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ENGINEERING MANAGEMENT

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ENGINEERING MANAGEMENT

Dedicated to my beautiful wife Marion
and my children, Kelly and Ted.

PREFACE

This book is about the management of technical organizations. Engineers typically find themselves in a dilemma 4 to 6 years after graduation, when technical management positions become available to them. They quickly become aware that such positions require new knowledge and skills that their previous professional training has not provided. At this point they either frantically try to discover on their own the methods and concepts that will allow them to understand the management process, or they read management texts and return to school. Although dozens of books have been written on managing almost every other business function, only a handful of books have recently appeared dealing with managing technical functions.

Statistically, 80 percent of all engineers will end up in some sort of managerial position during their working careers. In most of these positions engineers will manage professional personnel who perform technical functions. Technical functions are not managed the same way as an operating business or as nontechnical functions are. Technical functions are concerned with creating something new or improving the old. This is a future-oriented, "one-time" activity directed toward innovation and change. The resources required and the end results are highly uncertain and unpredictable. The technical manager must handle, motivate, and control highly trained, creative people in an uncertain environment that requires flexible planning, policies, and procedures. The activities of a technical group must be planned and controlled just as much as the other operational business activities. However, there are some significant differences. These differences form the rationale for this book.

The dilemma faced by anyone writing on engineering management is to determine whether one is writing about the management of engineers or the management of engineering. There are two aspects to any type of management, which I think of as the formal and informal aspects of management. The former deals with the official chains of authority, policies, procedures, forms used, etc. The latter deals with the interpersonal relationships among peers, managers, and subordinates. I firmly believe that these two aspects of management are equally important and interrelated. They are either mutually supportive or in conflict with each other. In this book I show this interrelationship.

The book is divided into four parts. Part One deals with the strategic level of management, the long-range, continuing problems faced by the technical manager. Chapter 1 is an introduction that sets the tone and scope of the book by discussing the environmental context within which the engineering manager operates and the functions and roles of the engineering manager as they relate to the unique characteristics of technical functions. The discussion centers on the conflict between the need for management controls versus the need for freedom of the creative individual; also stressed are the uncertainties faced and the nature of the output of a technical organization.

Chapter 2 reviews the problems associated with planning the work of technical groups, which includes technology forecasting, needs research, sources of ideas, and environmental monitoring. The types of planning required and suggested approaches are presented.

Chapter 3 considers the important function of organizing the technical group. Various possible forms of organization and their strengths and weaknesses are discussed. The dynamic nature of organization and formal and informal organizational structures are examined.

Chapter 4 goes into various staffing and training concerns. The difficulties of soliciting and selecting the right kinds of people and then maintaining them as viable, productive workers are discussed. Problems of new employees and those of midcareer employees and technical, managerial, and organizational obsolescence are analyzed.

Part Two deals with the personnel level, including the interpersonal relationships among peers, managers, and subordinates. Chapter 5 is about the "care and feeding" of creativity. The creative process and the personal and organizational barriers to creativity that must be guarded against are discussed. Some suggested techniques for enhancing creativity are offered.

Chapter 6 presents the problems associated with the motivation of engineers, scientists, and technicians. Behavioral science theories on motivation are evaluated from the technical manager's viewpoint. The effects of aging, both on the individual and the organization, are discussed.

Chapter 7 is about the problem of choosing a leadership style. Much of the discussion resolves around whether there is one best leadership behavior. The

effects of environmental factors and the personalities and expectations of the followers are presented.

In Part three we learn about the tactical level of management, that is, some of the day-to-day operational problems. In Chapter 8 the problems of deciding what projects are to be pursued by the technical group are explored. Both quantitative and qualitative methods are evaluated, and the limitations of quantitative methods and current practice are presented. A mixed approach to project selection is suggested.

Chapter 9 studies the various aspects of managerial control. The criteria for a good control system and suggested approaches for implementation are proposed. Management by objectives and methods for the planning, reporting, and appraisal of individual projects are discused.

In Chapter 10 we consider the unique problem associated with the management of complex systems projects and the utilization of the work breakdown structure and network analysis methods for the planning and control of complex systems projects.

Part Four consists of Chapter 11, which reproduces a series of papers written by W. J. King. This chapter offers some of the best advice I have ever seen to the new engineer just beginning his or her career and to the engineer who has just been promoted to management.

