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APPLYING TECHNOLOGY TO UNMET NEEDS. TECHNOLOGY AND THE AMERICAN ECONOMY, APPENDIX VOLUME V.

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Twelve studies dealing with the problems of applying technology to unmet human and community needs are presented. "Urban Planning and Metropolitan Development--The Role of Technology," examines the possibilities of the computer and other modern planning tools. "Technology, Automation, and Economic Progress in Housing and Urban Development" describes innovations in the housing field. "Technology and Urban Needs--A Report of the Engineering Foundation Research Conference on the Social Consequences of Technology" summarizes the conclusions of the 60 participants. "The Four Aerospace Contracts--A Review of the California Experience" reports on feasibility studies of the application of aerospace industry skills to problems of urban transportation and solid waste control. Another paper analyzes the same studies to determine the usefulness of the systems approach to large-scale social problems. "Technological Change As It Relates to Air Pollution," "Water Pollution Control," and "Report on the Solid Waste Problem" describe the problems and suggest alternative solutions. Other papers treat (1) transportation policy, (2) life sciences, (3) social, political, and economic models and simulations, and (4) techniques to assure the proper use of government developed technologies. Other appendixes to VT 003 962 are VT 003 960, VT 003 961 and VT 005 795-VT 005 797. (EM)

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APPLYING TECHNOLOGY TO UNMET NEEDS

Appendix Volume V
TECHNOLOGY AND THE AMERICAN ECONOMY,
The Report of the Commission

Studies prepared for the National Commission on Technology, Automation, and Economic Progress • February 1966

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PREFACE

This volume is the fifth of six appendix volumes to Technology and the American Economy, the report of the National Commission on Technology, Automation, and Economic Progress. The full series of appendix volumes is as follows:

I. The Outlook for Technological Change and Employment
II. The Employment Impact of Technological Change
III. Adjusting to Change
IV. Educational Implications of Technological Change
V. Applying Technology to Unmet Needs
VI. Statements Relating to the Impact of Technological Change

In pursuit of the Congressional mandate to "define those areas of unmet human and community needs toward which application of new technologies might most effectively be directed," the Commission prevailed upon various experts to assess the state of technologies related to various social needs. This volume, then, consists of 12 studies dealing with the problems of applying technology to unmet needs.

Richard Duke examines the possibilities of the computer and other modern planning tools in solving the problems of urban planning and metropolitan development. A team from the new Department of Housing and Urban Development describes new innovations under study in the housing field. The Engineering Foundation turned its annual research conference to consideration of the Commission's assignment. Its findings and recommendations are reported by James Alcott.

Simultaneous with the Commission's studies, the State of California undertook an important experiment in the application of the systems skills of the aerospace industry to the solution of social problems. Aerospace companies were asked to undertake feasibility studies of the application of those skills to such problems as urban transportation and solid waste control. Harold Walt of the California Department of Finance summarizes the results of those studies and the experiment. Black and Forman examine the same experience and extract from it an analysis of the usefulness of the systems approach in handling large-scale complex social problems.

The Division of Air Pollution of the Public Health Service describes the problem of air pollution and the alternative methods available for its control. The Federal Water Pollution Control Administration provides a similar analysis in its field as does the Office of Solid Wastes on the problem of handling solid wastes.

Edward Hassell describes various attempts underway to bring order out of the Nation's transportation chaos. James Dickson describes the impressive possibilities for health care of computerized diagnostic screening systems.

Clark Abt and Associates were asked by the Commission to inventory the present state of the art in using computer-aided modeling and simulation techniques in the solution of complex social, political, and economic problems. Finally, Howick and Lesher evaluate the various techniques in use designed to assure that potential civilian and commercial uses of technologies developed in the space and defense efforts are not overlooked and neglected.

Additional studies prepared for the Commission are contained in Appendix Volumes I, II, III, and IV. Appendix Volume VI contains a group of statements by various interested organizations and individuals in response to a request from the Commission for their views on the impact of technological change.

Though the Commission does not necessarily endorse the information and views of these documents, it considers them of sufficient value to have directed their publication.

This volume was edited and prepared for publication by Judith Huxley.

GARTH L. MANGUM,
Executive Secretary.

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OTHER APPENDIX VOLUMES PRINTED UNDER SEPARATE COVERS

I. The Outlook for Technological Change
II. The Employment Impact of Technological Change
III. Adjusting to Change
IV. Educational Implications of Technological Change
VI. Statements Relating to the Impact of Technological Change

URBAN PLANNING AND METROPOLITAN DEVELOPMENT—THE ROLE OF TECHNOLOGY

Prepared for the Commission

by

Richard D. Duke

Michigan State University

East Lansing, Michigan

206-754—66—vol. V——2

SYNOPSIS

America is an urban nation; its emerging metropolitan centers are a totally new phenomenon representing one of "the most serious single problems facing man. . . . " Intelligent management is urgently required to insure that the tremendous investment these centers represent results in a humane, as well as an efficient, environment.

While many disciplines are concerned with metropolitan growth, one, urban planning, is rapidly orienting itself towards comprehensive planning needs. Recent theoretical work in this area suggests that feasible metropolitan guidance systems can be developed.

Trial applications of these new concepts frequently founder on the core problem of a lack of intrametropolitan information. Such data are a universal common denominator in metropolitan problem solution. Because no single governmental unit typically represents the metropolitan area, information is not organized at this level. Thus, a comprehensive system is urgently needed.

The technology required to solve this need either exists or can reasonably be expected in the near future. Empirical efforts have been attempted, operating under severe resource constraints. Success to date has been limited, but extraordinary results can be expected if a "critical mass" of inputs is achieved.

The main barriers to action lie in the nature of the metropolitan complex. No single unit of government has the clear responsibility or the unobstructed authority to act. This diffusion of responsibility obstructs a clear vision of the need as well as of the potential benefits. Bold solutions are required—initially they will entail Federal financial aid as well as new State enabling legislation.

The product, a metropolitan management information system, would provide reliable information on intrametropolitan phenomena to the existing power structure, both public and private. This will inevitably result in changes within the operational structure of the metropolitan area; however, these will stem from local initiative, a logical consequence of the system.

The implications for national policy relative to metropolitan economic development are also outlined.

CONTENTS

Urban Planning and Metropolitan Development—the Role of Technology

The Nature of the Metropolis

> After the question of keeping world peace, metropolitan planning is probably the most serious single problem facing man in the second half of the 20th century.[1]

This statement by the World Health Organization in 1964 brings into focus the importance of metropolitan growth to the economies of the United States and the world. This country, which has not yet completed the transition from a rural to an urban society, now faces a phenomenon totally new to mankind. The changes resulting from urbanization and their implications are documented extensively.[2] This paper will not attempt an extensive review of the findings of this vast and growing literature; it will recapitulate certain characteristics basic to the solution of many of the problems of the typical metropolitan area:

1. It is a large and rapidly growing urban region. Estimates indicate that 85 percent of all new growth will locate in these areas in the next two decades.[3]
2. The area represents huge investments, both private and public.
3. Each of these areas is in competition with similar areas.[4]
4. Typically, its formal government consists of a maze of local units overlaid by a great variety of autonomous or semiautonomous authorities and special districts.
5. One of its greatest strengths is the diversity and tremendous variety of specializations found in the population.
6. It covers a large land mass frequently encompassing widely different geographic characteristics.
7. A great multitude of services must be performed, and these typically may be handled by either private or public agencies.
8. It performs a huge variety of functions for the region and Nation: Transportation and communications, health and welfare, labor pool, development of management skills, banking and finance, art and culture, law, a base point for scientists and research people, etc.
9. It is particularly sensitive to State and Federal programs;[5] the internal policy of a myriad of Federal agencies creates a kaleidoscope of local actions and reactions, often poorly coordinated or conflicting.
10. It is constituted by a diverse group of decisionmakers pursuing limited goals. Whether they are private or public, or operate cooperatively or competitively, these decisionmakers operate with incomplete knowledge, both of factual data and established policy.[6]

The metropolis, then, is vast, both in terms of land area and population; it is growing rapidly; it is extraordinarily complex—economically, physically, socially, politically. Representing a staggering economic investment, it will be the focal point of most national activity in the coming decades. It is managed by a wide assortment of political subdivisions, which function only after a fashion because each limits its concern to some aspect or areal unit of the whole. Its human resources are immense, and the skills they represent can only be developed and retained in an urban setting. Finally, growth, both qualitatively and quantitatively, is greatly influenced by exogenous forces, particularly the Federal Government.

Management of this resource in any comprehensive, rational, long-range perspective is almost nonexistent. An organization so huge, so complex, so critical to national strength, so interde-

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[1] John C. Bollens and Henry J. Schmandt, *"The Metropolis: Its People, Politics, and Economic Life"* (New York & Evanston: Harper & Row, 1965), p. 6.

[2] The literature on metropolitan phenomena is extensive; four references may serve as useful examples: Jean Gottman, *Megalopolis* (New York: The Twentieth Century Fund, 1961), which describes the urban community reaching from Virginia to Massachusetts along our eastern seaboard; Bollens and Schmandt, *op. cit.*, for a recent and thorough review of the metropolitan phenomenon and its impact on the American society; Roscoe C. Martin, *Metropolis in Transition*, Housing and Home Finance Agency. U.S. Government Printing Office, 1963, a review in detail of the various modes of adaption local governments have utilized to meet changing urban needs; Juan A. Casasco and Jerold V. Matthews, *Central Cities*, Executive Report No. 251, July 1965, which presents in capsule form the dimensions of the problem and highlights the potentials for industry.

[3] Roscoe C. Martin, *op. cit.*, foreword.

[4] For a review of the intermetropolitan bargaining process, see John E. Bebout and Harry C. Bredemeier, "American Cities as Social Systems," *Journal of the American Institute of Planners*, May 1963, pp. 64–75.

[5] Norman Beckman, "Our Federal System and Urban Development—The Adaptation of Form to Function," *Journal of the American Institute of Planners*, August 1963, pp. 152–167.

[6] For an examination of the provision of governmental services alternatively by a centralized or decentralized governmental system operating under quasi-market conditions, see Robert Warren, "A Municipal Services Market Model of Metropolitan Organization," *Journal of the American Institute of Planners*, August 1964, pp. 193–203.

pendent, so subject to outside factors requires some control mechanisms; management of urban resources at a metropolitan scale is mandatory.

Urban Planning—New Directions

The disciplines and professions concerned with urban phenomena are legion. Of these, urban planning, a relatively new area of study that has shown a remarkable flexibility in adapting to urban problems, may be of particular utility in aiding in the management of metropolitan resources. It is, perhaps, unique in combining a professional concern for: (1) Urbanism as a phenomenon; (2) coordination of the many specialties involved; (3) deduction of goals or objectives from a public perspective; and (4) formulation of alternative actions intended for the fulfillment of these goals.

Traditionally, city planning has been primarily concerned with physical growth in its various manifestations, emphasizing objectives such as orderly change, particularly of physical growth; high efficiency of physical relationships; high levels of public service; and development of an optimal environment for heterogeneous activities and individuals.[7] City planning has, to a large extent, focused on the concept of the "master" or "comprehensive" plan, a notion, which while still useful, is being supplemented by more sophisticated devices. These include policy plans as supplements to the old master plans, and the development of capabilities to quickly formulate and evaluate reasonable alternatives through techniques such as simulation.

One major result of this evolution is the development of what is essentially a new field of study, comprehensive planning, oriented towards metropolitan management problems.[8] This field incorporates such comparatively recent intellectual advances as information and decision theory, game theory, symbolic logic, communication theory, simulation, queuing theory, linear programing, and operations research techniques.

Evidence of the current emergence of comprehensive planning as a new field of endeavor may be found not only in the increased status of metropolitan planning agencies but in the development of a new theoretical base. Chapin's "Urban Development Guidance System" serves as one example of an operational framework for the new techniques.[9] The problem of goal formulation and public response in the context of metropolitan decisionmaking is critical to any metropolitan-planning approach and is also receiving increased attention.[10] Another related planning-development framework which has been proposed "focuses on the five classes of development assets—human resources, natural resources, private capital, public capital, and organization—and develops their implications at three crucial levels—suprametropolitan, metropolitan, and intrametropolitan."[11]

The rapidly emerging field of comprehensive planning, oriented toward the promotion of sound metropolitan growth, will pursue somewhat different objectives with new techniques. The new breed of planners will place considerably less emphasis on negative hopes (i.e., the restriction of growth through legalistic control) while pursuing the objectives of developing an increased understanding of the metropolis and the positive exploration of alternatives. The system will function best when the various decisionmakers (whether diverse, as in the typical situation, or centralized, as proposed in various forms of metropolitan government) have more complete knowledge.

Thus, the new metropolitan planning implies the need for an information system capable of estimating current states; the prediction of future states; the interpretation of this information in the public interest; the translation of significant findings into alternatives; the development of devices for the public evaluation of these alternatives; and the dissemination of these findings. This information at each stage must be freely available to all decisionmakers, public and private, if the metropolitan information system is to be effective.

Information—The Root Problem

Information (interpreted data) is the universal common denominator in metropolitan problem solution; it is the core of any metropolitan growth-management scheme, guidance mechanism, booster campaign, or research effort, both private and public. Many of the potential approaches alluded to above for metropolitan management are of limited value until a coherent information system exists. A tremendous range of metropolitan-oriented undertakings, private and public, operational and research-development oriented, founder for lack of data.

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[7] For an excellent summary review of the role of the city planner and the master plan as it now functions, see: Charles M. Harr, "The Master Plan: An Inquiry in Dialogue Form," *Land Use Planning, a Casebook on the Use, Misuse, and Reuse of Urban Land* (Boston: Little, Brown & Co., 1959), pp. 730–744.

[8] Melville C. Branch, Jr., "Comprehensive Planning: A New Field of Study," *The Journal of the American Institute of Planners*. August 1959, pp. 115–120.

[9] F. Stuart Chapin, Jr., "Taking Stock of Techniques for Shaping Urban Growth," *The Journal of the American Institute of Planners*, May 1963, pp. 76–86.

[10] The following articles typify this interest: Paul Davidoff and Thomas A. Reiner, "A Choice Theory of Planning," *The Journal of the American Institute of Planners*, May 1962, pp. 103–115; Janet S. Reiner, Everett Reimer, and Thomas A. Reiner, "Client Analysis and the Planning of Public Works," *The Journal of the American Institute of Planners*, November 1963, pp. 270–282; James Q. Wilson, "Planning and Politics: Citizen Participation in Urban Renewal," *Journal of the American Institute of Planners*, November 1963, pp. 242–249; Paul N. Ylvisaker, "Diversity and the Public Interest," *Journal of the American Institute of Planners*, May 1961, pp. 107–117; and Norton E. Long, "Planning and Politics in Urban Development," *Journal of the American Institute of Planners*, November 1959, pp. 167–169.

[11] Harvey S. Perloff and Lowdon Wingo, Jr., "Planning and Development in Metropolitan Affairs," *Journal of the American Institute of Planners*, May 1962, pp. 67–90.

The basic data required are formidable in themselves—people, automobiles, workers, levels of skills, housing available, number of unemployed, salaries, taxes, routes traveled, structures, land characteristics, utilities, ad infinitum—they are frequently dynamic in character, often subjective, seldom standardized (one basic source, the U.S. Census Bureau, finds it necessary to change procedures and definitions at each 10-year interval),[12] frequently recorded for a distinct geographic base, consistently permeated with error, always slow to be acquired, often in inappropriate format, seldom in proper mode, normally not compatible with data from other systems, always costly and generally incomplete, frequently politically sensitive, often too late, seldom available in historical perspective, frequently impossible to relate to associated data for want of mechanics. Metropolitan information needs are acute.[13]

Information is a root problem to many metropolitan development efforts—not only those described earlier, revolving about an increased understanding of the community and development of appropriate management tools, but equally in other areas of ongoing use and in research and development activities. There exists an almost infinite demand for current use of conventional data. In the private sector, there is the constant need for information for market analysis, industrial location problems, location of land for development, housing studies, urban renewal relocation and redevelopment efforts, shopping center location studies.[14]

Public needs are also extensive. An unending demand for information is created by such routine functions as tax assessment and licensing activities, evaluation of deterioration, plan effectuation efforts, school location problems, and studies of social pathology (venereal disease, crime, mental illness, juvenile delinquency, etc.) by appropriate social agencies.[15]

In city planning efforts alone, major percentages of resources are spent in data collection and analysis, with true planning functions being assigned minimal funds. Vast sums are expended for particular studies—traffic, land use, public opinion—inventories of every conceivable type. But these are not generally undertaken in the context of any overall framework, either because none exists or because the costs are prohibitive. Further, these data are frequently perishable, forcing complete resurveys to be undertaken after a brief interlude.

