages of increasing detail and specificity until the information necessary for manufacturing is complete.

The job structure in the drafting area closely reflects this dependence on graphic methods of expression. From senior draftsmen to junior detailer, the visible output of their work is in the form of drawings. At the detail draftsmen level the time spent on-the-board approaches 100 percent. While there is more variation at the upper end of the spectrum, even many senior draftsmen or designers may spend 80 percent of their time actually "on-the-board." This does not mean, of course, that this time is spent in actually drawing but rather in the total task of planning and checking for needed data and standards that contribute to the production of the drawings.

Impacts on drafting jobs in the design/drafting process can result from two trends: The introduction of technological changes which do away with the need for manual drafting, and the introduction of simplification and standardization techniques within manual drafting.

While the latter trend may reduce the number of drafting jobs by increasing the productivity of the draftsmen, it has no effect on the structure of the occupation. The former trend, however, eliminates the need for the man-on-the-board and thus threatens the occupation itself. Therefore, an evaluation of the future outlook for drafting jobs depends upon an assessment of the effects that the technological changes described in chapter 2 will have on the future form of, and need for drawings in the design process.

Effects from Technological Change

The use of computers for straight computation has little effect on the drafting operations or the requirements for drawings. The use of microfilm systems for storing drawings and of the computer for data handling such as parts lists, both influence drafting through simplification of manual methods. These applications reduce the time spent by the draftsmen by improving his access to data and reducing the information he must supply with the drawing. In addition, these applications provide a stimulus for introducing other simplifications into the body of the drawing itself. Estimates of the amount of time saved run as high as 20 percent per drawing.

When computers are used for processing design logic, the effects upon drafting become more diversified and the trends more difficult to distinguish. The effects can best be analyzed by first considering systems without graphic output and then those with graphic output.

Systems which handle part of the design logic but have no graphic output capabilities generally will have little impact on drafting unless the need for some types of drawings is reduced. To determine whether this is the case it would be necessary to examine each specific situation, before and after, in detail. In general, however, in the mechanical or structural area of design it is doubtful if many of the drawing requirements can actually be eliminated with this approach. In the electronic and to a lesser extent the electrical areas, the changes are greater.

When the system uses graphic output, some drawings may be eliminated while others may be created automatically. In processing the steps of the design logic the computer system may develop the data needed to produce the drawings previously prepared by the draftsmen. Illustrations of this type are found today in customized product design areas to a limited extent, and in several areas in civil engineering. In addition to the steel beam application discussed in exhibit 2, other illustrations are found in piping detailing for process plant construction and in road construction diagrams.

Because these systems do not have graphic input capabilities, it is unlikely that they can be used to produce complex dimensioned drawings. Therefore the use of these systems to replace manual drawings will be primarily in the nondimensioned areas such as electronic and electrical design.

It is difficult to generalize or to establish any rules of thumb on the extent of the effects on drafting from design logic applications because of tremendous variations which exist from one case to the next. In one instance, the number of draftsmen needed for one area of product design dropped from 96 on one model to 0 on the next when all the drawings were prepared by the system. In another basically similar case, a change was not perceptible.

When the design logic application is in a product area which does not require complex dimensioned drawings, then the inclusion of all drawing requirements within the computer system is more likely. As a result, the effects upon draftsmen are more pronounced.

With the introduction of time-shared systems with graphic input and output capabilities and graphic consoles the need to create drawings by manual methods will decrease substantially. It is possible to envision large design processes of considerable complexity operating with few if any drawings produced by the "man-on-the-board." Once the hardware and software are perfected to permit the computer to deal with graphics and their meanings, then it is possible to develop general solutions to whole ranges of problems common to many varying design/drafting processes in diverse industries.

Effects on Draftsmen to 1975

The effects from the technological changes described in this report on the total requirements for draftsmen during the 1965–75 period are expected to be moderate. The growth rate for the occupation in the next 10 years will be slowed somewhat, but the absolute number of draftsmen jobs will continue to rise.

The analysis of the effects of technological change on drafting requirements is based both on the expected rate of introduction and diffusion of technological change, outlined in chapter 2, and on the effects these changes will have on the drafting occupation. As has previously been stressed, it is extremely difficult to project draftsmen requirements during the 1965–75 period because of two important factors:

First, data relating to the number of draftsmen presently engaged in various types of drafting activity, e.g., design versus research drafting or electrical versus mechanical drafting, are not available. Thus, although it is possible to provide some indication of the way in which particular groups will be affected, estimates of the number of draftsmen associated with each of these affected groups are largely conjective.

Second, the application of many of the major technological developments which will be introduced in the design/drafting process is still in the very early stages. Although the general shape of these applications and even their ultimate impact is discernible at present, the rate at which these will be introduced and their interim effects on the drafting occupation are not clear.

As a result, the analysis presented here is highly judgmental. The conclusions reached are based upon consideration of all available information and upon a careful weighing of the effect of each of the factors involved, but for the reasons stated above, the estimates given indicate the maximum degree to which these technological changes may alter drafting requirements. The estimates derived are to establish a perspective and are not intended for use as projections of 1975 drafting requirements.

The number of draftsmen employed in industry as of January 1963 was 199,100.[1] The table shows a distribution of draftsmen by industry and size of establishment in which they are employed.[2]

If technological change does not accelerate between 1963 and 1975, requirements for draftsmen are projected to increase at roughly the same rate as in the recent past—5.2 percent per year [3] or 84 percent over the period from 1963 to 1975.

Recent advances in design/drafting technology are, however, expected to accelerate the rate at which technological changes will be introduced to, and affect, the design process. As has been pointed out, the extent to which a particular design activity is likely to be affected depends largely on the size of firm and the type of industrial activity in which it is engaged. For purposes of estimating the probable impact of these developments on the drafting occupation, the industrial and size of firm categories shown in the table have each been classified into one of four groups: (1) Unlikely to be affected, (2) likely to be affected slightly, (3) likely to be affected moderately and (4) special cases.

