A BIBLIOGRAPHICAL SURVEY OF LARGE-SCALE SYSTEMS

By

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FOREWORD

It is becoming increasingly clear that technology must serve man in improving the quality of life. This identifies the most important future role for control systems engineering, according to the respondents to a survey conducted by the Office of Control Theory and Application in the Fall of 1968. A report of that survey was published as NASA-ERC-PM-67. A symposium in early 1969 brought together leaders in broad application fields to discuss needs with control systems experts. The proceedings of this symposium were published as NASA SP-211. Since then various other means have been used to bring these insights and their implications for action to the attention of larger numbers of control systems workers.

Control systems engineering is seen to have a role in modern society that goes far beyond its traditional one of providing designs for relatively simple mechanistic systems, or even those incorporating a human operator. Complex, large-scale systems are the order of the day, and these increasingly involve aggregates of human beings.

Many attempts have been and are being made by workers in various special fields to analyse their large-scale systems through the use of models. The skills of control systems engineers - in analytic design, in modelling, and in simulation - can be integrated with the skills of specialists in the social areas to meet the problems of life on this planet.

This bibliography is a small start on bringing to the attention of all interested in large-scale systems the experience that has recently been accumulated. It is offered without apology for its inadequacies. Rather, it is offered with the hope that it will be initially helpful to those trying to get started in this most important area.

O. Hugo Schuck, Chief
Office of Control Theory
and Application
ABSTRACT

A limited, partly annotated bibliography was prepared on the subject of large-scale system control. Approximately 400 references are divided into thirteen application areas, such as Large Societal Systems and Large Communication Systems. A first-author index is provided.
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DEFINITION OF THE LARGE-SCALE SYSTEM

A large-scale system is one that is so large that it usually must be controlled by rule-of-thumb or heuristic techniques because one or more of the following conditions exists:

1. The number of parameters necessary to describe the system is too large to handle with conventional models and/or computing techniques.

2. The laws relating the parameters are not well understood.

3. The system is apparently irrational.

Note that sheer physical size is not a criterion for a large-scale system; rather complexity and inability to "get a handle" on the system are more significant.

Naturally there is a frontier zone between small-scale systems, which we can encompass theoretically, and large-scale systems which give us trouble in this respect. As new techniques of modelling, simulation, and analysis are created, this frontier zone moves forward into the region of more complex systems. It is in this frontier zone where excitement exists today, for here new ways of dealing with large-scale systems are being created.

It is well that theorists are paying more attention to large-scale systems because many of the world's most trying problems involve large-scale systems: the national
economy, the American welfare system, the American educational system, even our natural environment, all are large-scale systems. We must learn how to control these systems if society is to survive. At the moment, it appears that many large-scale systems, especially those involving society, are not under adequate control.

**OBJECTIVES OF THE SURVEY**

The objective of this survey was to make a preliminary sweep of likely sources of reports dealing with the control of large-scale systems. Where papers and reports could be easily obtained, remarks accompany the bibliographical material. The reader is hereby warned that, lengthy as the following bibliography is, it is certainly far from complete. It is hoped, however, that the key papers in every field have been found.

The present-day fragmentation of the field of large-scale systems is the major reason for embarking upon this survey. It was apparent to NASA that little effort was being made to bring together the results from the various programs dealing with large-scale systems, especially societal systems. The very strong shift of American technology into societal programs has stimulated a great deal of systems analysis dealing with cities, the environment, transportation networks, etc. It is the same old story
of people in various fields of endeavor, each unaware of the other, trying to cope with common problems. In this case, the applications themselves are often radically different but the theoretical tools; analysis, simulation, and modelling; are the same. The parameters have different names but there are a great many of them, and they are interrelated in complex ways whether we talk about U.S. power grids or air pollution control on a national basis.

By bringing these references from so many disparate sources together in one place we hope to show the fragmented groups how other people are tackling the same sorts of problems. "Cross fertilization" has become a hackneyed word in management lingo, but cross fertilization is the main intent of this survey.