One of the most important functions of the city is to spawn new ideas—to create an environment which will encourage "pure" or "basic" research activities. This function of research and development is vital to the private sector—industry and commerce—as well as to the public. Again, one of the major impediments to research on metropolitan problems lies in the information base. Perhaps the most striking example of this is the incongruous situation created by machine compatibility problems (computers generally can communicate readily only with similar equipment).

A major source of data is the U.S. Census which gathers with relatively high accuracy detailed data for small areas with an efficient, computerized modern system. Theoretically, these data can be transferred electronically to other systems; however, the type of equipment used by the census is not readily available, and obstacles to transferring the digital information into a form which can be handled by other computers are so formidable that they normally preclude the direct use of census information.

Increasing recognition is being given to the need for an adequate information base for research purposes, particularly small area data (intrametropolitan). The consistent failure to anticipate major changes in the transportation system and their subsequent obsolescence (for example, the need to plan *now* for the postinterstate highway era)[16] has resulted in the active concern of the Federal Bureau of Public Roads. A recently initiated requirement for Federal aid for certain highway programs requires that ongoing planning programs which utilize much small area data be operational in metropolitan centers.[17] The Bureau of Public Roads, the U.S. Census, and the American Institute of Planners have all formally acknowledged the data problem relevant to intrametropolitan needs, and several national committees are pursuing a solution.

Emerging Technology

Fortunately, the technology exists to quantify urban growth on a continuous basis for intra-

[12] Leonore R. Siegelman, "A Technical Note on Housing Census Comparability, 1950–1960," *Journal of the American Institute of Planners*, February 1963, pp. 48–54.

[13] John W. Bodine, "Penjerdel: A Partnership," *Journal of the American Institute of Planners*, August 1960, pp. 201–204.

[14] Edgar M. Horwood, "Public Policy and the Outlying Shopping Center," *Journal of the American Institute of Planners*, November 1958, pp. 215–222; Eleanor P. Wolf, "The Tipping Point in Racially Changing Neighborhoods," *Journal of the American Institute of Planners*, August 1963, pp. 217–222; Bernard J. Frieden, "Locational Preferences in the Urban Housing Market," *Journal of the American Institute of Planners*, November 1961, pp. 316–324; and Paul A. Wilhelm, "Industrial Development Planning," *Journal of the American Institute of Planners*, August 1960, pp. 216–223.

[15] Fred Rosenberg, "Intra-Regional Failures in School Planning," *Journal of the American Institute of Planners*, winter 1957, pp. 49–56; J. Douglas Carroll, Jr., Roger L. Creighton, and John R. Hamburg, "Transportation Planning for Central Areas," *Journal of the American Institute of Planners*, pp. 26–34; Robert E. Coughlin, "The Capital Programming Problem," *Journal of the American Institute of Planners*, February 1960, pp. 39–48; and Hans-Wilkin Von Borries, "Local Finance and Community Development," *Journal of the American Institute of Planners*, February 1964, pp. 34–45.

[16] Melville C. Branch, "Urban Planning and the New Mobility," *Journal of the American Institute of Planners*, February 1964, pp. 2–9.

[17] An early experiment along these lines is described in: Henry Fagin, "The Penn-Jersey Transportation Study—The Launching of a Permanent Regional Planning Process," *Journal of the American Institute of Planners*, February 1963, pp. 9–18.

metropolitan areas, to project urban data for various time periods with a reasonable degree of sophistication, and to simulate the effects of alternative courses of action and urban growth. In short, it is technologically feasible to develop an operational metropolitan management information system. This system could be designed to provide reliable information on many aspects of intrametropolitan phenomena to all potential users, public and private, on a small-area basis (parcels, people, etc.); and to provide the intermetropolitan information required for a proper regional and national perspective.

There have been a variety of efforts in this direction, ranging from low budget, limited objective efforts in small communities to ambitious, multiple-purpose efforts in metropolitan areas.[18] The Federal Government, through the Housing and Home Finance Agency, has sponsored research into the development of appropriate generalized systems, particularly in the metropolitan data center project in which five cities jointly attempted the development of a viable system. These various efforts have all met with limited success, but they do provide sufficient operational experience to form a basis from which more sophisticated systems can evolve. One result of these efforts is the enunciation of a basic conceptual approach to the problem. Hearle and Mason have spelled out the major characteristics and requirements of a metropolitan data system in some detail;[19] numerous others have contributed to the development of a theoretical base.[20]

The technology for a working system—hardware, software, data sources, updating procedures, trained personnel—exists at some level. There is no question but that technological barriers could be overcome (an industry that can launch astronauts or photograph Mars can most assuredly cope with these earth-bound problems). Further, available technology could be used intelligently now. Recent exciting advances in theory and concepts enable the applied use of elaborate information systems. Perhaps the best evidence of this is contained in a recent special issue of the *Journal of the American Institute of Planners* which was devoted exclusively to "Urban Development Models: New Tools for Planning." These models are notorious for their consumption of information—lack of data remains the greatest single restraint to their full effective use.[21] Other theoretical advances—systems theory, economic models (including a system of regional accounts), city finance and capital improvement programs, cost-revenue and cost-benefit studies, choice theory, decision theory, and a variety of operations research techniques—are continuing to emerge and their successful use hinges on an adequate data base.[22]

One major critical restraint impedes the successful development of a metropolitan management information system: Acceptance and use by the decisionmakers. While such a system is of value for theoretical work, its initiation, development, and continued maintenance require that it be accepted as an operational tool by both public and private decisionmakers in the metropolitan area.

Barriers to Action

If an information system is of great potential, and very likely is an inevitability, why is none functioning at an adequate level? There are a variety of reasons:

1. *Awareness of Need.* It has been suggested that the public demand for the ubiquitous ballpoint pen was nil prior to its development and initial marketing. Urban data needs are currently met, in one fashion or another, as particular circumstances require. There is little recognition of the tremendous utility of the system proposed, except among professionals and the more alert public management personnel. This situation can be remedied by proper marketing strategies, particularly through the demonstration of one major operational system.

2. *Diffusion of Responsibility for Initiative.* The system proposed represents a formidable undertaking. Because of the diverse decisionmaking structure in the metropolitan area, there is no agency or group clearly responsible or possessing the authority to undertake such a venture. Be-

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[18] For a recent thorough review of various efforts that have been undertaken, see: Richard T. McGinty, *Metropolitan Data Systems: A Review of Significant Developments and Suggested Principles for the Implementation of a System,* Master's Thesis, Michigan State University, 1965.

[19] Edward F. R. Hearle and Raymond J. Mason, *A Data Processing System for State and Local Governments* (Englewood Cliffs, N.J., Prentice Hall, Inc., 1963).

[20] A review of related efforts is presented in Richard D. Duke and Richard T. McGinty, *An Annotated Bibliography on Urban Data Systems,* Institute for Community Development, Michigan State University, 1964 (currently under revision).

[21] Britton Harris (ed.), "Urban Development Models: New Tools for Planning," *Journal of the American Institute of Planners,* May 1965. Also see the May 1959 issue which was devoted to similar material.

[22] The following articles serve as a cross section of the developing theoretical base which requires extensive data: Melville C. Branch, Jr., "Planning and Operations Research," *Journal of the American Institute for Planners,* February 1957, pp. 168–175; William L. C. Wheaton, "Operations Research for Metropolitan Planning," *Journal of the American Institute of Planners,* November 1963, pp. 250–259; Edwin Von Böventer, "Spatial Organization Theory as a Basis for Regional Planning," *Journal of the American Institute of Planners,* May 1964, pp. 90–100; William L. C. Wheaton, "Applications of Cost-Revenue Studies to Fringe Areas," *Journal of the American Institute of Planners,* November 1959, pp. 170–174; Edward G. Bennion, "Capital Budgeting and Game Theory," *Harvard Business Review,* vol. 34 (1956), pp. 115–123; Charles M. Tiebout, "Input-Output and Foreign Trade Multiplier Models in Urban Research," *Journal of the American Institute of Planners,* August 1957, pp. 126–130; Sidney Sonenblum and Louis H. Stern, "The Use of Economic Projections in Planning," *Journal of the American Institute of Planners,* May 1964, pp. 110–123; and John W. Dyckman, "Planning and Decision Theory," *Journal of the American Institute of Planners,* November 1961, pp. 335–345.

cause of its ultimate value to the Nation, impetus should come from a Federal source; this will in turn induce the States to provide adequate enabling legislation. The local regional planning agency, or similarly functioning group, might then be designated the responsibility and authority to develop the system.

3. *Finance.* The cost of such a system, particularly during initial development, will be high—too high to expect an adequate undertaking by funds drawn from local sources. The system, to work effectively, must reach a "critical mass" beyond which it will carry under its own momentum. While costly by any measurement, it is certainly many magnitudes less expensive than the exploration of space, and of no less critical value to the Nation. Initially, a combination of Federal, State, and local finance is necessary with particular attention directed towards developing financial support for services rendered to industry. Once operational, continued maintenance costs should be a local responsibility.

4. *Resistance of Local Decisionmakers.* Any scheme of this magnitude inevitably creates fear in the entire hierarchy of personnel who currently devote themselves to one aspect or another of providing information needs of the community. Evidence of technological unemployment abounds in their personal sphere, and they are quick to appreciate possible negative impact of such a system on a personal level (both through loss of power or prestige as well as loss of employment). The key to success here is the development of a system which provides information to the existing power structure, at all levels, whatever its composition—as opposed to any notion of reorganization of duties or centralization of power. Changes will occur inevitably after such a system is operational, but these should be the result of local initiative and should result in adaptations which best fit the peculiarities of local circumstances.

Operational gaming provides one potential device for assisting in overcoming the barrier of local resistance that may be based on fear or inability to conceive the utility of this new phenomenon. This would demonstrate to decisionmakers at all levels the potential and utility of an information system. Long in use for military purposes in the form of war games, the gaming technique is receiving increasing attention in a number of disciplines, particularly in an urban context. One federally financed project (the METRO project sponsored by HHFA) is making initial attempts in this direction.[23]

5. *Ethical Considerations.* Probably the most critical problem inherent in such a system is assuring ethical use. The information ultimately included in this system will represent tremendous power—power which can easily be subverted to undesirable ends. A file which reveals great detail on the personal lives and private properties of the citizenry does not imply a 1984. But it does require carefully detailed safeguards that protect the rights of individuals and the political philosophy of the Nation. State enabling legislation must recognize this hazard and include adequate legal safeguards.

Conclusion

A commission oriented towards "automation, technology, and economic progress," whose vast clientele are overwhelmingly urban dwellers, should consider the advantages of supporting the development of an "inventory control" scheme at the intrametropolitan level. Such an information system would be useful not only in the detection and solution of current or impending problems but also in exploring positive alternative policies for metropolitan development. Several possible ways are: (1) Development of the local economy, particularly through exploiting local advantages; (2) the amelioration of a variety of social maladjustments; (3) the pursuit of a more efficient physical plant, through development of deliberate policies for physical growth; and (4) increasing the inability of local political jurisdictions, resulting in increased responsiveness to their constituents. As a network of such systems emerges, it could assist in the development of resource use strategies at the regional level.

[23] Richard D. Duke, *"Gaming Simulation in Urban Research, Institute for Community Development,"* Michigan State University, 1964.

TECHNOLOGY, AUTOMATION, AND ECONOMIC PROGRESS IN HOUSING AND URBAN DEVELOPMENT

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CONTENTS

Technology, Automation, and Economic Progress in Housing and Urban Development

This paper outlines research and development programs which can be pursued in areas of unmet public servi_e and social needs related to housing and community development.

It is most important to note that in connection with some of the suggested technological developments indicated below, there would have to be accompanying planning for the economic impact of the innovations. A large proportion of the financial structure of the country involves home mortgages and municipal revenue bonds secured by existing homes and public facilities. They would be affected by the development of technological innovations, such as lower-priced homes and new types of sewer, water, and mass transit systems. Different types of labor might also be seriously affected. New developments under programs that would follow from the research and development indicated here may result in technological unemployment. Unless adequate provision is made to meet ensuing problems, there would be no net gain from an overall public interest viewpoint. Safeguards must be introduced against effects of unemployment in industries affected by new product competition.

It is essential, therefore, that the development of suggested technological innovations should be paralleled by economic analysis and planning for possible consequences. Such a course of action is needed from a substantive point of view; in addition, the existence of plans for economic adjustment would reduce opposition to the innovations.

Need for Mass Production of Low-Cost Homes

There is a sizable need for low-cost housing units in the U.S. According to the 1960 Census of Housing, about 6.7 million households with incomes under $3,000, and about 3 million households with incomes between $3,000 and $4,999, lived in units that needed either replacement or some rehabilitation. If the 1950–60 experience is any guide, roughly about 1.5 million of the 9.7 million units will be either demolished or lost to the housing inventory through some other means. Another 35 to 40 percent of the units would be either rehabilitated or otherwise changed to an acceptable cc-dition, even though some of these units may not be completely updated. This leaves about 45 percent of the units, or over 4 million, which would remain in unsatisfactory condition by the end of the decade unless they can be rehabilitated or replaced at a cost within reach of low- and moderate-income households. If we include, in addition, the number of low- and moderate-income families whose housing units, though previously in good condition, would deteriorate to the point of needing replacement, then 5 million low- and moderate-income families would be in search of suitably priced housing.

While the proportion of families and individuals in the lowest income brackets has diminished considerably within the last 10 years—more so for families than for unrelated individuals—the actual number of families and individuals in the lowest income brackets (when income is measured in constant dollars) has only decreased by 10 percent; and this number has been largely absorbed in the next income bracket, which is only slightly higher.

As new housing is being built, some of the existing units, particularly those that are somewhat outdated as well as those beginning to show some signs of deterioration, decrease sufficiently in value to become within financial reach of low-income families. However, this "filter-down process" operates slowly and ineffectually as a source of housing for low-income households. By the time existing units actually filter down to low-income households, many are in pretty bad shape.

While a potential for several million low-cost housing units seems to be indicated, one should not proceed before determining in greater detail the kind of units that may be needed. Thus, for example, it is not enough to know the number of households with annual incomes below some predetermined level, say $6,000 or $5,000. More precise income information is necessary, because at the low-income levels income differences of $500 are meaningful. The size of families is also relevant to the kind of housing to be designed, as is the relationship between size of families and family income. Similarly, it is important to know some of the other characteristics of the families, such as how many are elderly, how many have small children, and how many have adult members only, since each type of family requires different kinds of housing. Consequently, as a first step, a housing market study should be undertaken to determine the need in terms of these characteristics and other relevant factors, such as prices and rents at which marketability of housing units would be enhanced, and in which locale certain types of needs are more prevalant than others. All these factors would influence the design criteria.

Housing design and production must deal not only with single-family homes but also with multifamily units, inasmuch as the livelihood and the domicile of many low-income families are in central cities where land sites are too costly for single-family construction. Such newer ideas as solar heating and cooling, with attendant lower operating costs, might be feasible in certain areas, but that process still needs considerable development and improvement before it can gain acceptance. Development of thermoelectric technology in heating and cooling also promises lower construction and operating costs. This is dependent, however, on the ability to develop cheap sources of power as well as cheap conductor materials for wall construction.

It should be recognized that a gap would exist between the development of a technological breakthrough and sufficient acceptance in the market to warrant tooling-up and volume production in factories. Some means of interim subsidy, liberal financing, or guarantee of market would appear to be needed, as well as an estimate of costs to take care of this development period.

The availability of low-cost homes suitable for families with low incomes may not in itself assure marketability unless suitable financing is also available. Thus, families with low incomes do not generally have adequate cash for downpayments, and they are limited in the size of monthly payments they can afford. It is important, then, that suitable financing be designed as part of the package.

Present Housing Output

Initial capital costs and continuing maintenance costs must be reduced to enable limited-income families to live in desirable units of an adequate size and in a suitable environment without requiring the expenditure of an unduly large proportion of their incomes for housing.

A reduction in housing costs that would make new housing available for a broader income range of families would also improve the operation of the filtration process. For example, the resale of a new $9,000 house after 5 years or so of occupancy by the initial purchaser would provide acceptable housing for still lower-income families who acquire such units. In contrast, it would take many, many more years for a new house in the $15,000 to $20,000 bracket to decline in value sufficiently for it to be purchased or rented by such low-income families. In addition, by then the house may have deteriorated so badly that it would not provide acceptable shelter.

The proportion of low-priced new housing being produced is also quite small. HUD-Census joint surveys show that of the 1964 sales of new single family homes built for sale, only 11 percent were sold for less than $12,500, and only 25 percent for less than $15,000. The median sales price was $18,900. Moreover, in 1963, the comparable figures were 13 percent for homes under $12,500, and 29 percent for homes under $15,000. Thus, the trend is in the wrong direction because the proportion sold in the low-priced field is declining. For new multifamily units financed with FHA-insured mortgages in 1964—representing about 9 percent of the total multifamily production in 1964—the median rent for one of the largest programs which has the benefit of below-market interest rate financing was $102, and for another large program the median rent was $225. Although similar figures are not available for conventionally financed new multifamily units, we have reason to believe that the median rent would be higher than for those financed with FHA-insured mortgages.