The first group includes some entire industries where the introduction of these technological changes is not expected to exert sufficient influence to alter normal productivity and growth patterns for draftsmen. Since with only a few exceptions, it is not expected that small firms will adopt advanced design/drafting technology before 1975, all establishments employing less than 100 employees with the exception of those in the contract construction, engineering services and other services industries are also included. In this first group are 32,300 or 16.2 percent of all draftsmen.

The second group includes medium and large establishments in industry classifications where technological changes will have a perceptible, but not extensive, effect. Where technological changes with significant effects, such as design logic applications, are introduced within this group, their use will be confined to a small seg-

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[1] In 1952 there were an estimated 30,300 additional draftsmen employed in Government and universities. However, these were excluded from consideration in this report.

[2] These figures represent preliminary January 1963 data from the survey of employment of scientific and technical personnel in industry.

[3] This assumption is based on averaging the rates of change for technicians for 1959–60, 1960–61, 1961–62, from the surveys for *Employment of Scientific and Technical Personnel in Industry* conducted by the Bureau of Labor Statistics for the National Science Foundation. The reader is cautioned that these data were not developed for use in analysis over time.

Numbers of Draftsmen, by Size of Establishment and Industry, January 1963, and the Effects of Technological Change Upon Them

Industry	Draftsmen in all establishments	Draftsmen in establishments with total employment of—		
		Under 100	100–999	1,000 or more
All industries	199, 100	59, 600	67, 400	71, 700
Manufacturing	120, 100	15, 500	44, 200	60, 200
Ordnance and accessories	4, 500	([1,2])	[3] 800	[3] 3, 800
Food and kindred products	700	([2])	[2] 500	[2] 200
Textile mill products	200	([2])	[2] 200	[2] 100
Lumber and wood products, except furniture	700	[2] 300	[2] 400	([2])
Paper and allied products	1, 900	[2] 1, 100	[2] 400	[2] 400
Printing and publishing	500	([2])	[2] 300	[2] 200
Chemicals and allied products	3, 300	[2] 200	[3] 900	[3] 2, 200
Industrial chemicals	1, 600	....	500	1, 200
Plastics and synthetics, except glass	600	([1])	200	400
Drugs	200	....	([1])	100
Other chemical products	900	200	200	600
Petroleum refining	1, 100	([1,2])	[3] 300	[3] 700
Rubber and miscellaneous plastic products	1, 400	[2] 200	[4] 600	[4] 600
Stone, clay, and glass products	1, 500	[2] 400	[2] 700	[2] 400
Primary metal industries	4, 100	[2] 300	1, 400	2, 400
Blast furnace and basic steel products	2, 500	([1])	[4] 600	[4] 1, 900
Other primary metal industries	1, 600	300	[2] 800	[2] 500
Fabricated metal products	16, 700	[2] 3, 900	[4] 9, 100	[4] 3, 600
Machinery, except electrical	28, 300	[2] 4, 600	13, 100	10, 700
Engines and turbines	2, 100	100	[3] 200	[3] 1, 800
Office computing and accounting machines	2, 500	100	[3] 500	[3] 1, 800
Farm machinery and equipment	2, 400	800	[4] 1, 100	[4] 600
Other machinery	21, 300	3, 700	[4] 11, 300	[4] 6, 400
Electric equipment and supplies	27, 400	[2] 1, 800	9, 600	16, 000
Electric distribution equipment and industrial apparatus	8, 900	1, 100	[3] 4, 000	[3] 3, 900
Household appliances	1, 500	100	[2] 400	[2] 1, 000
Communication equipment	10, 700	200	[3] 2, 100	[3] 8, 400
Electrical lighting and wiring equipment	1, 300	([1])	[4] 900	[4] 400
Electronic components and accessories	2, 500	200	[4] 1, 600	[4] 700
Radio and TV receiving sets	1, 300	100	[4] 300	[4] 900
Miscellaneous electrical equipment and supplies	1, 100	100	[4] 400	[4] 700
Transportation equipment	19, 600	[2] 500	3, 500	15, 500
Motor vehicles and equipment	6, 100	100	[3] 1, 300	[3] 4, 700
Aircraft and parts	9, 000	300	[3] 1, 200	[3] 7, 500
Other transportation equipment	4, 500	100	[4] 1, 000	[4] 3, 400
Instruments and related products	5, 200	[2] 500	[3] 1, 800	[3] 2, 900
Engineering and scientific instruments	1, 800	100	400	1, 300
Instruments for measuring controlling and indicating physical characteristics	1, 800	100	800	900
Other instruments and related products	1, 500	200	600	700
Other manufacturing industries	2, 900	[2] 1, 900	[2] 500	[2] 500
Nonmanufacturing	79, 000	43, 900	23, 300	11, 800
Mining	4, 000	[2] 1, 300	[2] 1, 300	[2] 1, 400
Contract construction	10, 600	[5] 4, 600	[5] 4, 800	[3] 1, 100
Transportation	2, 000	[2] 300	[2] 200	[2] 1, 400

NUMBERS OF DRAFTSMEN, BY SIZE OF ESTABLISHMENT AND INDUSTRY, JANUARY 1963, AND THE EFFECTS OF TECHNOLOGICAL CHANGE UPON THEM—Continued

Industry	Draftsmen in all establishments	Draftsmen in establishments with total employment of—		
		Under 100	100–999	1,000 or more
Railroad transportation	1,300	....	(1)	1,300
Other transportation	600	300	200	100
Communication	800	[2] 200	[2] 200	[2] 400
Electric, gas, and sanitary services	5,000	[2] 400	[4] 1,400	[4] 3,200
Wholesale and retail trade	1,900	[2] 600	[2] 800	[2] 600
Finance, insurance, and real estate	(1)	(1 2)	(1 2)	(1 2)
Services	54,700	36,500	14,600	3,700
Engineering and architectural services	43,100	[5] 30,600	[5] 12,200	[3] 300
Other services	11,400	[5] 5,900	[4] 2,200	[4] 3,300

[1] Less than 50.
[2] Unlikely to be affected.
[3] Likely to be affected moderately.
[4] Likely to be affected slightly.
[5] Special cases.

NOTE: Totals have been calculated on the basis of unrounded figures and therefore may not correspond exactly with those indicated by the rounded figures shown.