Management today is more of an art than a science. Consequently, any book written on the subject reflects the personal views and value system of the author. This book is no exception, and many individuals have greatly influenced my ideas. Teachers such as H. G. Thuesen, Wilson J. Bentley, and Paul E. Torgerson shaped my early thinking. I later was privileged to work under Dr. William R. Lucas, Director of the George C. Marshall Space Flight Center, from whom I learned a great deal while gaining invaluable first-hand experience. Associations with other technical executives, such as Dr. John L. McDaniel, former director of the Research Development and Engineering Laboratory of the U.S. Army Missile Command and Dr. Rudolph Hermann, former Director of the University of Alabama Research Institute, have also influenced my thinking. Finally, I am especially grateful to my late friend, Alexander T. Flynn, whose great depth of understanding taught me the importance of honesty, fairness, and compassion.

I also thank the many individuals who have made it possible to complete this project, particularly Dr. Jafar Hoomani, Dean of the School of Science and Engineering, Dr. Robert A. Brown, Chairman of the Department of Industrial and Systems Engineering, and my colleagues at The University of Alabama in Huntsville for their help, understanding, and encouragement, my mother-in-law, Mrs. Maybella Day, for typing the basic manuscript, and Mrs. Judy Duvall, for typing the case studies.

ROBERT E. SHANNON

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CONTENTS

PART ONE

the strategic level

CHAPTER 1 environment of engineering management

1.1 Societal Changes

The search for knowledge and the means to utilize it to benefit humanity have occupied our minds almost from the very beginning of time. One of the most significant characteristics and phenomenon of modern society is the increasing rapidity with which nature is being made to serve the needs of people. Of all the forces that shape and reshape life in America, none is more insistent and powerful than those that spring from engineering and science. Our standard of living depends on technology to find new ways of using the resources we have, to find new products among the old raw materials, and to make life longer, safer, easier, and more productive.

The nation's two-hundredth birthday was celebrated with massive fireworks displays, historical reenactments, and thousands of other Bicentennial activities. During these first 200 years, world population increased sixfold, *but* real-world production multiplied 80 times over. At the same time, the distance a person can travel in a day stretched by a factor of 1000, the amount of energy we get from a pound of matter multiplied by 50 million, and our capability for instant communication multiplied several billion times. Technology was responsible for these changes.

In addition, during the last 100 years or so, American society went from an agriculturally based economy to an industrial economy and now to a service-oriented economy. Mainly because of the benefits of technology, for the first time in history, a nation now employs more than half of its working force in services. The

percentage of the U.S. labor force engaged in agriculture decreased from 90 percent in 1790 to 4 percent in 1970 and stabilized at that point. As employment in agriculture declined during the nineteenth and early twentieth centuries, there was a corresponding rise in the percentage of the work force engaged in manufacturing and construction. But, according to the Bureau of Labor Statistics, since the end of World War II, the percentage engaged in manufacturing has also been declining from 30 percent of the labor force in 1947 to an estimated 22.4 percent by 1980. It is even projected by one RAND Corporation study that by the year 2000 perhaps as few as 2 percent of the labor force will be required to turn out the necessary manufactured goods required by this country.

If we define an industrial society as one in which manufacture is the controlling force that shapes the characteristics of its labor force, then the United States today is *not* an industrial society. Although there is little agreement as to what to call the era on which we have embarked, there is general consensus as to its characteristics. These include:

1. *Economic Sector:* The change from a goods-producing to a services-producing economy.
2. *Occupational Distribution:* Increasing education for all citizens and the preeminence of the professional and technical class.
3. *Resource Base:* The centrality of theoretical knowledge and innovation as the source of power and policy formulation.
4. *Change:* Rapid technological change propelled by the explosion of knowledge.
5. *Decision Making:* The creation of a new "intellectual technology" to provide dynamic adaptation to the rapidly changing social environment.

As a part of the 1976 Bicentennial celebration, the Museum of Science and Industry in Chicago conducted a survey among leading engineers, scientists, and historians to select America's 10 greatest scientists, engineers, inventors, and innovators [3]. They also selected the 100 most significant American scientific discoveries, technological inventions, and industrial innovations. The selections were based primarily on the development's impact on its field and scientific, social, or economic progress. The results are shown in Appendices A and B.

Even a casual reading of these lists should be enough to convince the most skeptical reader that the fruits of American innovation have done more than anything else to shape the quality of this country's economy and national life. Technology has provided the gains in efficient use of labor, materials, and time. Innovation creates jobs and boosts productivity. Above all, innovation generates economic momentum and helps to guarantee American preemi-