Over the years, Federal aid for new building has been primarily financial. Downpayments required in connection with FHA-insured loans have been reduced and loan maturities have been stretched, thereby reducing the monthly payments on the mortgage. This is commendable because it has enabled many families who otherwise could not have done so to purchase new homes or rent new apartments. The liberalization in financing terms, however, has about run its course and little advantage is to be gained in striving for further liberalization. Needed now is a direct attack on reducing housing costs if the housing needs of moderate-income families are to be met and a high volume of housing production is to be maintained to help support general economic activity at a high level.

Potential Market for Mass Production of Low-Priced Vacation Homes

Anticipated increases in leisure time and continued high incomes could spur a growing market for vacation homes and second homes, particularly if attractive low-cost units can be developed.

There were over 2 million vacant housing units in 1960 which were either intended for seasonal occupancy (about 1.7 million) or for occasional use (roughly 300,000). (These are generally referred to as second homes.) About three-fourths of these units were outside standard metropolitan statistical areas; and about 50 percent of those within standard metropolitan statistical areas were outside central cities. In 1950, the number of seasonally vacant units alone numbered about 1.1 million. No figures are available for 1950 on the number of vacant housing units intended by the owners for occasional use. The seasonally vacant units are mostly vacation homes used for summer or winter recreation; others are cabins and houses reserved for lodgers, herders, and migratory workers. Thus, during the fifties seasonally vacant housing units increased by about 600,000, probably indicating an increase in the number of homes kept for occasional use too, although the extent of their actual increase is not known.

With continued increase in leisure time and high incomes, it would be reasonable to assume that the potential increase in seasonally vacant housing units during the sixties will be larger than during the fifties. It seems likely that if low-priced, attractive vacation homes and second homes could be developed, their potential market could be substantially increased.

Needs for Basic Community Facilities

Between 1960 and 1975 the urban population is expected to rise from 125 to 171 million, and the per capita use of municipal water systems is expected to increase from 140 to 160 gallons per day. As a result, municipal water consumption (excluding large industrial users) is expected to increase from 17.5 to 27.4 billion gallons per day.

According to a study by the Department of Commerce, public and private construction needs for water and sewer facilities during the period 1962–70 to provide for growth were estimated to cost $18.5 billion, with about $9.3 billion for water facilities and about $9.2 billion for sewer facilities. These construction requirements do not take into account the needs to remedy present deficiencies or to offset obsolescence and depreciation; these backlogs were estimated at $20.6 billion as of 1962.

Need for Urban Mass Transportation Facilities

In terms of broad public policy, assistance for urban mass transportation has two interrelated sets of objectives. The first is to help provide sufficient public transportation so that people can effectively choose between using it or their private automobiles, and to give those without direct use of automobiles an independent means of movement within urban areas. The second is to encourage urban areas to plan and provide sufficient public transportation as part of a balanced transportation system to meet areawide needs for growth and renewal at minimum total cost. The kinds of transportation facilities that are installed and planned in the next few years will profoundly affect the structure, appearance, and livability, as well as the economic efficiency, of rapidly expanding urban areas for at least the next generation.

The total need for capital investment in mass transportation in the period 1961–71 was estimated at $9.8 billion by the Institute of Public Administration. This includes $8.8 billion for improvements already planned at that time—extensions of existing systems, new systems, and rehabilitation and replacement of buses and other rolling stock. The remaining $1 billion was for new projects which might be initiated during the period.

Two developments since 1961 suggest that capital requirements for public transportation in the coming decade could amount to twice the estimated $9.8 billion. First, the national intent to give practical support to public transportation as expressed by the Urban Mass Transportation Act of 1964 has greatly heightened interest in the salvation, rehabilitation, and provision of new urban mass transportation. Second, substantial progress has been made in transportation planning for urban areas throughout the country; several of the more advanced studies indicate a more extensive need than anticipated earlier for expansion of existing public transportation or for installing new rapid transit facilities within the next decade. With effective assistance now available, urban areas can be expected to meet an increasing portion of their total transportation needs through public transportation rather than depending almost entirely on private transportation.

Technological Changes in the Past and Their Effects on Housing

Technological changes which have affected the housing product and the building process during the last several years have been essentially improvements of traditional methods and products. There have not been any radical changes in the type of product nor in the manner of its fabrication. Basically, the typical residential structure is still put together piece by piece and part by part—each supplied by individual supplier industries—at the building site. These suppliers enjoy varying degrees of technological advancement.

Two major and interrelated reasons exist for this adherence to traditionalism—cost and imperfect substitutability. Housing essentially is enclosed and equipped space, and its parts are heavy and bulky. There are physical and logistical problems of transporting a house or the parts for a model house from factory to the site. In fact, transportation costs are significant even for certain building items; for example aggregate block, an essential item, is provided in large localities almost exclusively by local manufacturers. Nevertheless, substantial progress has been made in factory prefabrication of standard components that make up the package for a home trucked to the site. A number of firms produce models of various sizes and quality, and the volume of such production has been increasing—manufactured home industry sources have estimated that shipments in recent years have accounted for more than one out of five single-family home starts.

Imperfect substitutability represents another barrier to technological breakthroughs. Conceivably, a whole bathroom assembly could be molded in a one-piece plastic form. This, however, requires use of a material that is both homogeneous and which can be shaped by heat and pressure. Whether it would be able to furnish the same degree of hardness, durability, and scratch resistance as vitreous china and porcelainized steel is questionable—especially at the same cost. Would the same material be suitable or economical for floor and wall sections? How would problems of sectional replacement be accommodated?

During the past several decades large advances have been made in getting a better and comparatively cheaper housing product, and these have been based upon an improved technology. In some cases, the improved technology has been represented by use of new tools and products; in others, through a more efficient "engineering" or "rationalization" of the job. The two are necessarily interrelated and interdependent.

Rationalizing the Building Operation

Rationalization of the building operation, just as rationalization of automobile production, depends upon an engineering breakdown of a many-faceted activity into a number of individual, noncomplex operations that have a logical time sequence. Economies are achieved by applying a repetitive operation to a product for production runs of long duration. This, of course, can be achieved only where there is a sufficiently large number of houses to be produced—for example, project construction. Project construction was motivated during World War II by the Federal Government in the development of war housing built under contract by private builders. After the war, they and other private entrepreneurs benefited from the Federal example.

A logical expression of rationalized housing production is to create a "housing factory" on the building site itself, something which has been done by the larger and more efficient builders. The principles of this mechanization process are simple and few: (1) Use of power equipment instead of hand tools, (2) use of jigs and dies to obtain uniformity and precision of standard components, and (3) where hand operations are involved, working at the bench in an upright position, instead of kneeling or bending.

To illustrate, the large-scale builder, after determining that he will market certain basic models of a home, will utilize a portion of his site for a factory operation. (In many cases, this consists only of a galvanized roof to provide protection against the rain.) Power saws will be used to make precision cuts in lumber; the precut lumber will be arranged on a jig (say, for modular wall sections); and a power press will apply nail plates for fastening. In many instances, this will represent the extent of the builder's own factory and preassembly operation, and he will depend upon subcontractors for other components. He will purchase millwork from a firm in the area which has a similar assemblyline operation. He will buy completely glazed and primer coated window assemblies for insertion into the fabricated modular wall sections and doors which will already have been hung on frames and furnished with hardware.

Precision-cut lengths of copper tubing will have been previously assembled into plumbing trees on flat benches by the builder or his plumbing contractor, and similarly sheet metal contractors will have assembled all ducts, gutters, and downspouts.

The actual homebuilding operation at the building lot site becomes primarily an assembly process with actual fabrication largely carried out under factory conditions. Practical problems of building site conditions and the building process frequently set the limits of factory preassembly. The site is frequently muddy and rough, and premature installation of exterior finish might require refinishing as a result of dirtying and splintering. Interior finishing must await completion of mechanical and electrical work.

Use of Mechanical Equipment

Use of power equipment has greatly increased worker efficiency. Earthmoving and trenching machinery have reduced the costs of site preparation. Carpenter productivity has been increased by electric handtools and such devices as guns which fasten wood to concrete. Improved staplers allow more efficient roofing installations. Portable cranes allow wall sections to be lifted into place on the foundation slab or wall.

New Kinds of Materials and Products

The cost of building is measured only in part by the cost of materials; equally critical is the cost of their installation. Enclosure of interior space has been facilitated by use of plywood and wallboard. A single 4 x 8-foot sheet of these materials can cover 32 square feet and obtain improved structural rigidity with fewer nailing operations. In the great majority of cases, interior wall installations have switched to gypsum sheets, replacing the substantially more expensive lath and plaster process. Copper tubing has generally replaced galvanized piping for water lines and, in fact, is replacing cast iron for waste lines. Asphalt and asbestos composition tiles have reduced costs of finished flooring. In masonry construction, aggregate blocks of over 100-square-inch lateral dimension have relegated brick to "finish" purposes.

What Has Not Been Done

If housing production can be compared to automobile production, the deficiencies of rationalization and technological advances achieved thus far are readily recognized. Many of the efficiencies in automobile production result from using a single material, steel, which is stamped, punched, drilled, and machined. In contrast, literally hundreds of different kinds of materials are used in housing production. There is much greater dependence upon outside suppliers, with attendant problems of obtaining ready flow of materials to the site and the disadvantages of small-scale purchases. Automobile production, despite annual style changes, relies upon long, continuous runs of the same components, such as frames and body shells. Prime manufacturers or subcontractors will modify such components, as axles, transmissions, and gear assemblies only infrequently, and only in response to engineering economies or improvements. So-called style changes in the automobile industry are essentially cosmetic, consisting of changes in exterior sheet metal work, glass, and trim. In contrast, each housing producer is required to work with a variety of modules, and even here the individual purchaser may demand basic structural modifications, e.g., a dormer roof, changes in fenestration, etc.

Although the homebuilder uses many power tools for assembly purposes, they are relatively primitive when compared to the tools used in the automobile industry. The casting and boring of a motor block, for example, is now a fully automated operation. In contrast, the assembly of a housing prefabricated roof truss or a wall module requires frequent manhandling of material.

Despite the large gains that have been made in rationalization of the process and application of new tools and materials, housing construction, in terms of a factory operation, is still a primitive operation.

Economies in Multifamily Housing

The foregoing has dealt primarily with small home construction; that is, single-family units, two-to-four family structures, and walkup garden apartments. There have also been technological advances in structures defined as elevator or high-rise construction, of either a fireproof or semifireproof type.

Such advances are more limited because of the higher requirements for structural strength, rigidity, and fire resistance which can be obtained essentially only from concrete or steel. Nevertheless, economies have been obtained as a result of improved flow of work and materials, which, in turn, have been abetted by an improved technology. High-speed construction elevators allow materials to be brought to each floor with minimum delay. Spectacular advances in crane design allow massive loads to be handled with precision and dexterity. Giant earth movers have accelerated foundation preparations. Use of new materials has been intermixed with new construction techniques. Treated plywood forms, as well as steel forms, have enabled neat pouring of concrete which does not need cosmetic finish. Improved qualities of concrete and mixtures used in conjunction with better reinforcing rods allow greater ceiling and floor spans to be achieved with fewer support walls and columns. There also has been substantial progress in precasting columns and beams (frequently prestressed) at a factory site, and there has also been factory prefabrication of concrete exterior wall panels, with vibration permitting exceptionally smooth surfaces. Thin-skin exterior walls of porcelain steel or metal have also been used, although more in commercial buildings than in residential structures. In terms of interior finish, vinyl flooring has replaced the more expensive terazzo floors, and some communities allow guns to be used to apply plaster to interior walls.

Probable Technological Advances in Building Methods in the Next 10 Years[1]

The next decade will see a one-third increase in the volume of annual housing production, from 1.5 million to 2 million units. This will be required to accommodate the accelerated rate of new family formations among the post-World War II baby crop, for continued rural-to-urban migration, and for continuing small town to metropolitan area movements.

Continuation, and, in fact, enlargement of large-scale project construction will be required. Such construction will be facilitated by Federal programs for land development mortgage insurance and loans and grants for community facilities. Expanded large-scale operations will enable continued progress in rationalization of the building process.

With better and more flexible equipment, housing producers will tend to use to an even higher

[1] See appendix for summary of survey results of building research in Government and industry and anticipated related technological changes.

degree "housing factories" at the site. Increasingly, factory operations will be substituted for in-the-house operations. This, for example, might be reflected in modular wall assemblies completely finished in the factory building with prewiring and preducting. Logically, this could be extended to fabricating utility wall or utility core installations on the site, which can be lifted by a crane and set into place.

New tools and equipment will help reduce labor costs. Lightweight automatic nailers, for example, requiring only positioning of the operator and his materials, could become commonplace. New and more efficient devices for handling and positioning materials will allow the use of larger components; for example, a giant jig set over a foundation with component parts dropped and held in appropriate place, leaving the worker concerned only with fastening operations.

New breakthroughs can be expected in masonry construction. Portable machinery may permit automatic bricklaying, in effect, with the equipment spreading mortar, setting the brick, and finishing the joints.

The need for interior mechanical equipment may be reduced to a minimum via centralized sources of heat and refrigeration in new and existing communities. A central source of hot or refrigerated water could eliminate individual furnace and air-conditioning equipment, with homes needing only valves, convectors, and fans.

The costs of wiring installation might be substantially reduced by low-wattage luminous panels for lighting. Replacement of separate heating and air-conditioning equipment would also reduce wiring needs.

With an outlook for a potential growth market, many of the very large industrial firms will channel their research and development talents to the field of housing. Some progress has already been noted.

The aluminum industry has been developing modular elements which allow flexible design, utilizing lightweight aluminum pillars and beams that can be bolted together at the site; these, in turn, provide support for thin-skinned metal-clad exterior walls. This construction technique can eliminate the need for expensive basement installations.

Some thinking and preliminary planning has been devoted to adapting the spinning of impregnated fiber used in making missile shells to making shells for housing units. The type of fiber and impregnation could be varied to meet desired specifications to produce thin, tough, and durable lightweight shells, with the prospects of low costs. Moreover, the spinning machines may not be too bulky, making temporary or movable factory-type operations feasible and permitting fairly small as well as large developments. However, the final product would be quite different in appearance from the traditional house, and marketability thus may be an important factor.

Suggestions have been made for a single pressing or extension of a whole house in two or three operations. A giant mold, into which a homogeneous plastic and fiber material would be injected, would allow the entire framing and exterior sheathing of a house to be accomplished in one operation. A second molding would provide the entire utility system, pipes, ductwork, and electrical conduits. A third molding would press out interior walls complete with built-in shelves, cabinets, and seating, and with receptacles for utility equipment, such as furnace, sinks, etc. In such an operation, the factory would have to be located immediately adjacent to the building site; this would be possible and economical where the project construction is large enough.

Advances can also be expected in the field of elevator apartment house construction. Continued progress can be looked for in the techniques of pouring larger components and lifting them into place with improved, more powerful cranes and jacks. Even now, entire floors are poured in one operation on an already completed slab, with the floor jacked into a second story position and supporting columns put in place. The completed second floor, for example, provides the base for pouring the third floor, and on to the very top of the building.

Another technique which might result in economies will be "hanging" floors from completed central utility core structural elements, representing a borrowing from bridge-building techniques. By freeing the exterior of the building from framing elements, thinner exterior walls are obtainable at cost savings.

Experience in other countries points the way to more efficient employment of existing technological know-how. In Russia, for example, entire apartment units are cast in a single operation and lifted by crane to their appropriate place in the structure. However, these are comparatively small units, and whether the technique is suitable for the larger-sized units of this country is questionable.

Chemical research will certainly develop new and better concrete aggregates that will supply equivalent or greater strength with less bulk and weight and which will require less reinforcing. This would result in lower cost foundations, greater efficiency of hoists and cranes, etc. These new aggregates, combined with improved pouring techniques, will also enable casting with much greater smoothness, thus avoiding expenses of final, cosmetic finish.

Technological know-how will also be applied to rehabilitation and property improvement. Many structurally sound but older buildings have become susceptible to rapid depreciation because their amenities no longer meet the requirements of a discriminating rental market. These buildings can be brought back to competitive status by, for example, installing modern elevators and new kitchens and bathrooms. One potentially promising way of approaching this job is a technique consisting of working from the top down. Kitchens and baths in most buildings are arranged in a vertical stack to obtain the economies of straight runs of water and waste lines. The roof over this "stack" can be opened, and after the old kitchens and baths have been removed by a crane, fully assembled units, complete to tiling and equipment installation, can be lowered into the vacated space. Interior stair wells can be converted to elevator shafts, and fire corridors and stairs installed as an "add-on," or by taking space from existing units.