SOURCE: *Employment of Scientific and Technical Personnel in Industry*, (Washington: U.S. Department of Labor, Bureau of Labor Statistics, 1963, Preliminary Data).

ment of the total industry. The types of technological changes which are expected to diffuse widely throughout this group are those, such as data handling applications, which have only a slight impact on draftsmen. Therefore the overall impact will not be pronounced.

This group includes 56,200 or 28.2 percent of total draftsmen in industry. Without an acceleration in technological change, this group could be expected to increase by 84 percent and reach 103,400 by 1975. The technological changes described in this report will reduce this 1975 figure by a maximum of 10 percent.

Group three includes medium and large establishments in industries where the impact from technological changes is expected to be most significant. In some cases this is because types of technological changes with pronounced impact, such as time-shared systems with graphic input-output capabilities, will be introduced into segments of these industries. In other cases, technological changes such as design logic applications with graphic output, will diffuse widely throughout the industry with more moderate effects within 10 years.

Small establishments in the "other services" classification are also included in this group. Many of the 5,900 draftsmen in this group are employed in firms which perform contract drafting services. While these firms will not implement major technological changes, they will be affected by the changes taking place in large firms because the large firms provide a substantial percentage of contract drafting business.

Group three includes 58,100 or 29.1 percent of all draftsmen. Within this group a maximum reduction of 25 percent in draftsmen requirements may reduce the expected 1975 needs from 100,900 to 80,100.

These three groups include 146,600 or 73.5 percent of the draftsmen in industry today. Even with the maximum expected reductions in groups two and three, the number of drafting jobs still can be expected to increase from the present 146,600 to at least 232,000 by 1975. In reality, the reductions will be spaced over the entire period with an acceleration between 1970 and 1975; as much as two-thirds of the impact from technological change may occur between 1970 and 1975.

Group four includes small and medium size establishments in engineering services and contract construction. This group is handled separately because the criteria used in assigning categories to the other groups do not apply. This total group is numerically significant since it includes 52,200 or 26.3 percent of all draftsmen in industry.

Many of the technological changes described in this report are well suited technically to the design work performed by contract construction and engineering service firms. However, because of the costs involved in implementing these changes, smaller firms are limited in their ability to utilize these advanced technological developments. Many experts believe that this situation will change considerably with the availability of time-shared, graphic input-output systems on a service bureau basis. There is no concensus as to whether these firms will start to use time-shared graphical systems prior to 1975. However, there is general agreement that when these systems with the required software as well as hardware capabilities are used, these engineering services and contract construction firms will begin to experience a rapid decline in requirements for draftsmen.

If the use of time-shared, graphics communication systems does not begin prior to 1975, then this group of draftsmen is unlikely to be affected by technological change. If systems use begins prior to 1975, then the extent to which this group will be affected will depend upon how much before 1975 initial use begins; initial use with graphic capabilities is not expected prior to 1970. Diffusion is expected to be rapid once the trend is established.

Across all of industry the reductions in draftsmen requirements which will occur before 1975 will be predominantly among draftsmen working with nondimensioned drawings such as those associated with electrical and electronic design. Toward the end of the 10 year period some draftsmen in the dimensioned areas, such as mechanical drawings, may be affected by the first time-shared, graphic input-output systems. Although the types of technological change which will take place to 1975 will affect all levels of draftsmen, the largest number of jobs affected will be at the detail draftsmen level.

Changes in job content due to simplification and standardization in drafting techniques during this period will occur. Adjustments to these changes will generally be relatively minor and any required retraining will be provided by the individual firms making the changes.

To this time, few new types of jobs requiring the knowledge of and experience with drafting principles and techniques have been identified. Some draftsmen are being trained as computer programers and analysts, but in most cases this is because of the competence and aptitude of the individual, not because the programer needs to be an experienced draftsman.

It is still too early in the development of time-shared graphic systems to speak with any confidence about the staffing requirements. However, it appears likely that some of the jobs will certainly require a knowledge of drafting principles and techniques although the man may work at the console rather than on the drafting board.

The major effects upon draftsmen from the current developments in time-shared, graphics communication systems will occur after 1975. Expert opinion is divided on how rapidly these technological changes will reduce the requirements for the traditional drafting jobs. However, there is general agreement that it will be technically feasible to significantly reduce the number of draftsmen needed by industry within 20 years.

Impact on Engineers

The introduction of computers in the early 1950's to perform mathematical computations marked the beginning of a trend in design engineering away from routine analytical tasks and toward creative activity. While the individual engineers were relieved of the necessity to perform routine computations, the power of the computer made it possible to increase the complexity, range, and amount of computation which could be undertaken in support of the design function. Decisions which previously had to be made on the basis of experience and intuition with limited computational backup could be substantially improved by extending the computational support. The availability of the results of sophisticated mathematical analysis has been increasing while the amount of human participation necessary to get these results has been decreasing.

New emphasis is being placed on the development and refinement of the analytical tools themselves. The designing and writing of computer programs for the new tools has been a concurrent development.

It is not possible to assess the effects of these developments on the numeric requirements for professional level people in the design/drafting function. This is partly due to the variations from industry to industry in the extent to which analytical methods are used; but more importantly it is because even within a given product design so many other technological factors are changing at the same time. Trying to assess changes in occupations or job content in depth poses the same difficulties.

The introduction of simple methods of data handling has had, and will have, relatively little effect on engineering other than to reduce the amount of time spent on clerical-type activities.

When the applications are extended directly to involve design logic, the impact upon the individual engineers becomes more pronounced. There is no question that substantially fewer engineering man-hours are needed to achieve the same amount of work. It is also true that what was previously the entire work activity for some engineers is now done by computers.

In general, these new methods are reducing the clerical-type and routine activities of the engineering workload. These activities presently require many man-hours. For example, in the aerospace industry it has been estimated that 80 to 90 percent of the average engineer's time is spent on tasks of this type.

While the feeling was widespread that this reduction in routine work would permit more time for creative engineering activity, some concern has been expressed about the ability of some engineers to make this shift readily. Besides the question of individual competence, the broader problem of keeping abreast of rapidly changing technologies was frequently mentioned. To this time the shifts required have been relatively minor in terms of the individuals.

