PRENTICE-HALL SERIES

IN

FUNDAMENTALS OF ENGINEERING DESIGN

ENGINEERING

COMMUNICATIONS

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ENGINEERING

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PRENTICE-HALL SERIES IN ENGINEERING DESIGN

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FOREWORD

All engineering is dependent upon the accurate, economical, and rapid transmission and processing of information. Communication is an indispensable activity in the engineering design process. The engineer must communicate with himself and he must communicate with others. The theory and practice of communication are the substance of the chapters which comprise this book.

A unified approach to engineering communication is presented. The basic concepts of information theory are carefully developed and shown to be an integral part of the modern theory of engineering design. The fundamentals of efficient engineering communications are presented from the viewpoint of information theory. This provides the logical basis to which the rules for effective reading, writing, and drawing are related.

In chapters one through three Professor Rosenstein presents a framework for communication based on information theory concepts. Everyday experiences are used to illustrate the meaning and application of the fundamentals of information theory. Professor Rosenstein's purpose is twofold: (1) to introduce the student to the quantitative aspect of information theory and (2) to provide him with a rational theory that will enable him to communicate more effectively. With an understanding of the basic requirements for all engineering communication, the reader will consequently be able to evaluate new situations for which he does not possess rote rules of behavior.

The practice of communication is succinctly developed by Professors Rathbone and Schneerer who show how the written and spoken words may be more efficiently organized to successfully transmit messages and how the three-dimensional world may be coded on the plane surface of a paper through systematic and optimum graphic representations. In chapters four through six Professor Rathbone sets down the results of many years of experience in teaching students and others how to write well in technical areas. His purpose is to combine a pragmatic exposition of how to write, read, and speak more effectively with correlative examples illustrating the principles set down by Professor Rosenstein in the earlier chapters. Professor Schneerer has undertaken to do much the same thing with graphics. He presents a concise description of sketching and the principles of graphic representation which allow one to quantitatively describe a three-dimensional object on a plane. He shows that visual communication is a form of coded data with tremendous information content

and he illustrates how information theory can point the way to more optimum and efficient communication in graphics.

The over-all aim of this book is to provide the student with a new conceptual framework for the methods of communication already familiar to him and to build on this framework with specific teachings which will enable him to read, write, speak, and draw more effectively.

During the past five years Professor Rosenstein has served as the Co-Principal Investigator of the UCLA Department of Engineering Educational Development Program. This program with assistance of a grant from the Ford Foundation has been devoted to an extensive study of engineering and engineering education. While it is impossible to adequately credit all contributions, this author wishes to acknowledge the insights gleaned from the discussions and investigations of the E.D.P. Design Subcommittee. Particular mention should be made of the contribution of Deans L. M. K. Boelter and M. Tribus, and Professors D. Rosenthal, J. M. English, M. Asimow, J. Beggs, A. Powell, F. Shanley, J. Lyman, and J. Powers.

Professor Rathbone acknowledges the encouragement and advice given him by Dr. Kenneth Wadleigh, Dean of Students at M.I.T.

Professor Schneerer expresses his appreciation to the many colleagues at Case who have encouraged and supported his efforts to present graphics as a language for the effective communication of technical information.

J. B. Reswick

Case Institute of Technology

ENGINEERING

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THE ROLE OF COMMUNICATION IN ENGINEERING DESIGN

INTRODUCTION

This book has been written to illustrate the role of communications in the professional activities of the engineer. Its purpose is twofold: to give the engineer new insight into the nature and role of communications of all types and to show him how to apply the theory of communication in his day-to-day professional activities. Since design is the essence of engineering, the need and the role of communications in design will be first presented. Following this a foundation for communications of all types will be developed through information theory. Next, the essential characteristics of the important communication means existing in our society will be explored. The application of the theory of communications to the all important problem of interpersonal communications will occupy the latter chapters of the text. Here the basic concepts originally developed for mechanical communications systems will be shown to establish the fundamental rules for effective communications among people.

To effectively present the place of communications in design, and consequently in engineering, it is desirable to have a concise definition of both design and communication along with a clear understanding of both the design and communication processes. As design and the design process is the central theme in this series, let us discuss design by first defining what we mean by the term "design." *Design has been defined as an iterative decision making process which is employed to develop means for optimizing the value of resources.*

The theories of communication have been developed to the point where they can be demonstrated to serve as adequate foundations for the description of any form of communication. In each case we find that communication involves a choice of alternatives or, in other words, a sequence of decisions just as does design. It is not surprising then to find that the basic ideas and methods of the discipline of design closely

parallel those of communication theory. In addition, of course, communication forms the sinews that hold the design process together.