Another suggestion for rehabilitating existing units consists of abandoning and disconnecting existing utility lines in obsolescent buildings and replacing them by entirely new systems. These would be installed at ceiling height and masked by a new, suspended ceiling. Many older apartment houses have ceilings in excess of 8 feet, which would allow such installations.

Advances in new resins and glues will reduce the need for mechanical fastenings and allow lighter components. These, in turn, will permit greater worker efficiency and will shorten construction time. Resistance to twist and distortion by heavy winds would be achieved by as simple a process as banding the completed structure with steel strips, such as that done in packaging. Instead of relying upon weight to resist gales and hurricanes, lightweight housing can be tied to the ground with cables attached to several buried anchors.

Current Experimental Building Projects

Another promising development in factory production of whole houses (as contrasted to components) is the low-cost concrete house where the whole house would be poured in one piece in a semiportable factory and transported to sites within 20 or 30 miles. More experiments in the factory production of whole houses are needed because of greater potential economies in this approach. Since these experiments are limited to single-family houses, results of these experiments also need to be adapted to multistory residential construction.

The Department of Defense has developed two types of collapsible houses built of wood. One—a 1,100 square foot, one-story house containing three bedrooms and one and one-half baths—is factory fabricated and can be collapsed and shipped over highways. It is also relocatable, in that once erected it can be collapsed and transported to another site. Contracts have been executed for 1,012 such houses at delivered price of $10,000 per unit, excluding land and foundation; 207 have been shipped on a flattop to the Philippines.

The second type is collapsible but is not intended to be relocatable. It is designed to take advantage of factory fabrication of large components and may be erected to form semidetached or row houses.

The HUD low-income housing demonstration program is assisting in the financing of a number of promising experiments. One experiment is being conducted by the University of California to develop a prototype low-cost house suitable for a hot-dry climate providing comfort without mechanical air-conditioning. The study phase, which is completed, indicated that utilization of natural breezes is the most efficient means of achieving comfort, and the experimental house is shaped so that all rooms benefit from natural air circulation. In addition shading devices around the windows minimize the effects of the sun, and reflective white paint is applied to the entire exterior, including the roof.

Experimentation with double roofs indicated that these reduce the inside temperature substantially, but in the absence of air circulation not to the point of comfort.

Construction of three prototype houses is expected this summer, with cost of each of the 900-square-foot structures estimated at about $7,000, including land.

A second experiment under the program is being conducted by Housing Research, Inc., in Michigan City, which is developing techniques for stacking factory-designed housing sections around a common utility core to achieve low-density, multilevel housing for low-income families. This represents an attempt to capitalize on the experience and know-how of manufacturers of mobile homes in developing component sections. Construction of a mock-up building is scheduled for the summer of 1966.

A third experiment is being conducted by Pratt Institute, New York, which is developing cost-reductive methods for the construction of multistory apartment structures under conditions free of building code restrictions which typically prevent the use of some possible techniques. The study phase, including survey and analysis of materials, costs, methods, and development of technical and livability standards, has been completed. Tested will be the cost-saving potential of several building systems, such as structural steel framing and precast concrete with prefabricated utility units (bath and kitchen); of materials, such as lightweight steel of higher stress capability; and of components, such as entire wall sections made of a variety of materials. A building under construction in Carteret, New Jersey, will test erection techniques, acoustics, fire resistance, durability, etc., and the development of the utility core for factory production is underway.

Potential Breakthroughs in Urban Development

In urban development, the potential breakthroughs with the greatest relevance would be the development of the waterless toilet; the elimination of industrial and residential wastes (detergents, for example) at their source, or failing this the development of economies in scale in the treatment of these wastes at a central point; the improvement of intrametropolitan transportation, including new developments such as the air-cushion principle, and better utilization of existing traditional facilities, such as dovetailing freight transportation during off-peak periods with transporting people during peak periods.

In recent years Federal assistance has also spurred the orderly planning of urban areas to meet future growth needs to provide for the creation of efficient economic entities. We incur considerable economic as well as social wastes because the location of jobs, homes, and shopping and cultural facilities necessitates needless transportation which is not only costly but also wasteful of a person's time.

Impediments

Problems of institutional rigidities that hinder wide technological breakthroughs will continue during the next decade. Anachronistic local building codes and resistance of the craft unions to possible loss of jobs will continue to be encountered. Progress with regard to building codes can be expected as increasing numbers of localities subscribe to national standards and criteria. With respect to craft unions, the prospects for continued full employment in the building trades and possible shortages in craft skills will lessen resistance to use of new materials and techniques.

The development of new materials and methods for residential construction cannot be adapted to a mass production market as long as there are thousands of different local building codes in the U.S. Even in a single metropolitan area there may often be 50 or more local building codes. Furthermore, many of the local building codes contain archaic specifications to protect the interests of particular materials manufacturers or building trades groups. Dramatic and forceful action is needed to initiate a means for modernizing building codes, for using performance standards, and for much greater uniformity among local building codes.

A high proportion of total housing construction expenditure is for labor, and labor costs have been increasing. Over the last 4 years, for example, average hourly earnings in building construction increased 12 percent. The wholesale price of construction materials, on the other hand, showed a slight decline.

According to a recent BLS study of labor and material requirements for private one-family house construction, wage payments to on-site labor averages about 22 percent of the total construction price. The on-site labor costs are those that many analysts believe to be an important factor in the high cost of construction. If more of the labor can be performed in a factory under controlled and more effective working conditions with closer supervision, productivity is bound to increase.

Obsolete construction methods often prevent the use of prefabricated assemblies. Varying codes also have made it impractical for a builder to buy many building materials in a large quantity or standardize in a significant way. Many building codes are tied to rigid and outworn specifications that prevent the use of new products and methods. Many new products could meet or exceed reasonable performance requirements and reduce construction costs since they are cheaper to produce and a number also cut installation time. Unfortunately, building trade unions in a number of areas support outmoded building codes for fear that less labor time will be required or that a craft skill might be made obsolete through the introduction of new materials or prefabricated components. If this problem is to be overcome, it may be necessary to work with the building trades unions and arrange for retraining and compensatory severance pay in substantial amounts for craftsmen who become technologically unemployed. The new materials and components might even be taxed slightly to provide the necessary funds.

Another deterrent to technological advance will be consumer tastes and preferences. An affluent society will insist that housing is attractive and distinctive, and the factory product will have to satisfy these desires. In this respect, departure from traditional exterior materials such as stone and brick may be difficult to achieve. The new materials will have to supply an equivalent degree of texture, shadow, and eye appeal.

The new technological breakthroughs, however, will also serve the purpose of obtaining greater efficiencies in the use of traditional materials and techniques. Advances in both areas can be anticipated.

Role of Government

The Federal Government should assume active leadership in research for housing—other than product research—and community development.

Private industry has made considerable progress in product development and can be expected to continue to do so. Research needed deals with the housing unit as a whole to improve building systems, livability, etc.; the relation of the housing unit to the site to reduce land and site development costs; and the relation of the house to the community to provide adequate public, commercial, and cultural facilities. This leadership role would fill a research gap left by the home building industry, which, because it is composed predominantly of small-scale builders, has very little resources for such research.

Governmental support is also needed for basic research to establish performance criteria (e.g., moisture resistance, cold insulation, light, etc.) for a house and various components. Such standards could be adopted in local codes, permitting manufacturers to develop various types of materials that could meet them. Appropriate Federal agencies should provide leadership for local government and industry in developing modern, acceptable codes that will lead to widespread adoption and greater uniformity. The groundwork for such an effort could be laid in the study of codes, zoning, and taxation to be undertaken by the Department of Housing and Urban Development under Housing and Urban Development Act of 1965 authorization.

There is also a need, as indicated previously, for Federal assistance to private concerns which have developed promising technological breakthroughs with factory tooling-up for a pilot operation and/or assurance of an initial market. It might be possible to organize a "trial market" for mass production of new materials or components under one or more of the Government-supported housing programs. This would help demonstrate the costs which are achievable and test the marketability of the housing unit.

Large-scale federally supported city reconstruction can be combined with efforts to raise the economic level of the poor by providing training and jobs in comprehensively organized efforts. This would be feasible under the Demonstration Cities Program proposed by President Johnson.

It will be increasingly necessary to provide a clearinghouse service for the collection and dissemination of these new breakthroughs and gains since present trade and industry journals will not be sufficient for comprehensive coverage. A logical source for such a service would be the Federal Government, which can also evaluate the physical and structural advantages of new products and processes.

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APPENDIX

Building Research and Anticipated Technological Changes in the Residential Construction Industry—Inventions and Innovations by Materials Producers

In response to a request by the Commission, the Department of Housing and Urban Development has made a review of building research within the Federal Government and anticipated technological changes in the residential construction industry. Summarized here are the findings of an investigation of the technological developments that are expected to occur in the private sector over the next decade.[1] Also summarized are activities of the two primary Federal agencies involved in building research: Federal Housing Administration, Department of Housing and Urban Development, and National Bureau of Standards, Department of Commerce.

Federal Housing Administration

The building research program of the Federal Housing Administration is carried out under its experimental housing program and technical studies program. The FHA experimental housing program is a mortgage insurance program designed to encourage the development of new designs, materials, and techniques in housing construction on homes and multifamily properties that incorporate new or untried concepts aimed at reducing housing costs, raising living standards, and improving neighborhoods.

The technical studies program is a technological research program employed as an aid in establishing minimum property standards as aids to operating sections and FHA management for decision making. Federal and private research facilities are used in this program.

In its technical studies program, the Federal Housing Administration recognizes the need for more knowledge of the performance of various building components. Although a large number of industry tests and criteria exist, many of these do not provide a sound product nor do they truly represent a minimum acceptable standard.

In addition, industry standards presently apply primarily to individual products, whereas these products are usually used in conjunction with others to form a system, such as a roof or a wall. One product when used with one type of material acceptable to FHA may be quite satisfactory, but when used with another type of material ·qually acceptable to FHA, it may give an entirely different performance. However, limited resources restrict the amount of technical studies which FHA can undertake in the area of performance standards.

Since the beginning of the technical studies program, FHA has given some emphasis to studies aimed at reducing the cost of developing land; for example, installation of utilities, earthwork, and streets. Completed studies in this general category, which include studies on earthwork, septic tank systems, and design of sewers, provide immediate usable results and fit into the broader concern of reducing land costs. Additional studies are either underway or planned.

National Bureau of Standards

The bulk of direct Federal activity in building research and technology is done in the Institute for Applied Technology in the National Bureau of Standards, particularly by the Division of Building Research.

The IAT mission is to create appropriate opportunities for the application of technology in government and in civilian industry. The Institute has a mediating role to play between the "development" and the "use" of technology; that is, it is involved in reviewing and analyzing the state of technology of the Nation in order to identify appropriate opportunities for the Government to promote the use of new technology.

In regard to building research and technology, the most important work of the Institute is centered in the Buildings Research Division, the central government agency for developing test methods and performance criteria (identification of important performance characteristics) related to the structural and environmental functions and the safety and durability of building elements and systems. To this end, the Division of Building Research conducts and sponsors scientific investigations and publishes technical information involving the chemistry, physics, mathematics, and engi-

[1] In August 1965, the Housing and Home Finance Agency, predecessor to the Department of Housing and Urban Development, gave a contract to Battelle Memorial Institute to identify the impact of technological change on the housing industry of the U.S. between 1965 and 1975. This summary is based on these findings.

neering of building materials, components, systems, and complete structures. The Division cooperates with public and private organizations which draft, promulgate, and distribute standards and codes for buildings.

The Division is comprised of five sections which are concerned with (1) structures, (2) fire research, (3) environmental engineering, (4) material and composites, and (5) codes and standards. Over the next 10 years the plans of the Division are to concentrate on the following six program areas:

1. A more comprehensive and effective flow of the technical information generated in building industry science to the Nation is planned.

2. Systems analysis in building design and performance will receive attention. Systems analysis often involves the use of computers, and because the effects of many interacting variables can be studied, it offers potential economy in materials technology and improved efficiency in building management.

3. Planned are studies on how building systems, components, and materials react or deteriorate in response to natural forces, such as heat, moisture, solar radiation, wind, corrosive and particular agents, and earthquake shock. These studies will be done to develop test procedures, identify essential performance characteristics, apply systems analysis, and understand design concepts.

4. Work will continue in identifying significant performance characteristics and developing test procedures to evaluate these characteristics.

5. The Building Research Division expects to expand its program of reviewing testing laboratories.

6. The Building Research Division plans to provide greater assistance to public and private organizations responsible for standards and codes by greater participation in appropriate committees, by directing more of its technical output to the needs of standards and codes, and by providing greater staff assistance to the committee in the preparation and reproduction and circulation of draft documents.

Expected Technological Inventions and Innovations, 1965–75

In the study on the impact of technological change on the U.S. housing industry between 1965 and 1975, a basic distinction is made between invention and innovation. Invention is usually defined as the design or development of a new product, piece of equipment, or process. When reasonably widespread use of an invention takes place, innovation has occurred. Market acceptance and use do not necessarily mean widespread diffusion throughout the industry or the economy. Thus, a technological advance which is accepted in 1965 may not have a significant impact upon the economy for several years or more.

The Battelle Institute report indicates that there is considerable difficulty in measuring the rates of diffusion of innovations. Any prediction of the degree of market acceptance of a particular innovation would require an in-depth study, and even then such studies might not provide a reasonable degree of certitude.

Acceptance of technological advance is often slowed or inhibited by labor union opposition, restrictive building codes, and reluctance of home buyers to accept major technological advances. The manufacturers of building materials know of these problems and the resultant risks in new product development. They are also aware of the time involved in diffusing a successful development in the marketplace.

The Battelle Institute study was based on a brief survey of the literature in the field and interviews with 19 industrial product manufacturers, 3 engineering firms, 3 research firms, 3 homebuilders, 2 architects, and 3 universities.

Technological advances of significance to the residential construction industry were classified in five general categories: (1) Design concepts, (2) construction methods, (3) manufacturing processes, (4) materials and products, and (5) building components. The study lists 80 inventions under these 5 categories. Estimated time for market acceptance and use of the inventions were categorized according to 1965–75, after 1975, or no estimate. Market acceptance and use between 1965 and 1975 were anticipated for 63 of the inventions, 7 after 1975, and for 10 inventions there was no estimate on the time of acceptance.

The categories of design concepts included such inventions as fold-out panel houses, preformed plastic houses, inflatable houses, and filament-wound houses. Included among new construction methods were totally adhesive-bonded housing systems, explosive-actuated devices to nail structural steel shapes and studs, and equipment to spray on plastic foam thermal insulation. Several new manufacturing processes were listed, including float glass, electromechanical stress rating of structural lumber, and automated steel sandwich panel production.

Over 40 of the inventions were classified under the category of new materials and products, including beam concrete, vinyl gutters and downspouts, electric radiant heating coils embedded in wall fabric, prefinished steel roof shingles, laminated melamine exterior surfaces, and photochemical glass. Among building component inventions were aluminum-faced wall panel with plastic foam cores, prebuilt brick wall panels, paper honeycomb wall, floor and roof panels, and stainless steel sliding and double-hung windows.

A summary of industry views and expectations on technological advances in their respective industries follows:

Chemical Industry. "Most chemical companies observe residential and nonresidential construction with interest. At the same time they approach any specific opportunity with caution. In spite of this general feeling of caution, they exude great optimism about the potential for plastics in construction."

Steel Industry. ". . . it appears that most steel companies will continue to develop and distribute materials and products to the residential construction field, but only incremental advances will be made as the market demonstrates its willingness to accept change."

The barriers to acceptance of new developments in steel mentioned most frequently were code restrictions, labor union objections, and consumer attitudes.

Aluminum Industry. "There is a great interest within aluminum companies to develop further markets for residential construction. The delays already experienced in developing a market will undoubtedly slow up further investments by aluminum companies. It may be 8 to 10 years before aluminum will make a significant impact in the residential field."

Aluminum is currently being made into exterior wa'' anels for high-rise apartments, and the next logical potential development in residential construction is the aluminum stressed skin panel.

Plumbing Industry. "There will probably be a greater trend toward the use of plastic for bathtubs, shower bases, laundry tubs, lavatories, and counter tops. Already plastic bathtubs and shower bases are being marketed. Within the next 10 years, it appears that combination plastic plumbing-fixture components will be developed and marketed."

Due to code restrictions and labor union opposition there is likely to be little trend toward preformed bathroom units within the next few years.

Wood Products Industry. Since wood products are the traditional ones used in residential construction, the industry generally favors the present system of homebuilding. Wood product companies are, however, expected to continue to develop new products that will help maintain their competitive position in the housing market.

Summary

In summary, product-oriented companies are expected to play an important role in technological advances made in the residential construction industry over the next decade. New products will not revolutionize the housing industry, but rather, according to the Battelle Report, "technological advances will occur in increments where new methods or new products substitute for conventional ones, and the risks of development and marketing are low." Companies not in the construction field who felt that there would be virtually no limit to their success in residential construction markets have learned to their dismay about the reluctance of builders, particularly tract builders, to install new products, about the reluctance of labor to accept new ways of doing things, and about the reluctance of the home buyer to live in a home with a unique design or one much different from his neighbor's.