Many believe that the time-shared man-machine interaction system is the most powerful tool ever developed to extend and amplify creative engineering. Limited knowledge of the creative process makes it impossible to estimate the results of this coupling of man and machine at this early state, but many are predicting a new era in engineering design.

U.S. GOVERNMENT PRINTING OFFICE : 1966 O - 222-699

WHERE TO GET MORE INFORMATION

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If major changes in his problem solution are needed, he may resubmit an alternative approach to the computer at a later time. When the display is acceptable, the designer instructs the computer to produce a copy of the drawing. If the statements used by the designer contribute toward the solution of a recurring problem, then these statements can be added to a library of programs maintained within the computer. This library continues to grow and programs from it can be used by any of the designers.

In addition to the programs produced by the designers using the descriptive geometry language, others are necessary, for example, to direct the computer hardware and to provide the translation from the descriptive geometry language to the computer language. In all more than three-quarters of a million operating instructions have been written by the computer programers.

One group of programs was developed to solve the basic problem caused by the different time scales in which the man and the computer operate within the man-machine partnership. The system is programed so that the computer can perform completely unrelated work until another request is made from the console. It is estimated that about 6 minutes of computer time are used for every hour of console time.

Because this is a constantly evolving laboratory project, the exact form that the system will take when it becomes feasible for production use is not yet known. Many man years of effort have gone into this project. The people involved have included many automotive designers, as well as computer hardware and software specialists.

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a time-shared system and specially developed graphics equipment including a man-machine console. Automotive designers and computer specialists are working with this laboratory project to develop methods for using systems of this type in the design of automobile bodies.

In addition to the projects combining both time-sharing and graphics communication, many projects are directed toward development of the time-shared concept. This concept for computer use has ramifications far transcending design/drafting. Much of the technique and software developments from these time-sharing projects will be applicable to design/drafting applications as a subclass within the total applications area.

The experimental projects in time-sharing and graphics communication have one common purpose: To permit the development of operational systems where the man supplies those elements in which he is strongest—imagination, creativity, and judgment—and the machine amplifies the man's abilities by supplying computational power, and speed and accuracy in carrying out routine repetitive tasks.

Future Operational Systems

The most significant future operational systems in design/drafting will be based on the two important concepts of man-machine interaction and direct graphical communication. With the addition of these concepts, it is possible to visualize a total systems approach to the design/drafting function beginning at the design concept stage and carrying through to the creation of the documentation for manufacturing, or where appropriate, of the tapes needed to run numerically controlled production equipment.

Selection of the equipment needed and desired for such a system can vary widely without exceeding the capabilities of existing and proposed equipment. Software and systems development projects already underway can technically remove any barriers to utilizing the equipment for greatly expanded segments of the total design/drafting process.

Thus systems can be designed which use the computer as a coordination center for the design process from product concept to manufacturing. While the details and exact nature of such a design process are not now known, the general outlines and trends seem well accepted.

The technical feasibility of such systems has been established, although considerable development work remains to be done. Determination of when the first systems will be introduced into design/drafting operations and who will be the first users depends upon an analysis of the costs involved and the ease with which these systems can be integrated into existing organizations.

Three major elements are involved in determining the cost of a proposed system: The cost of the equipment and personnel to operate and maintain the new system after it is in full operation; the cost to design the new system including analysis and programing; and the cost incurred in converting from the old to the new method.

Indirect as well as direct costs are implied here. For example, a 3-week reduction in leac'.ime might be assessed as permitting a 2-percent increase in sales.

While the equipment costs are relatively fixed over time, the development costs to a firm can vary tremendously depending upon how much the previous work of others can be utilized both in defining the approach and characteristics of the solution and in providing actual software tools to be used in implementing the solution.

Because the use of time-shared systems, man-machine interaction, and graphics communications is still in the early pioneering stage, most experts believe initial development costs for the first systems will run high.

Integration of total systems of this type into existing organizations is difficult and complex. As one man expressed it, "a system like this is not something which is developed and tested by the boys in the back room to be rolled out and plugged in some Monday morning." The impact of this type of system is not confined solely to the design/drafting part of the organization. It has a decided effect directly or indirectly upon the methods of operation in all phases of the business from manufacturing and research to procurement and marketing. The nature of this impact can range from as small an item as the requirement to change the layout of the engineering change order forms to as large an item as a major restructuring of the relationships between engineering and manufacturing.

Therefore, agreement is general that the path to a system of this type within a firm will have to be evolutionary not only with respect to the development of the system but also with respect to its implementation.

Two addenda to this position are worth noting. First, the rate at which the organization can adapt to change is a function of how used to change it is. Second, the extent of top management's commitment to the program largely determines the degree of difficulty in overcoming resistance to change.

Initial users of these systems will be large well-financed firms with complex and expensive design processes for sophisticated products. They will be firms which can afford and profit from expenditures on development running into the millions of dollars. They will be firms which can justify the installation of large-scale time-shared systems within their own organizations. They will be firms which have a history of widespread use of large-scale computers in both engineering and data processing and already are utilizing computers extensively in both operations and experimental projects relating to the design/drafting function.

There is presently little agreement about the type of firms that will adopt such systems after the first few large firms. This undoubtedly results partly from the increased distance into the future of the projections. However, the main cause appears to be the explosion in the number of assumptions which must be made and the number of variables which must be considered in determining the users after the first group.

For example, consider one of many possible categories remaining after the initial large firms: Smaller firms with design/drafting problems which require the capabilities of man-machine interaction and graphics communication but cannot support a time-shared system or underwrite the total development costs. Estimating how much time will elapse before these firms may be able to implement comparable systems raises a wide range of subsidiary assessments. How much of the software development for the first systems will be generalized so that it can be utilized by the smaller firms? Is the nature of these developments such that they will be made available or will they be considered proprietary by the original developers? Will time-shared systems be available on a service-bureau basis so that the using organization has only input-output equipment in his facility and rents the computer time on an "as-used" basis? Will these service bureaus provide generalized software or only hardware? Or will time-shared systems drop in price to the point where the smaller firm can have its own?