**SOURCES SEARCHED**

The routine portion of the literature search began with a survey of the two NASA-supported abstract journals for the period from January 1967 to October 1969: *International Aerospace Abstracts* and *Scientific and Technical Aerospace Reports*. Because these journals do not include all government work of possible interest, *Government and Research Reports* was checked for the same period. The 1968 edition of *Books in Print* was also examined. Another technique applied with good success was the search of recent journals
in the control field for key review and survey papers. Often as not, these papers would refer to older reports. To supplement references acquired through more or less conventional techniques, about fifty letters were posted to scientists and engineers known to be active in the field of large-scale system control. Inquiries were also sent to government agencies and private companies applying large-scale system concepts to societal problems. The preliminary nature of this survey should be obvious from the limited selection of source materials. Despite these restrictions, a rather large amount of pertinent material was discovered.

ORGANIZATION OF THE SURVEY MATERIAL

Except for the first section of references dealing with large-scale system theory, the material in this survey is categorized by application area, as indicated in the Table of Contents. Specialists can thus readily find reports dealing with their own areas of interest. However, it would defeat one of the main purposes of this report if specialists did not at least browse through other application areas to discover what other people are doing with large-scale systems. A first-author index completes the report.

A general and rather brief discussion of how systems analysis can be applied to management and urban problems. "Spin off" from the following NASA programs is suggested: GE Voyager study, MORL model, Texas A&M long-range planning study, General Dynamics manned spacecraft cost model, Apollo FAME program, and the Goddard GREMEX program.


Theoretical paper on reduction of the number of dimensions in a large-scale dynamic systems by "aggregation," a method of simplification related to "projection."


An excellent treatment on system theory as applied to a large variety of systems, some large-scale. A great deal on models; little on mathematical theory.


A general method of designing control laws for complex systems is described, with emphasis on large transportation systems. Chapter III is entitled "Multilevel Control," Decomposition technique used to simplify.


A class of optimization procedures is introduced that reduces computational difficulties by subdividing a large problem into many, smaller subproblems.


A classic text on systems engineering. Deals with several large-scale systems.

Multivariable information theory can eliminate such detail in large-scale models, while preserving information about the interrelations between parts of a system, even if the interrelations are very complex.
Durbeck, R. C.: PRINCIPLES FOR SIMPLIFICATION OF OPTIMIZING
CONTROL MODELS, Ph.D. Thesis, Case Institute of
Technology, Cleveland, 1964.

Dy Liacco, T. E.: THE ADAPTIVE RELIABILITY CONTROL SYSTEM,

Evans, G. W., Wallace, G. F. and Sutherland: SIMULATION
USING DIGITAL COMPUTERS, Prentice-Hall, Inc.,

Falb, P. L. and Wolovich, W. A.: DECOUPLING IN THE DESIGN
AND SYNTHESIS OF MULTIVARIABLE CONTROL SYSTEMS,

Falb, P. L. and Wolovich, W. A.: ON THE DECOUPLING OF
MULTIVARIABLE SYSTEMS, Proc. 1967 JACC, Philadelphia,
1967, pp. 791-796.

Findeisen, W.: PARAMETRIC OPTIMIZATION BY PRIMAL METHOD IN

Findeisen, W. and Lefkowitz, I.: DESIGN AND APPLICATIONS
OF MULTILAYER CONTROL, Proc. IV IFAC Cong., Warsaw,
1969.

Ford, L. R. and Folkerson, D. R.: FLOWS IN NETWORKS,

Foster, C., Rapoport, A. and Trucco, E.: SOME UNSOLVED
PROBLEMS IN THE THEORY OF NON-ISOLATED SYSTEMS,
General Systems, 2, 9, 1957.

Gilbert, E. G. and Pivnichny, J. R.: A COMPUTER PROGRAM
FOR THE SYNTHESIS OF DECOUPLED MULTIVARIABLE FEED-
BACK SYSTEMS, AD-686823, 1969.

Presents a practical synthesis procedure for decoupled
systems through the use of computers.