TECHNOLOGY AND URBAN NEEDS

A REPORT ON THE ENGINEERING FOUNDATION RESEARCH CONFERENCE ON THE SOCIAL CONSEQUENCES OF TECHNOLOGY

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Technology and Urban Needs

Summary

The growing disparity between our ability as a nation to create a highly sophisticated program for space exploration and our inability to deal successfully with community and human needs is a major paradox of our society. The engineering profession represents a principal body of technological capability and a group which should have as a vital concern the social consequences and implications of technology. The 1965 Engineering Foundation Research Conference on "Technology and Its Social Consequences" brought together a group of 60 leading managers of research and development to assess the subject.

The conference dealt with the overall charge of the National Commission on Technology, Automation, and Economic Progress, placing particular emphasis on the application of technology to unmet community and human needs in the urban context. The conference was structured to examine key areas of technology; study the complexities of applying technology to various nondefense, nonspace problems; and explore methods for accelerating the creative utilization of relevant technology in the urban community.

The overriding conclusion of the conference was that new kinds of programs and new kinds of political mechanisms are a prerequisite to the effective use of technology to solve most urban problems. Major barriers to realizing the full potential of technology include the lack of consensus and problem definition in the cities, the lack of awareness of new approaches, and the lack of interaction among politicians, planners, and technologists. The fact is that new technology has hardly been applied at all to our principal urban needs in a creative, integrative way, and this failure is the fault of both those who create the technology and those who would use it.

The conference focused its attention on mechanisms for applying technology to our unmet urban needs. The major problem areas—transportation, shelter, and communication—were described, but no attempt was made for a precise definition of either the extent of that need or the extent of relevant technology. It was generally agreed, however, that the existing stock of technology is adequate, at least in latent form, to solve many of the needs.

The conference also was in strong agreement that the task of the Commission is among the most significant issues confronting the American people today, and urged that means be found to extend the work of the Commission. The conference also urged that the Engineering Foundation take action to increase the participation of the engineering profession in urban problems, making better application of technology in the solution of social problems.

Introduction

The Engineering Foundation sponsors a series of conferences each year which deal largely with technical subjects of interest to the profession. Since 1963, one conference each year has dealt with broader policy questions, and in 1965 a week-long conference was held on "Technology and Its Social Consequences." That meeting was attended by some 60 persons, largely physical scientists and engineers from industrial management, universities, government, and research institutions. This report summarizes the conclusions and points of consensus of the participants.

I. Conclusions

The conference arrived informally at three basic conclusions about the social implications of technology.

1. Technology is now available, or can be readily developed, to make massive contributions to solving the major urban problems of the Nation. Most of the Nation's unmet social and community needs are subject to technical solutions or approaches not now commonly employed. Thus, the engineer should have an enlarged role in public programs directed to meeting these needs. In many respects, this is the traditional role of the engineer, as the problem solver who brings technology to bear on both public and private problems.

The assumption is probably oversimplified, however, that the needed technology without further refinement is now available to solve most urban problems. The evidence is good that the scientific base is adequate and that there is now technology for specific requirements; however, the need for new and better technology still exists. The engineering and technical community must have a better awareness of the needs for technology, incentives to develop the technology, support for that development, and adequate opportunity for application. There are many cases which would support this position.

2. Technology has become a major factor in economic growth, probably the key element according to studies by a number of economists. Dislocations caused by the introduction of new technology tend to be relatively short lived and may well be a necessary price for economic progress. Such dislocations are closely related to other purely economic factors. Automation, then, should not be regarded as a major national threat or problem, except in terms of short-term adjustment. The real problems of automation have to do not with the negative impact but rather with the opportunities and potentials afforded.

3. The role of government, and particularly the Federal Government, is well accepted in the areas of concern to the Commission. The scope of most unmet needs is such that only the Federal Government has sufficient reserve to cope with them presently. However, the conference felt that new government structures can and must be found to deal with technical problems and that the same sorts of organizational changes which occur in the business community are necessary and appropriate in the political sphere.

The major challenge confronting those concerned with the social implications of technology, then, has to do with finding or creating mechanisms for dealing with new technology and not with combating its adverse impacts.

II. Issues

The conferences identified 10 major issues for discussion.

1. Perhaps the single most important issue centers on the great need for political innovation to match urban development and the advance of technology. Most of our local government structures are inadequate to deal with these issues today. The result is twofold: (a) The Federal Government moves into areas of social need both directly and indirectly, and (b) the number of ad hoc, quasi-governmental units to deal with specific pieces of the larger problem is rapidly increasing, often under the stimulus of Federal funding.

2. The structure of our present urban society and many of our urban problems and needs are a direct result of Federal and other governmental policies and programs which have been operative in the past. Our cities are characterized by political fragmentation and by attention to pieces of the whole and to short-term, and usually capital, costs. This fragmentation of political jurisdictions continues to proliferate, further constraining future action.

3. Definition and resolution of urban goals represent an unmet need in this country today, with absence of clear understanding and agreement on goals a major barrier to achieving many other unmet social needs. Goal definition and resolution are a continuous and central part of the political process, for which our present methods are inadequate. Urban areas must be viewed by their citizens as real entities and their problems as related to the whole before effective action can be taken on many issues to which technology can contribute.

4. An absence of consensus resulting from several factors exists in this country about urban needs or the priorities for their solution. The problems exist most distinctly at the local level where consensus is frequently difficult to achieve and where the unit of government is small and focused upon largely obsolete or trivial issues. The very large number of units for political decision making greatly increases the probability of veto of new approaches.

The middle-class majority tends to dominate our cities today, unlike earlier periods when the political base was found in the lower socioeconomic brackets. The American middle class is characterized by growing affluence, upward mobility, and a "play-orientation." It is not sufficiently well informed about either the magnitude of the urban problems or the technological possibilities for their solution to provide a consistent, articulate constituency for change.

The lack of effective constituencies, or of a true consensus, finally means that there is no commitment or policy for dealing with urban problems. The result is that a number of different and often unrelated or conflicting policies are formulated at the Federal level to deal with various elements of urban development.

5. Our economic system is largely dependent upon the market mechanism to provide incentives for making investment decisions. Private investment in projects needed to solve urban problems will not be forthcoming unless a definite market for certain goods and services is established. Our economy is quite capable of providing technology or of organizing systems, but our present urban governments are not capable of creating a market for these products of private enterprise.

Unless ways can be found to bring private industry into the application of technology to urban problems through a newly derived economic mechanism, it seems likely that political forces, particularly at the Federal level, will move the decision process away from the local level, hence reducing the opportunity for exercise of local initiative and imagination.

6. The present structure of the market is such that there is little opportunity for field experimentation. In housing, for example, it is extremely difficult to assemble a large enough market to

demonstrate both technical and economic feasibility of new approaches. The incentives for experimentation on the part of private business, as a result, are largely negative.

The profit motive does not appear likely to be an efficient allocator of resources to the application of technology to urban problems. Part of the answer lies in creating a better match between the marketplace and the process of political decisionmaking.

7. Existing political mechanisms are adequate neither for the application of technology and systems approaches nor for good communication with those who can. Most political mechanisms were created to cope with specific problems or sets of circumstances, and they deal with problems of a technical nature only symptomatically. This means that in urban development today, technology is not used in adaptive, anticipatory ways characteristic of the systems approach that has been so successful in some other large-scale public and private enterprises. No self-correction factor is built in.

Part of the problem arises from our transition from an essentially individual-decision-based market of rural, small-town society to the group decisionmaking that is basic to the urban social and political situation.

Political entities and urban planners are using scientists and engineers with increasing frequency, but in the wrong way for the most part. Technical people are too rarely involved in political policy issues or goal setting. Instead they are called on for the solution to housekeeping problems within well established policy framework.

8. The engineer has been clasically thought of as one who modified his total environment, but today few scientists and engineers are prepared to participate effectively in public policy. This is one reason why technology has been applied, for the most part, only to social housekeeping. Engineers are trained to measure objective variables which exclude most of the social and political barriers that are frequently governing. Engineers are trained and rewarded for developing means rather than goals, which are traditionally viewed as the realm of the politician or the social scientist. The training and professional development of the engineer, then, are inconsistent with his role as the modifier of the environment.

The gap in his training lies in the area of helping to define needs in policy, in making his knowledge available to those charged with political decisionmaking, and in being able to pose alternatives which technology can offer.

Because of a lack of understanding most engineers do not trust or understand the political system, an attitude which is easily reinforced with some unfavorable experiences in the political realm. One outcome of such experience is the tendency to practice within apparent political constraints and to accept political and social barriers to new technology as largely fixed.

Science and technology have yet to demonstrate the ability to deal successfully with social problems of an urban nation or for urban life generally. There has been no real confrontation of science and technology and urban needs.

9. Responsibility for the consequences, particularly the social consequences, of technology is not agreed upon, but has gravitated very much toward the Federal Government. While there have been dramatic instances involving an individual scientist or engineer as to social responsibility, the overall problem is being resolved largely by default.

In the case of automation, there is little evidence of real planning for the problems of social dislocation. The burden of automation is seen to be borne by industry, and ultimately by the consumer. We have given inadequate attention to the burden on the individual worker for whom short-term dislocations may be all important. Our social and political institutions do not now adequately handle the problems of dislocation, with the result that the burden frequently falls on individual workers, those least able to cope with the problems.

In the case of environmental pollution or automobile safety, there is even less of a consensus as to responsibility. Regulation by various governmental levels is already in existence, but the problems remain.

10. General public awareness of science and technology or its consequences is inadequate. Outside of large-scale industry, there is relatively little receptivity to new technology on a broad scale. It is frequently viewed as a threat, at least in part, because of the great emphasis placed on employment today. The communication links between those who generate technology and those who constitute the technological potential market are least well developed in the public area.

III. Technology

While advancing technology is frequently a major cause of many urban problems and unmet needs—environmental pollution, traffic congestion, obsolete buildings—it also possesses the capability to offer the solution to those problems. The conference did not analyze the adequacy of technology in detail. Technology and its application were discussed in three broad and central areas: Shelter, communication, and transport.

One reason that technology has not played a more creative role in the development of better urban areas is that neither its generators nor its users consider urban requirements in any kind of a systems context; the focus is fragmented among individual products and buying agencies. Thus, we have the technology to construct the pieces of the city, but not the whole. Similarly, improvements in major urban subsystems, like solid-waste disposal systems, have not been developed for these reasons.

The ultimate limits of technology are probably found only in the very basic laws of matter; the real limits lie in our ability as a society or an urban area to use technology and to define requirements for it. It is likely that many of the most important changes in the next generation will relate to information and control technology which will extend and modify present know-how.

Historically, technical problems have not been the limiting ones. For technology to have its full impact on a given situation, however, has frequently required a group of technologists who are not a part of the functional group dealing with that situation. Several examples which suggest that imaginative approaches can yield highly significant results provide fruitful sources of knowledge and guidance for further application.

1. The Nation's present space effort provides perhaps the best case study of the massive application of technology to a social or political goal. NASA's program provides a large body of experience, insights, and innovations in organization as well as technology which may be useful for the job of building better cities. It has demonstrated a number of relevant factors:

The clear value of a strong consensus on a well-defined, narrow social and political goal.

How to go about a major project which involves the organization of new systems of information and decisionmaking.

How to use private industry and the profit motive to achieve a social goal.

How to go about a major national undertaking involving science and technology to achieve a social purpose.

2. The studies for the State of California on the application of science and technology to four major problems should ultimately be a rich source of knowledge for the solution of urban area problems. While the studies are not limited to urban areas, the subjects of the studies—crime, information needs, transport, and pollution—exist in their extreme form in large urban areas. They represent a real, and perhaps the first, test of the ability of the systems approach in resolving social and political issues.

3. The Communications Satellite Corporation provides an excellent large-scale example of an enterprise whose purpose was to apply technology to a public need for greater communication capability. While the problem was essentially one of communications, most of the early technical work was done outside that industry as then constituted. It is a primary example of technology developed for a military mission being used in the commercial sphere.

4. A much smaller but very significant case study is the work done by the School Construction Systems Development (SCSD) Group, an idea with English origins originated by a group of architects. The project was seen to have four requisites which were carried out simultaneously: (a) Development of a large enough market to make the proposition attractive to private industry; (b) support of an adequate number of school districts; (c) political approval at all necessary levels to the approach suggested; and (d) overcoming any legal problems which would preclude the program.

A Ford Foundation grant enabled SCSD to undertake a feasibility study and a user requirement study. The program maintained a high degree of action orientation throughout and held to realistic time limits within existing regulations.

The accomplishments of SCSD are many. Its members have been successful in defining secondary school construction in terms of component systems which are acceptable to educators, political authorities, builders, materials suppliers, and architects. They have created a market by getting consensus on their approach and commitments from 13 school districts to build 22 secondary schools. They have involved private industry—building materials suppliers—in the program as bidders and as system developers on the basis of performance standards instead of the usual materials standards. They have avoided expected opposition from various groups by allowing for adequate flexibility within the systems and the final configuration of each school. They have created a better quality product at a lower than standard cost.

IV. Mechanisms

Four major areas are critical in establishing mechanisms to link technology to the solution of urban problems.

1. Well-defined community goals with broadly supported commitments to those goals.

2. New political innovations to permit an effective utilization of public and private incentive systems.

3. An improved means of communication between public administrators and the technical community.

Many of the participants at the conference have been intimately involved in the issues which the Commission is studying; to others, their 5 days at the conference represented a first systematic exposure to thinking on these issues. The recommended mechanisms are not intended to be an official position but rather alternatives worth further consideration and exploration in the opinion of the conferees.

1. The universities of the country are traditionally thought of as a principal source of knowl-

edge and information, particularly that growing out of basic research. In some respects the land-grant colleges were a break in that general precedent. In the field of agriculture, the universities have an enviable record in both generating and stimulating the application of new knowledge to a major public need.

Just as the problems of agriculture and food supply were paramount to a growing nation 100 years ago, the social and political needs of an affluent urban society are of great importance today. Very few universities, however, have taken really significant steps to investigate and solve urban problems from an interdisciplinary point of view. A major reason is, of course, the absence of funding which will encourage such activity.

Provision of Federal endowments to universities to sponsor new programs in research and education on urban problems should be initiated. A total of several billion dollars would probably be required to be really useful. The specific programs undertaken with these funds would be determined by the universities themselves, within the framework established by the endowment. The endowment mechanism is favored over the more usual grants and contracts because of the greater flexibility it could offer the universities in arriving at the truly new and interdisciplinary approaches needed.

In time, universities developing good programs would come to constitute a major national resource for an urban nation. Federal agencies with research needs and programs in urban problems would work closely with schools whose programs and capabilities appeared most relevant. The work of the participating universities would be published widely, and perhaps a central library or clearinghouse would act as a national information center on research on urban problems.

Perhaps the greatest value in the endowment proposal is that it would create education centers which would train a wide range of people to understand and deal with urban needs. One of the great problems today is a lack of people with adequate training to bridge the technology-urban need gap; such programs would graduate people specifically trained to do so.

2. The Federal demonstration grant has proved to be a powerful incentive for creating new approaches and new ways of doing things. Many of these have been underway for some time in such areas as housing, urban renewal, and transportation.

A more comprehensive program for demonstration grants should be available to both public and private groups interested in trying new approaches to urban problems. Some of these grants would be, in effect, controlled experiments, specifically designed to test the feasibility of new concepts. Administered by an agency like the Department of Housing and Urban Development, these grants could serve as test or pilot models which would find their way into official policy and practice when they proved useful and workable. They would act as pilot programs which, when either successful or unsuccessful, could be visited and examined by other groups for their relevance and applicability to similar situations.

A second approach to demonstration grants is to use as demonstrations already existing programs in which the Federal Government is a purchaser. In the construction of new buildings and houses, for example, the Federal Government could well use the approach of the several California school districts which are part of the school construction systems development program. The Federal Government already has massive and almost continuous opportunities to stimulate and demonstrate the creative use of new technology in areas relevant to unmet urban needs.

3. A basic difficulty in any discussion of urban needs is that efforts to attack the problem, like the problem itself, are badly fragmented, resulting in a very inefficient use of skilled talent. There is not now an adequate forum for dialogue among various groups with interdependent interests in urban technology, nor a good mechanism for the many alternatives to be considered and evaluated on a continuing basis.

A mechanism is needed for continuing confrontation of representatives of all interested and involved groups from government, industry, and labor. The Commission provides this mechanism in microcosm, but its mission and life would need to be expanded considerably to meet these goals.

The functions of such a congress should include:

Consideration of the functional needs of society—transportation, shelter, education, etc.

Narrowing down the choices of alternatives for meeting needs, using sophisticated cost/benefit analyses to help place alternatives in good economic and social perspective.