It is not possible to answer these and similar specific questions with any degree of confidence at this early stage in the development of total design systems. However, it does seem clear that once it begins, the trend toward adoption of systems of this type will continue until all design/drafting processes are affected.

Rate of Introduction and Diffusion to 1975

The rate of introduction and the diffusion of technological changes in design/drafting to 1975 can be discussed under two separate headings. The first deals with the probable status of the leading edge of advanced technology, i.e., the operational status of the most advanced types of man-machine, time-shared, graphic communication systems encompassing a broad application scope in the design/drafting process.

The second heading excludes these advance systems and deals with the probable status of all other technological changes in design/drafting.

Time-Shared Graphics System

Estimates of when man-machine time-shared graphic communications systems will be in operational use to develop the data to produce drawings or numerical control tapes for manufacturing range from 5 to 20 years; operation within 10 years seems to be most generally accepted.

The 5-year estimates are predicated on the development of generalized software for interpreting graphic input in 2 years, plus an additional 3 years for application development completion and conversion. Those who estimate more than 10 years emphasize development costs and the difficulties of integrating such systems into existing operations and organizations rather than any technical limitations.

Stemming from these differences on the time of implementation of the first systems are similar differences on the extent and rate of diffusion within 10 years. Those authorities with the earliest expectations for the first systems anticipate a faster rate of dispersion as well. The number of these systems expected to be in operation in 10 years ranges, accordingly, from 0 to over 100.

Many of those who expect early use of these systems also expect the early appearance of service bureaus which will make the capabilities of these systems available on a part-time basis to a variety of organizations. They therefore expect that the number of organizations using these systems will exceed the number of systems installed.

Firms installing these systems in the next 10 years are expected to be large or, as indicated above, organizations serving multiple users. Many experts believe that this first group will be widely scattered with respect to industry classifications. The only industries consistently mentioned by both their own representatives and others as likely to be among the first system installers are the aerospace industry and the computer industry itself. It is also expected that establishments in the engineering services industry will be among early users of service bureau type systems.

Because for large firms the path to installing these systems must be evolutionary, the first users will also be active in expanding their use of conventional computer systems during the next 10 years. These users, therefore, come under the second as well as the first heading.

Other Technological Changes

Excluding time-shared graphics systems, the types of applications in design/drafting in 1975 will be quite similar to what they are today. And, as is the case today, the advanced applications which will have the greatest effects will be found in a large number of diverse industries. For example, applications in electronic systems design will continue to advance but these systems are found in many industries: Computers and office equipment, aircraft manufacture, communications equipment, and engineering services. Similarly, the customized product group which will continue to make extensive use of these systems includes parts of instruments, electrical equipment, and nonelectrical machinery. Advances also will continue to be made more quickly in electrical as opposed to mechanical design areas, but segments of each of these are found in many of the same industries.

Conclusions relating to future applications of technological changes cannot, therefore, be synthesized into a unified framework of industry classifications but hopefully can serve as guides to evaluate future trends.

Although the expected extent of application varies from one segment to the next within any single industry, the industries active in introducing technological changes into design/drafting today are expected to continue in the forefront to 1975. Within manufacturing, these industries are electrical equipment, nonelectrical machinery, transportation equipment, ordnance, petroleum refining, chemicals, primary metals, fabricated metals, and instruments. Outside of manufacturing, significant activity is found in contract construction and engineering services.

Within these industries activity in some smaller segments is particularly strong. These industry segments include distribution equipment, industrial apparatus, communications equipment, engines and turbines, computing equipment, motor vehicles, aircraft, and guided missles and space vehicles.

In all industries, size of firm is an important factor in determining the rate of introduction of computer-based systems in design/drafting. The proportion of small firms utilizing computer-based systems in design/drafting has been very small. While this proportion may increase somewhat in the next 10 years, small firms will continue to lag behind larger firms in introducing major technological changes into the design/drafting process.

The number of systems in each of the four categories of design/drafting applications—computation, data handling, design logic, and specialized applications—will continue to expand over the next 10 years.

Specialized applications are most likely to develop in large firms with sophisticated products such as aerospace systems. The extreme complexity of the problems makes it possible to justify the development of highly specialized applications such as that described in exhibit 3 for detail drawings. The directions of future extent of these specialized systems is, of course, extremely difficult to predict.

The area which will show the greatest increase in the number of new applications added will be data handling in support of the design process. Within 10 years, it is expected that most of the medium and large firms in these industries will be using computer systems to some extent to control and coordinate the flow of nongraphic data associated with design.

The rate of growth in pure computation applications will be slower than in the past few years because much of this work is already being performed by computers except in small firms.

When the design logic element is added to computation and data handling, predictions of diffusion are much more complex and the conclusions which can be drawn are difficult to synthesize. Design logic systems will be used universally by 1975 in the design of customized products such as transformers, generators, pumps, and some types of instruments. Products included in this class, however, represent a small percentage of the total products manufactured.

Design logic systems will probably not be used in designing standard consumer products within the next 10 years. These are products which are designed to satisfy the need of the market. While modifications may be made over the product life, these modifications are not introduced according to a preestablished schedule and are frequently cost improvement changes designed to reduce manufacturing cost. While there are a great number of these products, few draftsmen and engineers are involved in their design.

Few design logic systems will be used for products or segments of products which presently require complex dimensioned drawings such as those needed in much of mechanical design.

Design logic applications will be applied primarily to the design process of segments of products rather than complete products. These product segments will be widely scattered among industries and types of product. Although the number of design logic applications will increase significantly in the next 10 years, the effect on the total design processes in industry will be moderate.

3

Manpower Implications

Technological changes affect the design/drafting function in a variety of ways, depending upon the area of the process into which they are introduced. The manpower effects from these changes also depend upon the extent of the applications. Some of the applications of technological change affect either engineers or draftsmen. Others affect both groups.

Impact on Draftsmen

Traditionally, drawings have served as the primary medium for communication in the design process. This medium is used in the early stages to assist in capturing the ideas and concepts of the engineer. Then drawings are used to transfer these ideas in successive stages of increasing detail and specificity until the information necessary for manufacturing is complete.