Gilbert, E. G.: THE DECOUPLING OF MULTIVARIABLE SYSTEMS BY

Goode, H. H. and Machol, R. E.: SYSTEM ENGINEERING: AN
INTRODUCTION TO THE DESIGN OF LARGE-SCALE SYSTEMS,

Grabbe, E.M., Ramo, S. and Wooldridge: HANDBOOK OF AUTOMATION,
COMPUTATION AND CONTROL, John Wiley & Sons, New York,
1961.

Nothing significant on large-scale systems.


Hertel, H. F. and Humphrey, SHARE XXIX TALK ON MODELING LARGE SYSTEMS, Simulation Project, Miami Beach, 1967.


This analysis concludes that systems analysis has been over-rated as a cure-all for urban ills.


Summarizes several pertinent papers:

An early look at complex systems.


A two-level scheme for easing problems of high dimensionality.


Decomposition used to break system into small subsystems, each suboptimized separately. A hierarchy of control functions distributes the load and responsibility for satisfying overall control objective.


Lerner, A. Ya.: CONTROL IN LARGE SYSTEMS, JPRS-46561, 1968.

Chapter 9 of Technical Cybernetics in the USSR, A. Ya. Lerner, Nauka Press, Moscow, 1968. A most excellent survey of the large-scale system problem and various techniques being tried to analyze complex systems. About 100 references are numbered in the text but not reproduced in the JPRS translation.


An excellent popular description of telephone networks and what makes them large-scale systems. McKay notes that the U.S. and Canadian telephone systems are too large to simulate on a computer and that large engineering decisions must be made on the basis of experience.


A linear dynamic system is decomposed into subsystems which are optimized with respect to subgoals. A coordination scheme is introduced.


Discusses general approaches to the design of hierarchical systems.


Presents a design technique for linear, continuous controllers for multivariable process systems.


Presents a mathematical model for decision making in human-operated systems.


Chapter 2 is entitled "Multilevel control."
Chapter 4 is entitled "Variations of the Optimal Control Problem for Distributed Parameter Systems and Their Effect on Multilevel Control." Both of these chapters have application to systems with many variables.


LARGE SURVEILLANCE SYSTEMS


A fascinating account of the development of large computer-based systems, such as SAGE. Lots of philosophy and history, but an excellent collection of large-scale system descriptions and experiences with them.


Description of NORAD control system.
LARGE VEHICULAR CONTROL SYSTEMS


CONSAD Research Corp.: IMPACT STUDIES: NORTHEAST CORRIDOR TRANSPORTATION PROJECT,
Vol. I. Background, Overview, and Summary, 1967, PB-176, 478;
Vol. II. Models, Results, and Technical Discussion, 1968, PB-177 611.

A classic study in depth of a large-scale system. CONSAD developed economic/demographic impact models.


The numerical analysis of Markovian queueing networks and graphical communication of problem statements and results offer the potential for the truly conversational use of computers for "high traffic design" of large-scale systems.


A general treatment of the subject. No specific discussions of large-scale systems. Some modelling of costs.
LARGE COMMUNICATION SYSTEMS


Defines a large-scale system as one that three or four people cannot understand in its totality. The authors believe that decomposition into subsystems is the best philosophy.


Dedicated to the proposition that better large-scale communications can relieve traffic problems over wide areas. A highway communications model is presented, and there are lengthy treatments of traffic theory and operations research. Simulation is discussed, too.

CONSAD Res. Corp.: AN INFORMATION SYSTEM DEVELOPMENT PROGRAM. PB-177 809, 1968.

Some discussion of models of information systems.


Describes how to evaluate large on-line generalized data management systems. Good definition and qualitative model of these kinds of large-scale systems.


Lockheed Missile & Space Corp.: CALIFORNIA STATEWIDE INFORMATION SYSTEM STUDY. Sunnyvale, 1965.


Discusses North American Continental Switching Network as a large-scale system.


LARGE LOGISTICS SYSTEMS


Describes in detail a model for simulating operations and support functions at an Air Force Base.


Treats Rand simulations of large-scale systems.


LARGE ELECTRIC POWER GRIDS


An excellent popular account of power transmission systems, their complexity and automation.


Uses a "compartment" model to help explain multi-variable data taken from a complex system.


Describes the model of the Susquehanna River Basin, including water, employment, and many other societal factors; also reviews the history of models in societal systems.