Working to create an environment for optimum allocation of resources through its influence on all parts of the society, including government.

Fostering a good understanding of the issues and interests involved between complementary power groups.

4. Science and technology have been applied on a massive scale to solve a number of very difficult problems involving social and political goals and issues; one of the most notable of these is the national space program. It would seem that a similarly carefully organized and well-run program could be mounted to apply science and technology in the solution of urban problems. The magnitude of such a program would require that it be undertaken in a series of steps.

The first of these steps would be best undertaken and supported through a group like the Commission or a major foundation to insure that it had the needed stature and independence of action. The founding group would designate a panel of "experts" to (a) pick a problem area in which technology will most likely demonstrate what can be done, and (b) pick a specific urban area where it can in fact be applied with strong support and cooperation from local people. (Experts would include urban planners, economists, political scientists, and technologists and engineers.)

The second step would presumably require Federal funding because of the magnitude of the effort. It would involve (a) a systems study to define more precisely specific problems to be solved, (b) commitment of adequate funds to implement a feasible solution, (c) proposals for solution from private industry, and (d) detailing the probable output of the implemented solution, preferably in measurable quantitative terms.

Contracts would then be awarded to private industry to provide the system and hardware required for the solution, and their output would be compared with the predicted results. The accomplishments of the project should be dramatized widely to demonstrate what can be done in urban technology. A successful program would then be extended into other areas of the country and other technical problem areas.

5. The current national competition for the proposed 200-300 BEV accelerator facility demonstrates the interest and effort which can be generated throughout the Nation for a well-defined national project. We have seen similar competitions in the aerospace industry for the SST, the Gemini, and other programs.

Substantial Federal cash awards to communities developing the best new approaches to resolving various urban problems could be expected to result in competitions like that for the proposed accelerator or the NASA Electronics Center. The major difference would be that while only one locale would "win," the entire country would benefit both from the various efforts expended and from the thinking and experience of the successful bidder.

Financial incentives at the Federal level would foster local and regional cooperation among industry and interested public groups and would stimulate them to focus on major problems and to find viable solutions. Knowledge gained in the process, both technical and organizational, would have multiple benefits; all competing communities would have mobilized their best resources for a major social goal; local goals would have to be much more precisely defined and evaluated than is usually the case; various alternative means to selected goals would have undergone serious and thoughtful scrutiny; and communities would learn much from each other.

One possible implication of this program is that it would require a "supra-agency" at the Federal level which could concern itself with the entire range of major urban problems to which technology can contribute, and to prepare policy and action guidelines for other Federal agencies concerned to follow after the competition had been completed. Federal agencies should adopt the winning approaches whenever feasible so that the best thinking of the country could be incorporated in their future plans and programs.

This plan has a number of advantages at the local level: All of the diverse resources must be focused on the problem; private industry can be involved; there is a financial reward; risk taking involves the public; and a systems approach is required. Using a COMSAT-type approach, all communities could hold a proprietary position in their system and could ultimately sell or license other groups. Winning concepts would be implemented through matching Federal funds or perhaps grants. Other communities, for which the approach or a modification of it appeared feasible, would be encouraged to use it by similar Federal funding devices.

6. Since a major factor in the solution of many problems to which technology is applicable is that political boundaries act as barriers, many problems are best handled on a regional basis. Yet there are no established means for the Federal Government to deal with regions except for those specially structured around a given problem (like air pollution or subaverage income).

The establishment of regional groups with highly skilled staffs would bring together the scarce talent of a region capable of working with the Government and acting as a focal point in solving regional problems with technological content. Such a group would have as its assignment the definition of significant regional problems amenable to technical solution, the evaluation of alternative solutions, the application of systems concepts to the problems (both singly and in relation to other problems), and the stimulation of regional industries, government, and universities to join forces in the solution. Such a regional group might be a nonprofit corporation to act as a systems manager for appropriate Federal and Federal-State programs; as such it would fill a considerable missing link between agencies operating at national and local levels. Its ultimate objective would be to encourage regional industry to become involved in the successful solution and exploitation of many areas not now dealt with.

7. There is considerable agreement that new cities or model cities afford one of the best possible opportunities to make massive innovations in urban design and living, yet there have been few

such developments in this country. The continued rapid growth of the Nation's urban areas and the very heavy existing Federal investment in urban areas (through highways, housing, schools, hospitals, etc.) suggest that the Federal Government should take a more active role in encouraging new cities around the country. They would not only take into account local characteristics but would also provide the opportunity for a number of different approaches. Finally, they would provide good demonstration projects easily accessible to large numbers of interested persons—builders, financial institutions, consumers, social scientists, educators, material suppliers, labor, etc.

The precise vehicle for building these model cities might vary from place to place, but some sort of public-private partnership would be desirable to join diverse interests. The experimental nature of the projects would probably preclude most private enterprise participation unless it was joined in some way by government at various levels. Labor groups with an interest in capitalizing on new technology might be expected to join in some cases, as should groups of financial institutions.

8. School construction systems development provides an almost singular example of the systems approach to a given problem; namely, better school construction at lower cost. The same approach should be most fruitful in areas like low-cost housing, low-cost rehabilitation in housing, hospitals, and other health-care facilities (including mobile), and transport subsystems. The financial support required to launch such a project, provided by the Ford Foundation in the SCSD case, should logically be provided by a similarly innovative group. The Federal Government should encourage other foundations and associations to fund similar experiments and should sponsor some itself. Federal participation can be justified on the basis of greatly improved knowledge for decisionmaking in these areas of heavy capital involvement.

SCSD should be studied carefully as a prototype for the systems approach to various social needs because it has successfully overcome a wide range of apparent barriers to the application of technology. The general philosophy as well as specific actions can be extended and extrapolated to a variety of situations.

9. The National Institutes of Health provides an excellent example of what is possible in the application of science to major national social needs. NIH is well accepted as a mechanism for dealing with critical national problems. An analogue in the area of urban "health" would seem to be a very logical development, perhaps growing out of the existing Institute for Applied Technology in the National Bureau of Standards. The constituent institutes could follow various functional areas of transport, shelter, communications, pollution, etc. They could provide a national focal point for both research and clinical programs which would involve, as does NIH, the best groups in the country through grants and contracts. As a national institution, the Institute would be required to take the broadest possible overview, relating the various pieces of the program to overall national needs and goals. It could be a logical policy formulation group, as well as a national resource, for government programs at all levels. It would probably function best if it did not have overt control or regulatory responsibilities. The Institute would have a relatively small inhouse staff of very high quality and would rely to a significant extent on cooperative programs. Such an institute should be the focal point in government for policy, planning, and research in urban technology.

10. The final mechanism or family of mechanisms recommended by the conference was directed to the professional engineering community. Much of the responsibility for the application of technology to urban and social problems must rest with the engineer, the professional societies, the engineering schools. Ways must be found to involve engineers, particularly at the subnational level, in the formulation of urban policy where technology is involved.

State and local societies should work more closely with all levels of government to provide the kinds of information and insight necessary in policy formulation. Opportunities and alternatives must be posed to the appropriate political groups involved in urban planning.

The engineering schools should take a more active role in developing curriculums which go well beyond those now available in equipping men to deal with urban technology. This is needed at both the undergraduate and the postgraduate levels.

The National Academy of Engineering should be encouraged to concern itself with appropriate research-based policy statements which can serve to inform national policymakers of the scope and value of the potential contributions of technology to unmet public needs.

The Engineering Foundation should sponsor a second conference on the social consequences and implications of technology which would carry forward the discussions begun in 1965 and would serve in part as a continuation of the work of the Commission.

THE FOUR AEROSPACE CONTRACTS: A REVIEW OF THE CALIFORNIA EXPERIENCE

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The Four Aerospace Contracts: A Review of the California Experience

In November 1964, the State of California announced a plan for the application of systems engineering techniques to four important public problems. The event was notable, representing a great departure for any State government, and has received much attention in the press and at all levels of government. What follows is an attempt to summarize this experience: How it happened, what the results to date have been, and what it may mean in terms of the future.

1. The Origin and Development of the Idea

In order properly to explain the plan for applying new technological concepts to State problems, it is necessary to sketch in briefly the background as it existed at that time. Three particular points are crucial.

First, national consideration was being given to the question of possible reduced Federal spending in defense and the economic impact such a reduction would have. It seemed clear to most individuals and agencies which considered the question that the funds which would become available from a defense cutback would have to be applied somewhere else in the economy, particularly to research and development in nondefense areas.

Second, California has a large investment in defense, aerospace, and electronic industries generally (receiving a larger share of the market in these areas than any other State), and was thus particularly vulnerable to a possible cutback. A defense cutback would release a large number of highly trained persons who would have to find other work within California or elsewhere. A question of concern to the State government was what could be done to help these people and keep them in California. Could their talents be converted or applied directly to some other field? Governor Edmund G. Brown formed a Panel on Aerospace and Electronic Industries composed of industry leaders to consider these problems.

Finally, the State has a continuing concern with a number of problems: air and water pollution, crime, population growth and planning, welfare, education, and so on. In a number of these areas there was a growing feeling that new and dramatic solutions would have to be found and that present techniques for dealing with them were only barely keeping a step ahead of the problem. These problems, of course, are not uniquely California's; because of its size and growth rate, however, California feels them more keenly than many other States.

Within this framework, it is not surprising that personnel in the Governor's office began to link these three points together. There were problems; there were people; and the concern of the Federal Government suggested that there might be money to support a pilot study. Preliminary discussions with industry leaders indicated considerable enthusiasm for the idea. There was a feeling that the people could profitably be applied to the problems. At this time, the term "system engineering" and "systems analysis" began to be used for that aspect of the technology of the aerospace industry which was most transferable to new problems. It is the general technique for planning and problem-solving, and was evidently more applicable than some of the more specialized aerospace engineering techniques.

While these discussions were being held, the possibility of reduced Federal defense spending abated somewhat, or at least appeared less imminent. As a consequence, the focus of the idea also changed somewhat, from how to help the distressed aerospace industry, to how to make a new and broader use of available skills. Interest was, however, never totally lost in helping the industry to broaden its scope of applications.

The Governor's Panel on Aerospace and Electronics Industries, which took a vital role in advising the Governor in this area, volunteered to come up with a list of problem areas which seemed to lend themselves most naturally to study.

At this point it was clear what was wanted and a concrete plan began to be formulated. The list of possible areas of study was reduced to the four most promising ones. All had important characteristics: They represented pressing problems to the future of the State; they were different enough from one another to test the transferability of systems analysis under various conditions; they would involve a large number of State agencies;

and they were of enough interest and concern (to the public and to the Federal Government) that money could probably be found to implement any sound and feasible plans that came out of the studies.

Rather than apply for Federal assistance, it was decided that the State could find money for the first-stage study in each of the four areas: It appeared that about $500,000 could be set aside for this purpose. The contracts would be short so that the preliminary results could be demonstrated and used to help get further funding for continuing the work. Each would be for $100,000 for a 6-month study. It seemed imperative to get started quickly; in an area where much discussion and speculation had already taken place, it was too easy for this plan also to become bogged down in over-definition.

The four areas finally selected were these:

a. A study to develop broad guidelines for the establishment of a total system to manage waste disposal. By waste management is meant all of those things done to transport, treat, and remove waste materials in order to prevent and minimize pollution of land, air, and water.
b. A study aimed at the design of a new system toward which the State can advance in the next 25 years for handling the criminal and mentally ill populations.[1]
c. A study to determine whether a coordinated approach to data-gathering, processing, storage, and retrieval would achieve cost savings over present methods and simultaneously increase accuracy, comprehensiveness, and accessibility of the information.
d. A study of the problem and specifications for a program to overcome the difficulties of the design of an integrated, intrastate land, sea, and air transportation network.

Although some preliminary documents had referred to them as "design projects," all four were finally announced as "studies." In 6 months, little more could be expected. But all were expected to result in plans for future action. It is significant that three of the four Requests for Proposal sent to firms likely to seek the contracts contained this paragraph on economic feasibility:

> The contractor should consider the financial feasibility of implemeting successive phases of the overall system. He should suggest alternative methods of financing to include participation by Federal, State, and local governments and private users of the system.

On November 15, three requests for proposal were sent out, to some 200 firms. The fourth, for the transportation study, was sent out 2 weeks later. These four documents were rather unusual in the generality of statement of their requirements—compared, at least, to what the potential bidders were used to seeing. They asked for the ideas of the bidder as to what could be done. The following appears in all of the requests:

> The purpose of this request for proposal is to draw upon the imagination of the contractor in approaching the optimal solution to the problem at hand. It is the assumption of the State of California that a systems approach to this problem will be useful in analyzing proposed solutions.

The broadness of the requests was both a strength and a weakness. Many prospective bidders felt that they did not know what to propose, since they did not know what it was that the State wanted. On the other hand, what was being offered the bidders by the State was an opportunity to show what the aerospace industry could do for the State's problems. The best way of doing this was to allow maximum freedom within a broad area of study and approach.

The response was good: A total of 51 proposals was submitted for the 4 areas. Work groups were set up to evaluate each set of proposals. Each group consisted of members of the Department of Finance (which had done the preliminary planning) and personnel representing the agencies with an interest in the substantive areas. The four separate groups evaluated the proposals. One group experienced difficulties: None of the proposals for the criminal and mentally ill populations was found to be able to fuse the problem areas successfully into a single systems study. The evaluation group was, however, much more favorably impressed by one of the proposals than the others, particularly those parts dealing with the criminal problem. They, therefore, asked this bidder to submit a new proposal, deleting the mental illness portion and devoting the entire study to the criminal problem.

In evaluating the proposals, one other difficulty appeared. The State personnel were, of course, eminently capable of judging the proposals from the point of view of the substantive areas involved. But some believed they needed assistance in judging the methodological aspects of the proposals. The requests had asked that systems analysis be applied to the study areas. Now it was necessary to judge whether the proposals did in fact contain a proper use of systems analysis and whether it was being applied in the best of all possible ways. It was further obvious that this difficulty would persist through the life of the contracts. The State, therefore, decided to bring in a consultant organization to aid in evaluating the proposals and in monitoring the progress on the contracts themselves. This would supply additional technical competence to the staff and also assure the objectivity of the review. The responsibility of this organization would be specifically to examine the work performed from a systems analysis point of view, while the State agencies involved would examine it from the viewpoint of the substance. The

[1] This study area was later modified and further delimited. See below.

organization selected for this task was the System Development Corporation (SDC).

Within the next few months, four contracts were negotiated and signed as follows:

a. Waste Management Study: Aerojet-General Corp., Von Karman Center, Azusa, Calif.
b. Prevention and Control of Crime and Delinquency, Space-General Corp., El Monte, Calif.
c. Statewide Information System Study, Lockheed Missiles and Space Co., Sunnyvale, Calif.
d. Integrated Transportation Study, North American Aviation, Los Angeles, Calif.

Each of the contracts was monitored closely by a group formed in the State government. Where interdepartmental groups already existed, they were used. For example, in the case of the information system study, the Governor's Automatic Data Processing Advisory Committee served in this capacity. In other cases, interdepartmental groups were set up especially for this purpose.

The monitor groups worked closely with the contractors. It was definitely a cooperative venture. The contractors had to assemble enormous amounts of data: Lockheed reported, for example, having conducted more than 600 interviews in many departments of State government and with city and county agencies as well. The monitor groups guided them and helped gain access to these sources of information.

The monitor groups also advised on the general conduct of the studies, suggesting changes and shifts of emphasis. The relationship was a healthy, working one, occasionally becoming controversial and heated. Out of the heat and discussion and revision, however, evolved more realistic recommendations and a better understanding by both partners of the concepts involved.

The 6-month periods during which the studies were conducted produced a mutual education of industry analysts and State administrators which may have been one of the most significant products of the effort.

2. The Contract Reports and the Current Status

The four studies are now completed, and summaries of the final reports can be found in the appendix. The monitor group responsible for guiding and assisting the work of the study teams reviewed the final reports as they were completed, but evaluation is by no means complete. An ever-widening group of interested organizations and agencies are reading and commenting on the reports. This widespread review and evaluation is an important step in the process since it will influence to what extent the State will accept the conclusions of the contractors and what direction future implementation of the recommendations might take.

It must be remembered in attempting to evaluate the accomplishments of the studies that the purposes for which they were carried out were multiple and complex. First, specific plans of action were wanted for specific areas of public concern. Second, a demonstration was sought of how the aerospace industry and systems technology could help solve public problems. And, finally (the other side of the coin), a demonstration was sought of how aerospace technology could be transferred to new areas in short order without elaborate retraining of personnel.

The first, and most important question, however, is to what extent the studies succeeded in their specific fields of attack. For it is clear that if they failed to produce useful results regarding information systems, crime and delinquency, waste management, and transportation, the answers to the more general questions are bound to be negative.

All four reports agreed that systems analysis was a useful and effective tool in this environment and that work could be done to provide systems to the State which would supply better service at less cost. All contained bold and imaginative ideas.