The job structure in the drafting area closely reflects this dependence on graphic methods of expression. From senior draftsmen to junior detailer, the visible output of their work is in the form of drawings. At the detail draftsmen level the time spent on-the-board approaches 100 percent. While there is more variation at the upper end of the spectrum, even many senior draftsmen or designers may spend 80 percent of their time actually "on-the-board." This does not mean, of course, that this time is spent in actually drawing but rather in the total task of planning and checking for needed data and standards that contribute to the production of the drawings.

Impacts on drafting jobs in the design/drafting process can result from two trends: The introduction of technological changes which do away with the need for manual drafting, and the introduction of simplification and standardization techniques within manual drafting.

While the latter trend may reduce the number of drafting jobs by increasing the productivity of the draftsmen, it has no effect on the structure of the occupation. The former trend, however, eliminates the need for the man-on-the-board and thus threatens the occupation itself. Therefore, an evaluation of the future outlook for drafting jobs depends upon an assessment of the effects that the technological changes described in chapter 2 will have on the future form of, and need for drawings in the design process.

Effects from Technological Change

The use of computers for straight computation has little effect on the drafting operations or the requirements for drawings. The use of microfilm systems for storing drawings and of the computer for data handling such as parts lists, both influence drafting through simplification of manual methods. These applications reduce the time spent by the draftsmen by improving his access to data and reducing the information he must supply with the drawing. In addition, these applications provide a stimulus for introducing other simplifications into the body of the drawing itself. Estimates of the amount of time saved run as high as 20 percent per drawing.

When computers are used for processing design logic, the effects upon drafting become more diversified and the trends more difficult to distinguish. The effects can best be analyzed by first considering systems without graphic output and then those with graphic output.

Systems which handle part of the design logic but have no graphic output capabilities generally will have little impact on drafting unless the need for some types of drawings is reduced. To determine whether this is the case it would be necessary to examine each specific situation, before and after, in detail. In general, however, in the mechanical or structural area of design it is doubtful if many of the drawing requirements can actually be eliminated with this approach. In the electronic and to a lesser extent the electrical areas, the changes are greater.

When the system uses graphic output, some drawings may be eliminated while others may be created automatically. In processing the steps of the design logic the computer system may develop the data needed to produce the drawings previously prepared by the draftsmen. Illustrations of this type are found today in customized product design areas to a limited extent, and in several areas in civil engineering. In addition to the steel beam application discussed in exhibit 2, other illustrations are found in piping detailing for process plant construction and in road construction diagrams.

Because these systems do not have graphic input capabilities, it is unlikely that they can be used to produce complex dimensioned drawings. Therefore the use of these systems to replace manual drawings will be primarily in the nondimensioned areas such as electronic and electrical design.

It is difficult to generalize or to establish any rules of thumb on the extent of the effects on drafting from design logic applications because of tremendous variations which exist from one case to the next. In one instance, the number of draftsmen needed for one area of product design dropped from 96 on one model to 0 on the next when all the drawings were prepared by the system. In another basically similar case, a change was not perceptible.

When the design logic application is in a product area which does not require complex dimensioned drawings, then the inclusion of all drawing requirements within the computer system is more likely. As a result, the effects upon draftsmen are more pronounced.

With the introduction of time-shared systems with graphic input and output capabilities and graphic consoles the need to create drawings by manual methods will decrease substantially. It is possible to envision large design processes of considerable complexity operating with few if any drawings produced by the "man-on-the-board." Once the hardware and software are perfected to permit the computer to deal with graphics and their meanings, then it is possible to develop general solutions to whole ranges of problems common to many varying design/drafting processes in diverse industries.

Effects on Draftsmen to 1975

The effects from the technological changes described in this report on the total requirements for draftsmen during the 1965–75 period are expected to be moderate. The growth rate for the occupation in the next 10 years will be slowed somewhat, but the absolute number of draftsmen jobs will continue to rise.

The analysis of the effects of technological change on drafting requirements is based both on the expected rate of introduction and diffusion of technological change, outlined in chapter 2, and on the effects these changes will have on the drafting occupation. As has previously been stressed, it is extremely difficult to project draftsmen requirements during the 1965–75 period because of two important factors:

First, data relating to the number of draftsmen presently engaged in various types of drafting activity, e.g., design versus research drafting or electrical versus mechanical drafting, are not available. Thus, although it is possible to provide some indication of the way in which particular groups will be affected, estimates of the number of draftsmen associated with each of these affected groups are largely conjective.

Second, the application of many of the major technological developments which will be introduced in the design/drafting process is still in the very early stages. Although the general shape of these applications and even their ultimate impact is discernible at present, the rate at which these will be introduced and their interim effects on the drafting occupation are not clear.

As a result, the analysis presented here is highly judgmental. The conclusions reached are based upon consideration of all available information and upon a careful weighing of the effect of each of the factors involved, but for the reasons stated above, the estimates given indicate the maximum degree to which these technological changes may alter drafting requirements. The estimates derived are to establish a perspective and are not intended for use as projections of 1975 drafting requirements.

The number of draftsmen employed in industry as of January 1963 was 199,100.[1] The table shows a distribution of draftsmen by industry and size of establishment in which they are employed.[2]

[1] In 1952 there were an estimated 30,300 additional draftsmen employed in Government and universities. However, these were excluded from consideration in this report.

If technological change does not accelerate between 1963 and 1975, requirements for draftsmen are projected to increase at roughly the same rate as in the recent past—5.2 percent per year[3] or 84 percent over the period from 1963 to 1975.

Recent advances in design/drafting technology are, however, expected to accelerate the rate at which technological changes will be introduced to, and affect, the design process. As has been pointed out, the extent to which a particular design activity is likely to be affected depends largely on the size of firm and the type of industrial activity in which it is engaged. For purposes of estimating the probable impact of these developments on the drafting occupation, the industrial and size of firm categories shown in the table have each been classified into one of four groups: (1) Unlikely to be affected, (2) likely to be affected slightly, (3) likely to be affected moderately and (4) special cases.