IBM Corp.: PROCEEDINGS, IBM SCIENTIFIC COMPUTING SYMPOSIUM, WATER AND AIR RESOURCE MANAGEMENT. White Plains, 1968.


LARGE ECONOMIC SYSTEMS


A non-mathematical study of marketing systems. Nevertheless, this book represents a rather thorough identification of the factors and interrelations involved in marketing systems.


The Klein-Goldberger model is an economic model of the U.S.


Kuhn, H. and G. Szego, eds.: MATHEMATICAL SYSTEMS THEORY AND ECONOMICS. Springer-Verlag, New York, 19__.


Orcutt, G. H.: SIMULATION OF ECONOMIC SYSTEMS.

Scott, A. M. et al: SIMULATION AND NATIONAL DEVELOPMENT.

Tinbergen, J.: AN ECONOMETRIC APPROACH TO BUSINESS CYCLE
PROBLEMS. Hermann et Cie, Paris, 1937.

A classic in econometric model building.

Trapeznikov, V. A.: PROBLEMS OF THE CONTROL OF ECONOMIC
SYSTEMS. JRPS-47802, 1969.

A qualitative discussion of large economic system with
a section entitled - "Control of 'Large Systems' - Is
this an Art or Science?"

Tustin, A.: THE MECHANISM OF ECONOMIC SYSTEMS.
LARGE MANAGEMENT SYSTEMS


Non-mathematical description of the system approach and its application to automation, large companies, and government projects.


Modeling and simulation of a large industry.


A thorough treatment of the field, including PERT, gaming, economic models, heuristic methods, computer techniques, etc.


An excellent annotated bibliography.


Does not tackle large-scale systems as such.


Applies General Purpose Simulation System (GPSS) to production management.


Stochastic models in economics.


LARGE PROCESS SYSTEMS


General Purpose Simulation System (GPSS) applied to the National Airspace System multiprocessing system.


Collection of papers applying computer control technology to various industrial processes. Some of the systems are big, but they only approach large-scale systems in size and complexity.


Second and third proceedings of Louisiana State University Annual Workshop.


LARGE BIOLOGICAL SYSTEMS


A semitechnical exploration of models of the mind. Some discussion of hierarchies in thinking.


Deals with irrational behavior of humans in systems analysis.


Discusses various formalisms for expressing the structure and behavior of biological systems. Some characteristics of biological models are proposed.


An excellent text covering many aspects of control theory as applied to biological examples. In addition to chapters on control theory, there are chapters covering modelling and computer simulation of biological systems and subsystems. Section 9.5 is entitled "Simple Models for High-Order Systems," indicating one approach towards handling large-scale systems.

LARGE SOCIETAL SYSTEMS


A qualitative and fascinating discussion of the control of all facets of society from the viewpoint of communism.


A largely mathematical treatment of stochastic models of societal processes.


Stochastic models of social processes.


A qualitative study of the elements of control in societies.


A discussion of city modelling, including a treatment of control aspects.


A critique (by a sociologist) analyzing the California experience with aerospace-type systems analysis of societal problems. Generally favorable to systems analysis, particularly as aids to defining large-scale system interrelations.


Describes general problems involved in modelling health services. One simulation model presented.


A short discussion of methodology.


Maccia, E. S. and G. S. Maccia: DEVELOPMENT OF EDUCATIONAL THEORY DERIVED FROM THREE EDUCATIONAL THEORY MODELS. Ohio State U., Columbus, 1966.


A collection of nine papers dealing with traffic, medical, justice, city planning, and government systems. The special problems of large-scale systems are not covered in any depth.


"BUILD" is a role-playing computer game designed to help planning new communities within a city. The model's emphasis is on human values. BUILD's purpose is to provide a mechanism whereby people in a community can participate in the decision-making process.


Recommends specific steps to be taken in applying systems analysis to societal problems. These are management-type items, however.


A brief case history.


MISCELLANEOUS LARGE-SCALE SYSTEMS


Simulation applied to large complex of electronic equipment.


A decomposition technique called "stratification" is applied to simplifying some aspects of checkers and chess, both of which are large-scale systems.


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