The report on information systems provided a 10-year plan for the development of a statewide federation of information systems. The report has generally been accepted enthusiastically by the persons concerned as a blueprint for data-processing decisions and as a direction in which to move. The study sketched in a vast plan; while it is not totally clear that the entire plan will be implemented as originally designed, it is evident that the concepts delineated in the plan represent the framework in whose terms the State must operate.

This study had some advantages over the others, which may account for its evident success. First, information processing is an area more closely allied to the aerospace field than any of the others; a large part of the systems technology of aerospace is specifically devoted to information systems. Second, those concerned with data processing in the State had previously conducted a substantial study of computer planning for the State and were ready and knowledgeable in the field. The area perhaps did not have the intuitive appeal of the others; its importance is not as clear to the layman, but it was of vital concern to many persons in State government who were ready for a plan of action. Another advantage has made moving on from the preliminary study easier: The liaison personnel responsible for monitoring the contract took the precaution of involving all of the important decisionmakers early so the study recommendations were viewed universally as an opportunity and not as a threat.

The personnel involved in information systems in the State are now actively seeking budg[illegible]y support and are introducing more and more co[illegible]y and local government agencies in their plans. The study is helping the State to make a significant step forward.

The crime and delinquency report objectively outlined the problems of the study area and showed the consequences—in terms of cost and effect on the criminal justice system—of either ignoring them or introducing changes. The report indicated, for instance, the fact that the increasing crime rate is not a result of a breakdown in the social structure, but primarily the result of the tremendous increase in the population within the age group from 16 to 29, which contributes most heavily to crime in California.

The report recommended a 5-year program which it indicated would cost approximately $25 million a year. Implementation of this proposal will require vast coordination among many agencies throughout the State, both to secure their cooperation and to find the funds necessary to get the project started. Local enthusiasm and legislative interest must be developed before any real and concrete plan can be formulated for proceeding. "Government is ponderous," one of the responsible State officials explains, "and it will take time to generate the organization which will be necessary." The Governor subsequently established a Joint Council on Technology and the Administration of Justice, which is an important first step in this organization. The council, headed by the attorney general, is representative of all functional and geographical components of law enforcement, prevention, and administration in California.

The waste management study demonstrated the necessity for considering all waste within a single system. It made obvious the difficulty of attempting to consider this single study when there was no single agency responsible for the overall problem. Within the limits of time and resources for the study, it was not possible to produce the detailed estimates of anticipated waste loads. Also, within a sample area, it was shown that it is necessary to begin immediately to consider the coordinated handling of all wastes in order to hope to have an efficient waste management system in a number of years hence. A major recommendation was to place all statewide waste management problems within the purview of a single agency which would have to be established. The report also indicated that additional legislation would ultimately be required to make more local government units comply with the wider requirements of the State. Such recommendations will obviously take considerable time to implement.

The transportation study stressed the need for a large-scale mathematical model of the complex transportation system required by the State in the future. Such a program includes the derivation of the effect of changes in living and transportation habits, changes in the mix of goods shipped throughout the State, and the effects of new technology. Information about many aspects of the State, seemingly unrelated to the problems of transportation as such, were shown to have an effect. What would be required is virtually a complete model of the State's economy. However, a complex model of the State's economy, population growth and movement, land use, and so on, has implications beyond transportation. It can probably be constructed in such a way that it will be useful to numerous State agencies in planning. There is some question, then, whether these other agencies should not share in the planning and the cost of it. Problems such as this create administrative delay.

Thus, in the case of three of the studies, the systems approach led the contractors to view the problem in such broad terms that their recommendations fall across a large range of government agencies. This, it is possible to see now, is a fairly natural consequence of examining large, complex government problems as functionally defined problems which cut across political jurisdictions. It does, however, make implementation difficult.

Besides looking at the specific recommendations of the four reports and noting the current status of their implementation, it is necessary to look at another aspect of the reports and their consequences. Participation in these four activities has had a strong and lasting effect on the people and agencies involved.

There has been a wide range of reaction, of course. Some are bound to feel threatened by anything new; others feel that any change at all would be an improvement. But among those who have taken the events of the past year seriously and have studied the reports carefully, there has arisen an excited awareness of new possibilities. A 6-month study is not liable to uncover many new or hitherto undiscovered facts. To a seasoned government employee in corrections, or highways, or finance, there was little fresh data. But the conclusions drawn from these facts were new and different. For in each study the factual evidence was incorporated in a more comprehensive set of relationships than has been customarily considered. The contractors had looked at the facts in a different way and demonstrated a new way of solving problems.

The information systems report, for example, dramatized the sources and uses of information, making explicit the interrelationships of many levels of government. Once people have seen the scope and depth and involvement of information with everything the State does, they have a new outlook.

One of the chief virtues of the reports was in their concentration on the problems as functional systems problems with a willingness to look beyond the immediate constraints of political jurisdictions and traditional administrative boundaries and their focus on what should be done rather than on who has the authority to do it. The government decisionmaker who reads these reports is bound to be impressed by the capabilities to deal with problems in new ways. Perhaps he will become aware that asking which freeway route or what kind of smog-control device is not enough; that there are possibly more fruitful ways of asking questions.

These effects will be hard—in most cases impossible—to measure. But they will exist. Here and there will appear more imaginative solutions to problems and a greater awareness of the interrelation of many of the problems of the State which are not imaged in the organization of its government.

In summary, the four studies in and of themselves have been notably successful. They have introduced new ways of thinking and new concepts to many of the agencies involved. They have generated, even in offices not involved in the studies themselves, an excitement about these and other new things that government can do. The specific recommendations of the studies have a good chance, by and large, of implementation. The chief current difficulty in the way of such implementation is getting the necessary money. But funding is actively being sought in all four areas.

3. Future Prospects

In announcing its intention to let these four contracts, the State began a new type of relationship with industry. It turned out to be a two-way discovery: The State attracted the attention of industry to its problems, and industry made the State aware of its capabilities. The prospects are good for this relationship to continue and to grow. The necessary liaison has been established for further fruitful conversations to take place. It is indicative that two companies involved in this experiment now have Sacramento offices which they did not have before.

It was truly a cooperative venture where each partner contributed in such a way that more was produced than the money spent would indicate. The State contributed access to the problem, its vast store of data, and its knowledgeable and talented personnel. The contractors contributed their brightest employees and the very real interest and concern of their top management. Because it was an experiment that meant a great deal to both partners, both tried very hard to make it a success and a prototype worth copying.

Both partners did something unusual. The active participation of the State in an effort to help its industry is unique. State governments frequently exert efforts to encourage new industry to enter the State but this was an attempt to use people and talents that already existed in the State. Industry, on its side, was very generous when it was never clear that there would be much fiscal payoff for it. It was the urge to try something new. It was also a contribution to the community and an opportunity to demonstrate an awareness of social responsibility.

Once one has seen this relationship in action, it is hard not to believe that it will continue. The form it will take as it prospers and grows, however, is more difficult to predict. Will more such pilot studies take place in different areas? Will larger contracts be signed for industry implementation of the recommendations announced in the concluding reports of these first four studies? None of this is clear. This first effort was started by the Governor's office with a minimal involvement of the operating departments or the legislature. Now that the first effort is complete, its future is up to the legislature and the various State agencies involved. The future does look bright, but it also seems clear that the whole question of how industry can best serve itself while serving government has not yet been answered. It may be that other approaches need to be tried to see which will work best.

This was a new type of experience, not only for the State but for the contractors as well. The techniques for performing the studies and for interaction of State and contractor personnel had to be worked out as they progressed. An important aspect of the newness is that the contractors were asked to perform work which had heretofore always been performed by State personnel themselves: The planning of future State organization and function. This has considerable advantage, obviously. It allowed the State to use for a short period of time some very talented people it could not have hired. But the disadvantages are also patent. Such efforts, misapplied, could shortcircuit the traditional systems of government operation. The problems, of course, are not unlike those that the military experienced when they first began using similar organizations for similar purposes. The State, however, is smaller, newer at the game, and more entrenched in its traditional modes of operation, which make these problems seem more intense.

Such work is by necessity largely a cooperative venture since the State personnel have the facts which the contractor must analyze and since the State monitors and guides the work as it progresses. It is difficult to draw a line between the work that the contractor should perform and the work that should be performed by civil servants. The systems analysis and the recommendations based on it do not always present the whole picture. We have pointed out above how some of the analyses in these four studies, while technically apt, were perhaps politically naive. The contractor personnel can sometimes be overpowering and it becomes difficult for the State personnel, who are ultimately responsible for the making of decisions, to evaluate the contractor's work. One method of solving this problem, used in California, is to employ another organization skilled in systems analysis to advise the State in its dealings with the contractors. This was quite successful, but it is also clear that greater systems analysis capability must be developed by the State administrators themselves.

Not all areas of State government appear to be equally likely prospects for systems analysis and planning. There are both technical and political reasons for this. In order to define a certain set of affairs as a "system," not only must they have certain things in common, but it must be possible to isolate them from the rest of the world. It must be clear where this system leaves off, and another begins.

Some areas have more budgetary and political problems than others; also, some have better prospects and are riper for study and redesign. The personnel in the agencies involved must be ready for a change and willing to accept new ideas. Funds must be available as well as enough concern to secure funds and the necessary work. Areas selected for study should be those whose problems can be expressed in clear and meaningful terms to the layman.

Although these reasons make it clear that subjects for analysis must be chosen with care, we are confident these studies have demonstrated that systems analysis can, in fact, be applied to a wide range of social problems.

4. Problems

A number of stumbling blocks exist in the way of making such cooperative ventures between State government and industry successful. Some of these have been alluded to above, but it seems worthwhile to assemble all the problems that must be overcome.

1. Many agencies of the State government lack capability in systems analysis, and it is needed in order properly to monitor the contracts, guide the progress of the analysis, and evaluate the results. Permanent employment of systems analysts is not always a solution to the problem. They are hard to justify for the use that is likely to be made of their talents, and they are very expensive. Frequently contracting with consultants may be the most economical course. The State must, however, have some systems analysis capability for continuing work within well-defined areas and for working with contractors.

2. Throughout the study, continuous coordination is necessary among all who will be involved in its conclusions and whose support will be needed if they are to view it as an opportunity and not as a threat. A serious problem in the California experiment was the lack of early participation by the leaders of the State legislature and by city and county government.

3. A problem of communication exists which is difficult to overcome in 6 months. The systems analysts frequently talk a jargon all their own without realizing how strange it sounds to outsiders. Nor are public administrators wholly guiltless in this regard; they too have a technical terminology which can be difficult for the analysts to understand.

4. There is frequently a disparity between the natural dimensions of a socioeconomic problem and political boundaries. The waste management study, for instance, indicated the need for considering waste in terms of larger geographic areas than is being done now. Solutions to such problems require coordinated action across traditional geopolitical boundaries and through various levels of government. This may very well mean larger units than States. California is relatively unique in its geographical independence from its neighbors. In the northeast, for instance, most major socioeconomic problems are interstate.

5. Another important problem is highlighted by the fact that each of these studies resulted in a recommendation that long-range programs be undertaken. In general, political tenure seldom coincides with the duration of such efforts, and planning and funding cannot be guaranteed. Thus, the best solutions to be derived from systems analysis may be, in the short run, politically unproductive and thus call for statesmanship of a high order. This, in turn, implies that the public will have to be educated with respect to the wisdom of adopting solutions that accrued to their benefit only incrementally over a relatively long period of years.

6. Systems analysts from the aerospace industry are accustomed to working for large, rich, monolithic organizations. They are charged with finding the best, most economical, fastest way of solving a clearly stated problem. The customer if he likes the results can then implement the recommendations. The State of California is a very different sort of organization, and the implementation of the systems analysts' recommendations is not so easy. The political administrative problems of the transition must be considered as well as the economic and scheduling problems.

7. In one other way, the environment of State government is different from aerospace: There is less autonomy—it is less clear what is and is not subject to change. Is it fair game, for instance, to conclude that certain county functions should be made State functions or that certain affairs now under control of the State should be handed over

to the Federal Government? Systems analysis naturally tends to think in terms of bigger and bigger systems, and therefore larger and larger accretions of power.

Usually, the customer for the systems analyst's services has clear and quantifiable objectives. Also, the value system is defined: It is evident how much it is worth in dollars to have the system sooner or how much in capability we are willing to give up to make the system cheaper. But in the context of social problems, none of this is clear. How much is it worth to reduce air pollution—25 percent? 50 percent? 100? What is it worth to prevent a murder? These are difficult questions, and the lack of answers is bound to affect the usefulness of systems analysis.

Techniques developed for a small range of applications cannot be expected to be applied universally without revision. Systems analysis performed for State government is bound to be different, in the long run, from systems analysis performed for the National Aeronautics and Space Administration and the Department of Defense. But the four California aerospace contracts have demonstrated that the switch can be made and that profitable things can be learned from the attempt. And that, at least, is a beginning.

5. Conclusions

These problems indicate that the application of systems analysis techniques to public problems is not easy and that the way is not always totally clear. But we knew this before we began. If it had been obvious how the tasks were to be done, the California experiment should have been no more than a meaningless exercise. Only because the questions posed were both serious and difficult do the conclusions have meaning.

We now have the final written reports from all contractors and we continue to be highly enthusiastic about the success of the venture. The persons involved are totally convinced that California's initial investment was a wise one and that it is being paid back many times over.

In four areas of government—areas with serious present problems which threaten to become greater in the future—plans have been made to take significant steps forward. We are actively working at implementing these plans.

Those in government who participated in these studies and those who observed the participation of others have seen new possibilities in ways of solving the State's problems. This experience has convinced them not only that the techniques of systems analysis are useful but that such an approach may be essential in coping with some of today's and tomorrow's public problems.

Industry in the State, both those companies which participated in the studies and those which observed, has realized a new range of possibilities for diversification. The attention of many companies has been called to a new type of problem to which their talents can be applied and they are actively engaged in finding additional tasks in this broad area.

The overwhelming interest displayed outside of California itself demonstrates that our findings have meaning beyond our boundaries. The Committee on the Economic Impact of Defense and Disarmament (the Ackley Committee) writes in its report of July 1965, "The Government of California may well have taken one of the most significant and promising steps toward defense conversion." Mayor Lindsay of New York has acknowledged the fact that the systems studies being planned for New York City follow the leadership of the California studies. Senator Gaylord Nelson's bill to fund further studies was largely prompted by the California work.

Interest has been shown not only in the technique of implying systems analysis to the State's problems but in the substantive conclusions of the four studies as well. The Resources and Transportation Division of the United Nations Secretariat has expressed an interest in the transportation study. The Department of Health, Education, and Welfare has encouraged California to prepare a regional study carrying forward the waste management work.

Such interest and influence as these studies have had indicates, we feel, their success both as particular ventures and as prototypes for furture cooperation between industry and government.

Appendixes

APPENDIX A

Statewide Information System

The Lockheed Missiles and Space Co. was asked to conduct an overall study of State and local governments' requirements for information, and to formulate and recommend general concepts for developing a comprehensive system for handling this information need.

A broad study was conducted of information uses and requirements in State and local government. On the basis of both present uses and future projections, some conclusions were reached about the nature of information flow in government in California; for example, extensive flow exists among State level organizations, but local governments are the largest collectors of information, with a heavy flow of data moving upward from local to State agencies; electronic data processing is growing widely and rapidly at State and local levels, with a large potential for duplication of effort.

The study team demonstrated the feasibility and desirability of a statewide information system and recommended the evolution of a federation of information processors and users. Geographic centralization of organizational files was not recommended, nor was the rigid restructuring of existent files.

The recommended system would allow various State and local agencies to remain autonomous and independent; they would be required only to maintain standards of compatibility so that information exchange would be possible. The heart of the system would be an Information Central, the nerve center of this network of information agencies. The Information Central would perform two primary functions for the system as a whole: Information indexing and switching. The Central would contain an index of all information it has access to, allowing an individual agency to locate any information it required by contacting the Central. It would, further, act as a switch, transferring data requests to where the data are.

A more detailed description of the study and the conclusions follows.

1. The Goals

The goals of the study were formulated in terms of these objectives:

> Perform a survey of information needs of the State government, taking into consideration future requirements.
>
> Analyze the information interdependence of California public jurisdiction and prepare an information flow "map."
>
> Evolve a conceptual design for a statewide information system to satisfy the needs of California State government, present and future.
>
> Evaluate the potential benefits and impact of a statewide information system.
>
> Evolve a development plan for the recommended concept and produce initial cost estimates for the development and operation of the information system.

This, as everyone concerned recognized, was a large undertaking. Information is the raw material and the end product of almost every government activity. An agency receives papers, forms, and questions by mail, phone, and personal interview; at the end of the process, the agency has produced new papers, more forms, as well as answers by mail, phone, and individual contact. Like any administrative activity, to consider the information requirements of the State is to consider the State; and to improve the handling of information in government is to improve government.