The first group includes some entire industries where the introduction of these technological changes is not expected to exert sufficient influence to alter normal productivity and growth patterns for draftsmen. Since with only a few exceptions, it is not expected that small firms will adopt advanced design/drafting technology before 1975, all establishments employing less than 100 employees with the exception of those in the contract construction, engineering services and other services industries are also included. In this first group are 32,300 or 16.2 percent of all draftsmen.

The second group includes medium and large establishments in industry classifications where technological changes will have a perceptible, but not extensive, effect. Where technological changes with significant effects, such as design logic applications, are introduced within this group, their use will be confined to a small seg-

[2] These figures represent preliminary January 1963 data from the survey of employment of scientific and technical personnel in industry.

[3] This assumption is based on averaging the rates of change for technicians for 1959–60, 1960–61, 1961–62, from the surveys for *Employment of Scientific and Technical Personnel in Industry* conducted by the Bureau of Labor Statistics for the National Science Foundation. The reader is cautioned that these data were not developed for use in analysis over time.

NUMBERS OF DRAFTSMEN, BY SIZE OF ESTABLISHMENT AND INDUSTRY, JANUARY 1963, AND THE EFFECTS OF TECHNOLOGICAL CHANGE UPON THEM

Industry	Draftsmen in all establishments	Draftsmen in establishments with total employment of—		
		Under 100	100–999	1,000 or more
All industries	199, 100	59, 600	67, 400	71, 700
Manufacturing	120, 100	15, 500	44, 200	60, 200
Ordnance and accessories	4, 500	(1 2)	3 800	3 3, 800
Food and kindred products	700	(2)	2 500	2 200
Textile mill products	200	(2)	2 200	2 100
Lumber and wood products, except furniture	700	2 300	2 400	(2)
Paper and allied products	1, 900	2 1, 100	2 400	2 400
Printing and publishing	500	(2)	2 300	2 200
Chemicals and allied products	3, 300	2 200	3 900	3 2, 200
Industrial chemicals	1, 600	....	500	1, 200
Plastics and synthetics, except glass	600	(1)	200	400
Drugs	200	....	(1)	100
Other chemical products	900	200	200	600
Petroleum refining	1, 100	(1 2)	3 300	3 700
Rubber and miscellaneous plastic products	1, 400	2 200	4 600	4 600
Stone, clay, and glass products	1, 500	2 400	2 700	2 400
Primary metal industries	4, 100	2 300	1, 400	2, 400
Blast furnace and basic steel products	2, 500	(1)	4 600	4 1, 900
Other primary metal industries	1, 600	300	2 800	2 500
Fabricated metal products	16, 700	2 3, 900	4 9, 100	4 3, 600
Machinery, except electrical	28, 300	2 4, 600	13, 100	10, 700
Engines and turbines	2, 100	100	3 200	3 1, 800
Office computing and accounting machines	2, 500	100	3 500	3 1, 800
Farm machinery and equipment	2, 400	800	4 1, 100	4 600
Other machinery	21, 300	3, 700	4 11, 300	4 6, 400
Electric equipment and supplies	27, 400	2 1, 800	9, 600	16, 000
Electric distribution equipment and industrial apparatus	8, 900	1, 100	3 4, 000	3 3, 900
Household appliances	1, 500	100	2 400	2 1, 000
Communication equipment	10, 700	200	3 2, 100	3 8, 400
Electrical lighting and wiring equipment	1, 300	(1)	4 900	4 400
Electronic components and accessories	2, 500	200	4 1, 600	4 700
Radio and TV receiving sets	1, 300	100	4 300	4 900
Miscellaneous electrical equipment and supplies	1, 100	100	4 400	4 700
Transportation equipment	19, 600	2 500	3, 500	15, 500
Motor vehicles and equipment	6, 100	100	3 1, 300	3 4, 700
Aircraft and parts	9, 000	300	3 1, 200	3 7, 500
Other transportation equipment	4, 500	100	4 1, 000	4 3, 400
Instruments and related products	5, 200	2 500	3 1, 800	3 2, 900
Engineering and scientific instruments	1, 800	100	400	1, 300
Instruments for measuring controlling and indicating physical characteristics	1, 800	100	800	900
Other instruments and related products	1, 500	200	600	700
Other manufacturing industries	2, 900	2 1, 900	2 500	2 500
Nonmanufacturing	79, 000	43, 900	23, 300	11, 800
Mining	4, 000	2 1, 300	2 1, 300	2 1, 400
Contract construction	10, 600	5 4, 600	5 4, 800	3 1, 100
Transportation	2, 000	2 300	2 200	2 1, 400

NUMBERS OF DRAFTSMEN, BY SIZE OF ESTABLISHMENT AND INDUSTRY, JANUARY 1963, AND THE EFFECTS OF TECHNOLOGICAL CHANGE UPON THEM—Continued

Industry	Draftsmen in all establishments	Draftsmen in establishments with total employment of—		
		Under 100	100–999	1,000 or more
Railroad transportation	1,300	....	(1)	1,300
Other transportation	600	300	200	100
Communication	800	[2] 200	[2] 200	[2] 400
Electric, gas, and sanitary services	5,000	[2] 400	[4] 1,400	[4] 3,200
Wholesale and retail trade	1,900	[2] 600	[2] 800	[2] 600
Finance, insurance, and real estate	(1)	(1 2)	(1 2)	(1 2)
Services	54,700	36,500	14,600	3,700
Engineering and architectural services	43,100	[5] 30,600	[5] 12,200	[3] 300
Other services	11,400	[5] 5,900	[4] 2,200	[4] 3,300

[1] Less than 50.
[2] Unlikely to be affected.
[3] Likely to be affected moderately.
[4] Likely to be affected slightly.
[5] Special cases.

NOTE: Totals have been calculated on the basis of unrounded figures and therefore may not correspond exactly with those indicated by the rounded figures shown.

SOURCE: *Employment of Scientific and Technical Personnel in Industry*, (Washington: U.S. Department of Labor, Bureau of Labor Statistics, 1963, Preliminary Data).

ment of the total industry. The types of technological changes which are expected to diffuse widely throughout this group are those, such as data handling applications, which have only a slight impact on draftsmen. Therefore the overall impact will not be pronounced.