THE DESIGN PROCESS

Studies of the process invoked by engineers in designing a variety of systems ranging from electronic controls to airplane wings have shown that regardless of the end object the design process is essentially the same. The basic elements of the process have been collected and called the "Anatomy of Design"—the following steps, which are repeated over and over until a satisfactory product is produced.*

Anatomy of Design

1. *Identification of the needs (i.e., defining the problem).* A careful analysis of the extent and validity of each need is required.
2. *Information collection and organization.* All factors which relate to the system need to be considered. Where necessary, experiments must be devised to obtain data otherwise unavailable.
3. *Identification, modeling, and statement of system variables.* All factors influencing the system—the so-called "boundary conditions."

   Engineering systems (and, in principle, subsystems and components) can be analyzed into basic elements which, when described or prescribed in appropriate detail and when properly synthesized, will constitute the design of the system.

   a. Inputs: Those resources and other environmental factors which are converted (or modified) by the system in question.

   b. Outputs: That which is produced by the system.

   c. Transforming means: The device used to obtain the relationship between inputs and outputs.

   d. Constraints: All elements and factors which express limitations and/or need to be accounted for in the design.

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* The basic elements of the design process are listed in the "Anatomy of Design." "Design as a basis for an Engineering Curriculum," (Allen B. Rosenstein, J. M. English, *Proceedings of the first conference on Engineering, Design Education,* Cleveland, Sept. 8, 9, 1960, pp. 1-28.) The detailed *sequence* of steps described in order of occurrence has been called the "Morphology of Design." (Morris Asimow: *Introduction to Design;* Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1962). Taken together, the "Anatomy" and the "Morphology" offer a complete description of the design process and all of its elements.

4. *Criteria development for optimum design.* The rules for judging relative merit.
    a. Development of value system.
    b. Criteria relationship among values.
5. *Synthesis.* Evolving of systems to convert the inputs into the desired outputs. At this step only the requirement of realizability is usually met.
    a. Physical realizability.
    b. Economic worthwhileness (realizability).
    c. Financial feasibility (realizability).
    d. Realization of producibility.
    e. Realization of reliability.
    f. Realization of maintainability.
6. *Test evaluation and prediction (analysis) of performance.*
7. *Decision steps.*
8. *Optimization.* (Maximizing the performance. Reduction to "best" system with available knowledge.)
9. *Iteration.* It is recognized that the above operations are found throughout the design process. Many iterations will be taken around several or all of them. In particular, the engineer continually re-examines his previous findings and decisions in the light of new information.
10. *Communication, implementation, and presentation.*

COMMUNICATION AND THE DESIGN PROCESS

The Anatomy of the Design Process can serve as an excellent outline for our study of communications. The basic problem lies in the need of the engineer to communicate with other men, with machines, and with himself. Without highly developed, and in many instances highly sophisticated, communication channels and techniques, the engineer is rendered helpless. If his incoming communications are blocked, he becomes sterile. The problems available to him become restricted and his knowledge of new resources becomes limited. If his outgoing communications are reduced, he is shortly reduced to futile frustration. For again, an engineer who cannot effectively communicate his design results or who cannot quest for new knowledge will be of little practical value. Let us discuss the major aspects of engineering communications in terms of some of the elements of the anatomy of design.

Definition of the Problem. This is normally the first step in any design.

The engineer may receive the problem in the form of a set of specifications that must be satisfied or he may be confronted with the physical situation itself. In any event, a major concern is the translation of some situation in the real world into a suitable model or representation that can be studied and manipulated. This translation can be effected by means of words, pictures, sketches, graphs, equations, audio-visual means such as motion pictures, and/or even scale models.

Information Collection and Organization. The merchandise or medium of exchange in communication is knowledge or information. We shall use the word information and, in developing Information Theory, shall give it a quantitative definition. Consideration of information leads us to the second element in the Anatomy of Design. Since design is a decision-making process and decision denotes a choice between alternatives, a design project of any magnitude entails the gathering and organizing of substantial amounts of information. In addition to the information-transmission problem that is beginning to take shape, the reader should now begin to comprehend the need for systems of information storage and techniques for information organization and retrieval.

Of course, substantial blocks of technical information are stored in men's minds. In addition to these living information storage bins, engineers have found that information can be stored as well as transmitted by pictures, sketches, written reports, etc. In recent years engineers have greatly extended man's ability to collect, store, and organize information through the use of computors and their magnetic memory drums, tapes, and cores.

Development of a Value System. Unique answers to substantial engineering problems are obtained only in light of the value scales of contemporary society. By changing the value system, we can change the correct answer to almost any engineering problem. The task of developing communications and applying the value system often requires more effort than the pure technical aspects of a problem.

Synthesis and Optimization. We consider the *synthesis* of a *possible* answer complete when the proposed solution is shown to be physically, financially, and economically realizable as well as being producible, reliable, and maintainable. The *optimization* step is complete when the "best" solution in light of our value system is produced from the array of realizable solutions.

Communication, Implementation, and Presentation. The study of the communication, implementation, and presentation of a design is the concern of this text. Again let us state that a design that cannot be implemented, cannot be tested, or cannot be communicated might just as well not exist at all. Unfortunately, it is just in these very stages that many excellent pieces of engineering have been defeated or depreciated.