Systems Concepts

Lectures on Contemporary Approaches to Systems

Systems Concepts

LECTURES ON CONTEMPORARY APPROACHES TO SYSTEMS

1971 Lecture Series at the California Institute of Technology, Sponsored by the Divisions of Biology, Chemistry and Chemical Engineering, Engineering and Applied Science, and the Humanities and Social Sciences, the Faculty Committee on Relations with Industry, and the Industrial Relations Center

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SYSTEMS ENGINEERING AND ANALYSIS SERIES

In a society which is producing more people, more materials, more things, and more information than ever before, systems engineering is indispensable in meeting the challenge of complexity. This series of books is an attempt to bring together in a complementary as well as unified fashion the many specialties of the subject, such as modeling and simulation, computing, control, probability and statistics, optimization, reliability, and economics, and to emphasize the interrelationship between them.

The aim is to make the series as comprehensive as possible without dwelling on the myriad details of each specialty and at the same time to provide a broad basic framework on which to build these details. The design of these books will be fundamental in nature to meet the needs of students and engineers and to insure they remain of lasting interest and importance.

Foreword

In 1971 a series of lectures was given on systems engineering at Caltech under the auspices of the Industrial Relations Center, the Divisions of Biology, Engineering and Applied Science, Humanities and Social Science, and Chemistry and Chemical Engineering, and the Faculty Committee on Relations with Industry. Course credit was also given to Caltech students under the course Ae 241, Systems Engineering. A notable array of speakers participated in the series of 10 lectures.

The lectures were very well attended and enthusiastically received. Indeed so great was the response that Caltech and Dr. Ralph Miles, who was responsible for the idea of the lectures and for organizing them, decided that it would be useful to a large number of people to have the material available in more permanent form. This book is the result.

Systems engineering is a necessity for the optimal solution of today's complicated technological problems; this is true even though such problems were being solved many years before the discipline known as systems engineering came into existence. The individuals and organizations that solved these problems were systems engineers, whether or not they knew it. (One is reminded of M. Jourdain, the hero of *Le Bourgeois Gentilhomme,* who discovers in the course of the play that he has been speaking prose all his life.) Yet the creation of a formal discipline, largely as the result of the aerospace efforts during and after World War II, has produced a depth of understanding and skill that has made possible the solution of enormously more complex and difficult technological problems than before.

I am convinced that somewhat the same approach must be applied to the far more complicated social and economic problems that advanced societies face, if we are to make substantial progress in solving them. At the same time, it is clear that systems engineering by itself will not be enough. We do not know enough about the behavior

of the components of the socioeconomic problems—the people and the human institutions—to be able to have much confidence in the results of systems engineering approaches to such problems at the present time, no matter how elegant and proven such methods may be in technological areas.

Thus systems engineering is a necessary, but not a sufficient, input for the solution of this class of problems. It is a way of illuminating the facts. The decisions and conclusions in nontechnological areas will have to be reached through the exercise of a great deal of judgment and experience. But, if the facts are not presented and compared and all alternatives exposed through the methods of systems engineering, those judgments, however experienced and able, will have to be made on the basis of faulty data and on the basis of comparisons less precise than they could be.

HAROLD BROWN
President
California Institute of Technology

January 1973

Preface

This book is an edited version of the lecture series, "Systems Concepts for the Private and Public Sectors," delivered in Ramo Auditorium, California Institute of Technology, in the spring of 1971. The 10 lectures of the series were given by renowned experts in the various aspects of systems concepts. The series was attended by members of the Caltech community and by subscribers from the general public. Subscribers to the lecture series represented a diverse spectrum of Southern California technical, business, and government organizations.

There is an abundance of books on systems concepts. The bibliography contained herein lists more than 300. The majority of these books, especially those used as classroom texts, are heavily technique- or analysis-oriented. Little attention is given to such matters as who uses these tools, why they use them, or how successful they have been in implementing their recommendations. Thus the student gains little understanding or appreciation of the difficulties of actually applying systems concepts in realistic environments.

The chapters of this book constitute a set of readings on the application of systems concepts to a wide range of disciplines. The writers discuss the relevance of systems concepts to their professions, what success has been realized, and the possibilities for the future. This book can be considered as supplementary reading to the standard texts for introductory courses on systems engineering or operations research.

Dr. Harold Brown, President of Caltech, provided the initial funding for the "Systems Concepts" lecture series from the President's Venture Fund. The lecture series was sponsored by the Caltech Divisions listed on the title page. Special mention must be made of Robert D. Gray and the personnel of the Caltech Industrial Relations Center for their administrative support in conducting the lecture series.

I am indebted to Professor Francis H. Clauser, Chairman of the Division of Engineering and Applied Science, for the invitation to

spend the 1970–71 academic year at Caltech as a Visiting Assistant Professor. I am also indebted to Dr. William H. Pickering and the Jet Propulsion Laboratory for providing my financial support during this period.

RALPH F. MILES, JR.

Pasadena, California
January 1973

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Introduction

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Ralph F. Miles, Jr., received his Ph.D. in Physics from the California Institute of Technology in 1963. At the Jet Propulsion Laboratory he was the Spacecraft System Engineer for the Mariner Mars 1969 Project. During the 1969–1970 academic year he was a Visiting Fellow in the Department of Engineering-Economic Systems at Stanford University. During the 1970–1971 academic year he was a Visiting Assistant Professor in Aeronautics and Environmental Engineering Science at the California Institute of Technology. Presently he is the Mission Analysis and Engineering Manager for the Mariner Jupiter/Saturn 1977 Project at the Jet Propulsion Laboratory.

Systems Concepts

Most people have intuitive ideas about the systems approach, or "systems engineering" as it is called in the more technically oriented contexts. Civil engineers have been constructing large systems for a long time—systems such as cities, roads, aqueducts, and pyramids. Today aeronautical, chemical, and electrical engineers design large technically complex systems with complicated man–machine interfaces. Computer programmers, biologists, economists, and sociologists all use systems concepts.

To a large extent these intuitive notions of systems are correct. After all, is systems engineering not just "good engineering," what we have been trying to do all along?

Systems engineering *is* good engineering. And beyond that it is more a change in emphasis than a change in content—more emphasis on defining goals and relating system performance to these goals, more emphasis on decision criteria, on developing alternatives, on modeling systems for analysis, and on controlling implementation and operation.