This group includes 56,200 or 28.2 percent of total draftsmen in industry. Without an acceleration in technological change, this group could be expected to increase by 84 percent and reach 103,400 by 1975. The technological changes described in this report will reduce this 1975 figure by a maximum of 10 percent.

Group three includes medium and large establishments in industries where the impact from technological changes is expected to be most significant. In some cases this is because types of technological changes with pronounced impact, such as time-shared systems with graphic input-output capabilities, will be introduced into segments of these industries. In other cases, technological changes such as design logic applications with graphic output, will diffuse widely throughout the industry with more moderate effects within 10 years.

Small establishments in the "other services" classification are also included in this group. Many of the 5,900 draftsmen in this group are employed in firms which perform contract drafting services. While these firms will not implement major technological changes, they will be affected by the changes taking place in large firms because the large firms provide a substantial percentage of contract drafting business.

Group three includes 58,100 or 29.1 percent of all draftsmen. Within this group a maximum reduction of 25 percent in draftsmen requirements may reduce the expected 1975 needs from 100,900 to 80,100.

These three groups include 146,600 or 73.5 percent of the draftsmen in industry today. Even with the maximum expected reductions in groups two and three, the number of drafting jobs still can be expected to increase from the present 146,600 to at least 232,000 by 1975. In reality, the reductions will be spaced over the entire period with an acceleration between 1970 and 1975; as much as two-thirds of the impact from technological change may occur between 1970 and 1975.

Group four includes small and medium size establishments in engineering services and contract construction. This group is handled separately because the criteria used in assigning categories to the other groups do not apply. This total group is numerically significant since it includes 52,200 or 26.3 percent of all draftsmen in industry.

Many of the technological changes described in this report are well suited technically to the design work performed by contract construction and engineering service firms. However, because of the costs involved in implementing these changes, smaller firms are limited in their ability to utilize these advanced technological developments. Many experts believe that this situation will change considerably with the availability of time-shared, graphic input-output systems on a service bureau basis. There is no concensus as to whether these firms will start to use time-shared graphical systems prior to 1975. However, there is general agreement that when these systems with the required software as well as hardware capabilities are used, these engineering services and contract construction firms will begin to experience a rapid decline in requirements for draftsmen.

If the use of time-shared, graphics communication systems does not begin prior to 1975, then this group of draftsmen is unlikely to be affected by technological change. If systems use begins prior to 1975, then the extent to which this group will be affected will depend upon how much before 1975 initial use begins; initial use with graphic capabilities is not expected prior to 1970. Diffusion is expected to be rapid once the trend is established.

Across all of industry the reductions in draftsmen requirements which will occur before 1975 will be predominantly among draftsmen working with nondimensioned drawings such as those associated with electrical and electronic design. Toward the end of the 10 year period some draftsmen in the dimensioned areas, such as mechanical drawings, may be affected by the first time-shared, graphic input-output systems. Although the types of technological change which will take place to 1975 will affect all levels of draftsmen, the largest number of jobs affected will be at the detail draftsmen level.

Changes in job content due to simplification and standardization in drafting techniques during this period will occur. Adjustments to these changes will generally be relatively minor and any required retraining will be provided by the individual firms making the changes.

To this time, few new types of jobs requiring the knowledge of and experience with drafting principles and techniques have been identified. Some draftsmen are being trained as computer programers and analysts, but in most cases this is because of the competence and aptitude of the individual, not because the programer needs to be an experienced draftsman.

It is still too early in the development of time-shared graphic systems to speak with any confidence about the staffing requirements. However, it appears likely that some of the jobs will certainly require a knowledge of drafting principles and techniques although the man may work at the console rather than on the drafting board.

The major effects upon draftsmen from the current developments in time-shared, graphics communication systems will occur after 1975. Expert opinion is divided on how rapidly these technological changes will reduce the requirements for the traditional drafting jobs. However, there is general agreement that it will be technically feasible to significantly reduce the number of draftsmen needed by industry within 20 years.

Impact on Engineers

The introduction of computers in the early 1950's to perform mathematical computations marked the beginning of a trend in design engineering away from routine analytical tasks and toward creative activity. While the individual engineers were relieved of the necessity to perform routine computations, the power of the computer made it possible to increase the complexity, range, and amount of computation which could be undertaken in support of the design function. Decisions which previously had to be made on the basis of experience and intuition with limited computational backup could be substantially improved by extending the computational support. The availability of the results of sophisticated mathematical analysis has been increasing while the amount of human participation necessary to get these results has been decreasing.

New emphasis is being placed on the development and refinement of the analytical tools themselves. The designing and writing of computer programs for the new tools has been a concurrent development.

It is not possible to assess the effects of these developments on the numeric requirements for professional level people in the design/drafting function. This is partly due to the variations from industry to industry in the extent to which analytical methods are used; but more importantly it is because even within a given product design so many other technological factors are changing at the same time. Trying to assess changes in occupations or job content in depth poses the same difficulties.

The introduction of simple methods of data handling has had, and will have, relatively little effect on engineering other than to reduce the amount of time spent on clerical-type activities.

When the applications are extended directly to involve design logic, the impact upon the individual engineers becomes more pronounced. There is no question that substantially fewer engineering man-hours are needed to achieve the same amount of work. It is also true that what was previously the entire work activity for some engineers is now done by computers.

In general, these new methods are reducing the clerical-type and routine activities of the engineering workload. These activities presently require many man-hours. For example, in the aerospace industry it has been estimated that 80 to 90 percent of the average engineer's time is spent on tasks of this type.

While the feeling was widespread that this reduction in routine work would permit more time for creative engineering activity, some concern has been expressed about the ability of some engineers to make this shift readily. Besides the question of individual competence, the broader problem of keeping abreast of rapidly changing technologies was frequently mentioned. To this time the shifts required have been relatively minor in terms of the individuals.

Many believe that the time-shared man-machine interaction system is the most powerful tool ever developed to extend and amplify creative engineering. Limited knowledge of the creative process makes it impossible to estimate the results of this coupling of man and machine at this early state, but many are predicting a new era in engineering design.

U.S. GOVERNMENT PRINTING OFFICE : 1966 O - 222-655

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