2. Data Collection and Analysis

The initial phase of the study consisted of intensive interviews and fact gathering to determine organizational course and objectives both now and in the future. Detailed information flow was obtained from over 600 interviews of 80 major organizations. State organizational units were covered, as well as city and county units. The study considered not only the major office units but also a sample of outlying units, such as San Quentin, highway patrol stations, employment offices, and mental institutions, to obtain the complete spectrum of requirements. As could be expected from an executive governmental structure composed of 8 major agencies, 40 departments, and some 300 boards and commissions, the area was large.

This vast fund of facts then had to be analyzed and put into a form which would lend itself to the task. For each agency studied, pictorial information flow charts were prepared, showing the flow of information to and from all the other organizational entities having contact with it. Incidence charts were developed, portraying the variables of data flow among organizations of the State to help determine the requirements of a statewide information system. One of the principal purposes of the analysis is to determine high incidence data flow between State units; this is useful in planning the basic internal structure of the information system. Some of the conclusions of this analysis are of interest:

> The heavy volume of data flow is, by far, in the vertical direction, although the greatest number of information interfaces is in the horizontal.
>
> In the majority of State line organizations, more data flow vertically from the people and local governments than horizontally among State organizations. The interdepartmental flow is considerable, however, and the need for additional information exists.
>
> Line organizations handle the largest quantity of data.
>
> Among line organizations, those handling people-related data handle by far the greatest data load within the State government.
>
> Most horizontal flow is between staff and line or staff and staff.

Simultaneous with the production of the incidence charts, another aspect of the analysis was taking place. During the interview phase, facts were gathered from each of the departments on specific problem areas. Many departments needed better statistical data, for example, or faster response, or a greater ability to forecast and predict trends. These problem areas were listed and categorized. Examination of the problems which many departments had in common suggested the most serious requirements and areas where major effort should be expended.

With this detailed description and analysis it was possible to consider some of the design alternatives of a statewide information system.

The statewide information system has as its basic objective promoting maximum effectiveness in the utilization of information and improving efficiency in the handling of information. Although the study touched on several functional tasks suitable for automation, the emphasis was placed on the major statewide considerations and those elements of the system which interrelate organizations. But in achieving this objective, various technical, jurisdictional, implementation, and legal requirements must be satisfied. These considerations act as guidelines for the designer.

Within the constraints, then, of these criteria, and of the statement of needs and requirements which resulted from the analysis of the interview data, the study team derived a concept of a statewide information system and a means for gradually achieving it over a 10-year period.

3. The Proposed System

It was proposed that the statewide information system be developed as a federation of organizational computer centers (State and local) tied together by an Information Central and operating within a framework of compatibility rules.

A basic conclusion of the study was that independent, geographically distinct information processing centers in California State and local government should be integrated without being physically consolidated. The system should be developed so as to allow separate centers to communicate with one another. It is the basic purpose of this concept to amalgamate the information resources of all California public jurisdictions into a single, integrated system serving the information requirements of individual State and local organizations as well as the needs of the entire State.

The proposed system thus has two important parts: First, the various information centers and computer complexes throughout the State, and, second, the Information Central which ties them together.

4. The Information Central

The Information Central is a computer-based communication system joining independent centers information processing facilities regardless of their physical location in an automated information exchange. The Information Central consists of two basic components: A statewide data network and switching facility and a central electronic index of information stored in the files of particular computer centers. The Information Central will perform the following functions:

Information Indexing. Information Central will contain an index of all information it has access to, no matter where in the system that information is located. Ultimately, the total spectrum of State and local government information in California should be classified and indexed. The index will indicate where a particular item of information is stored, and the conditions for gaining access to that file. The Information Central will not, itself, have the data, but only the locations for the data. This is the concept of centralizing information about information, rather than the information itself.

Information Retrieval. Requests for information from both human users and computer systems will be received by Information Central. The user may request direct retrieval of particular items of information, searches for information, and computations based on retrieval of source data from files.

Switching and Transmission. Information Central will provide the communications network for transmission of data and requests for data among the various centers connected to the center. In one mode of operation, the Central will serve solely as a switching device, directly connecting the requestor with the organizations known to possess the desired information.

Information Conversion. Computer programs will translate incompatible representations of information whenever possible. Programs will also convert information from one file structure to another.

File Updating. Computer programs will inform appropriate organizational facilities of changes in information in which they have interest.

Transaction Analysis. Message and information flow through Information Central will be automatically recorded to provide a firm factual and statistical basis on which further statewide information system developments can be planned.

5. Information System Operation

Associated with the Information Central will be all the information centers and computer complexes of the State and local departments. These facilities may be individual departmental centers, shared facilities, or regional complexes. The State service center will provide automatic data processing services to organizations lacking these capabilities. The system will operate in three primary information modes:

It will respond to queries for detailed information. The total system can serve as a fact retrieval system available to any associated user. The user will request information, the Information Central will locate the source of this information and forward the request. The response to the user will include the itemized facts and the sources of the facts, including file location.

It will respond to requirements for input to operational programs at terminals. A using organization may have programs which generate reports, requiring as input data available from other organizations. These programs can automatically request up-to-date data from any of the other files in the system, thus reducing the need for human intervention at the point of routine or repeated information retrieval.

It will update files automatically. Data collected by one organization can be used to update the files of other organizations. The procedure for updating files is determined by certain considerations concerning the currency required of the updated data and the way time is utilized in a large data processing system. No need exists for information to be updated on a real-time basis except for some few categories.

6. Compatibility and Standardization

The federated system with Information Central as its nerve center will require less standardization than a completely centralized system. Nevertheless, compatibility is part of the price for integrating a number of diverse operating systems into a larger system. Clearly codes, inquiry languages, and information cataloguing techniques must be standardized. It is also desirable that file structures of similar functional files be standardized. However, the federated system gives freedom of choice in computer equipment selection and data processing methods in individual participating units.

A major challenge in developing the concept will be to strike the exact balance between standardization and operating autonomy; this will require the cooperation and participation of potential users and should be developed on a joint basis, with the State furnishing the initiative and motivation.

In examining data and information flow patterns, massive quantities of information were found to flow into State units from local government, which provided the basis for recommending that the statewide information system include local jurisdictions. In the interest of built-in compatibility, and also as a possible motivational factor, it is recommended that the development of the system include the preparation of standardized electronic data processing (EDP) packages consisting of computer programs and equipment specification for voluntary use by local governments. Significant savings in reduced EDP developmental costs will result to local governments using these packages, and thus will provide an incentive for participating in the statewide information system.

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7. Development Plan

Plans call for complete development and activation of the California statewide information system to take place over a decade, with initial operation beginning in 5 years. Initial activities are concerned with two major areas:

Establishment of a pilot program; and

Specific studies aimed at defining the overall program and establishing the broad policies under which the system will be designed, activated, and operated.

The Information Central will be activated in steps, beginning with the establishment of a computer center primarily to support the programing effort. In 5 years, the Information Central will be ready to begin organizational tie-in and will be functioning as an information exchange. State organizational tie-in will be essentially complete in 6 to 8 years, and the total system will be fully activated in 10 years.

In order to cause minimal disturbance to State and local organizations having functional EDP programs, their integration into the statewide information system will be timed to correspond with normal equipment or software upgrading. Organizations still considering EDP when information system standards are evolved should plan to conform with these standards.

The integration of local government EDP will be preceded by the joint State and local development of interface standards for statewide adoption. As with State organizations, local governments are expected to integrate their EDP equipment into the network gradually, as each unit upgrades its installation to system standards or installs a new, conforming facility.

8. System Values and Costs

The value of a statewide information system to California government is directly related to how well the system supports the needs of relevant agencies:

To meet expanding service demands with limited resources; and

To provide new and different solutions to a vast array of problems brought about by the impact on the State of social and technological changes.

The system offers real potential in avoiding inevitable costs if no such system is implemented. For example, a projection of the current growth rate in State employees places this work force at 219,000 people in 1980 with a total payroll of more than $2 billion. By 1980, $1 billion will be spent for information handling, much of which could be mechanized at substantial savings. Although much of this information handling is not amenable to electronic data processing, net savings of perhaps $116 million annually are possible for the State government as a whole by installation of a statewide information system. This far exceeds the operating costs of the system.

The specific benefits are categorized into four groups:

Cost avoidance and reduction—those which produce dollar savings by applying more efficient procedures to present operations and those which reduce expenditures in operations planned for the future.

Increased revenues—those which produce additional income.

Better services—those which provide better service to the public in its interactions with the State and to the State departments in the performance of their own operations.

New services—those which will make possible services which cannot be undertaken by present methods.

The development philosophy of the information system is to build upon the EDP fabric of the State, adding only the increments needed to convert this collection of statewide computer facilities into a statewide information system. Consistent with this philosophy, costs have been developed for Information Central and those items of communication interface equipment needed to tie organizational EDP into the network. Also included are the developmental costs of the standard EDP packages. Organizational EDP for both State and local organizations are not costed since they will come into existence whether or not the statewide information system is implemented.

The program has been costed on the basis of a 10-year span, at the end of which the statewide information system is planned to be fully operational, with State and local government units connected to Information Central. This 10-year period, however, includes some operation, as organizational tie-in will occur on an incremental basis beginning at the end of the fifth year.

The summary of costs is a follows:

10-year developmental costs	$68,400,000
10-year operational equipment rental	29,800,000
Total 10-year program	98,200,000
Estimated annual operational costs (after 10 years)	13,400,000

These costs have been based on current equipment rental prices. If, as generally expected, EDP continues its current trend toward lower prices, costs will be accordingly lower.

APPENDIX B

Waste Management Study

The study of California's waste management problems was performed by Aerojet-General Corp. The objective of the study was to produce a plan by which the State could accelerate the development of waste management techniques responsive to the demands of the future.

Several important concepts and conclusions emerged from the study. One of the most important was that waste management deals with one single system—the environment—which in turn is divided into three closely related systems—air, water, and land. Presently in California there are a large number of independent State, regional, and local bodies regulating, collecting, and disposing of different wastes. The report points out that unless these diverse and dispersed activities are properly articulated, and unless the interfaces between solid, liquid, and atmospheric wastes are recognized, no effective waste management system can be developed.

Related to this concept is the realization that wastes cannot be efficiently managed in geographic plots dictated by the boundaries of political jurisdiction, but that the geographic boundaries must stem from the analysis of the waste system itself. These considerations demand a statewide plan and large operating regions.

Another important concept in the study was the focus of attention on output and criteria for environment, rather than on the disposal of wastes at least cost. The waste management system of the State must be optimized for the total population, rather than for the waste possessors.

The recommendations of the study were for an organized and positive effort directed towards a high quality environment. Society's requirements for its environment must be made explicit. The technical design of a waste control system must be begun, and legal moves must be taken to form the authority necessary to implement and enforce the plan.

1. Definitions and Criteria

A waste management system is a group of organized activities that produce certain specified effects upon the environment by using materials that waste producers discard. Waste disposal, a more usual term, is most often used in a sense that implies that pollution is permissible up to a certain level, or that it is not necessary to obtain any positive result from the process—only get the waste material out of the way. A waste management system must consider all significant effects, interactions, trade-offs, costs, and other factors which can be balanced for optimum benefit toward a specified environmental result.

In order to create such a system, it is necessary first to evoke the environmental requirements of the community. These criteria must define the amount of pollution that is acceptable in terms of cost, health hazard, and aesthetic considerations.

A large part of the effort of the study group was devoted to the collection of information about the present and future waste problems in California. For all types of waste (gaseous, liquid, solid, and radioactive), waste production rates were obtained. Estimates of future trends made it clear that generation rates for all types of waste will continue to rise over the next 35 years.

This does not, of course, imply pollution. Some types of waste are more easily handled than others. Large quantities of solid waste can be handled in many regions without noticeable increase in environmental effects. In general, however, the quality of the environment may be expected to degrade, particularly as a result of air pollution. The effects of such pollution are bound to be widespread, but there is a dearth of specific information that relates pollutant concentration to effects at the levels of pollution encountered in the environment.

Even with today's technology, almost completely pure environments can be maintained, but people are generally unwilling to pay the price for such conditions. The target environments for the system analysis must be realistically established on the basis of what the people who must live in them are willing to pay to do so. No other criterion is ultimately meaningful.

2. A Unified Waste Management System

After a detailed study of the characteristics of waste to be expected and methods of control possible, an analysis of the waste management problem was begun. The system must first be defined and delimited, its interfaces with other systems must be made explicit, and its inputs and outputs must be established.

The environment of air, water, and land affects people, machines, plant and animal life, and many of people's activities. These affected items can be considered as other "systems" whose inputs are the outputs of the waste management system—the contaminants or pollutants that the affected systems permit to remain in the environment. Similar "systems" are also affected on the input side, principally through feedback mechanisms. Pressure on waste generators toward waste prevention is an example. Thus, the waste management system has multiple interfaces with many other systems.

The results of this analysis presented several sharp contrasts with more conventional approaches to the waste handling problem. There are complex interrelationships and trade-offs among the choices of discharging waste into air, water, and land and the resultant effects on water supplies, air purity, land usability, and neighboring community interests. First, then, it became apparent that in waste handling all of these elements must be considered simultaneously.

Second, past methods of waste handling have focused attention on the waste itself; that is, on the input to the waste handling system. Preoccupation with how to get the waste away from the immediate area of its generation has precluded much concern with the ultimate or total effect of selected disposal methods. Expediency has generally overridden long-range implications. There has been relatively little concern with the system output; that is, its effects on the environment. To waste disposers, the dump site has ordinarily been considered to be beyond the disposers' environment or outside of their system boundary. From the system management point of view, this unwanted byproduct is an input to the waste management system, which is evaluated by the acceptability of its outputs. The conventional approach of waste handling by concentrating on disposing of inputs leads to an open-ended system that is driven by its input. The output of such a system may diverge drastically into unacceptable behavior. The affected environment may influence the waste handling capability to some extent, but again, this is in an uncontrolled and not necessarily stable manner. However, when output information is fed back and combined with the input and when the system is stabilized with this combination of input and feedback output driving it, then the output (or here, the environment) is maintained at a controlled level.

Third, the natural preoccupation of individual local operations with selection of the cheapest available method of waste disposal has tended to conflict with objectives which emphasize health, aesthetic values, and broad and longer range economic considerations. This study shows that waste-handling operations can be effectively integrated into a system aimed at satisfying these various considerations at minimum cost.

Finally, although there are distinct unifying forces that require the system to include all wastes over a broad geographical area, there are administrative and fiscal factors that recommend that certain coordination activities be regionally oriented. A regional, State, or national outlook on this problem tends to be in sharp contrast with current operations which are predominantly locally oriented.

Meaningful control of environmental states produced or caused by waste disposal requires management of all controllable wastes. The effect of the waste on the environment can be controlled by modulating the rate or composition of the various wastes disposed into it. Therefore, to meet an environmental output specification, an integrated control of all means of disposition is necessary.

When each affected system attempts to manage its immediate environment according to its own needs, there are extensive duplications, overlapping efforts, and controversy concerning priorities. Separate facilities lead to costly operation. By combining the environmental requirements of these systems into a specification and by imposing this specification on a waste management system, an environmental level of pollution that is most nearly satisfactory for all affected systems can be obtained.

There are many points in a waste system at which changes may be produced. This multiplicity of choices provides a potential for reducing the waste management cost through (1) the producer's selection of the waste produced; (2) conversion of one type of waste to another; (3) selection of means to perform functions; (4) sequence of functions; and (5) total capacity and geographic extent of the system. Choices can be made in the means of transportation, processing, collection, and final disposal. Exploiting the many choices at various decision points is best accomplished when the system is considered as one with subsystem divisions that can be altered according to technical requirements.

By considering the total waste management problem, optimal systems can be obtained, and latitude is provided for evolving subsystems from one form to another. For instance, in the future, it may become desirable or even necessary to convert all wastes to solid waste or to liquid-borne waste. As it becomes technically feasible to do so, suitable latitude in the total system must be provided to facilitate the incorporation of future technical innovations.

Only after basic decisions are made regarding the types of wastes produced, their quantities, their rates of conversion from one form to another, and their impact on the air, water, and land environments should the system be divided into subsystems. After these basic decisions are made, the interfaces between the various subsystems of gaseous wastes, liquid-borne waste, and solid refuse become definable. Therefore, the waste management system should be considered as one system with gaseous, liquid, solid, and radiological waste subsystems.

3. Geographical Boundaries of a Waste Management System

Waste disposal and handling systems have typically been designed to correspond with political boundaries of cities and counties, as a natural result of administrative jurisdiction. However, a lower per capita cost system for a densely populated area can generally be realized by enlarging the district or region in which the disposal system operates. If the area is large enough, relatively low per capita cost systems are realized because of economies that usually accrue from large-scale operations.

Systems based upon political boundaries may be unable to solve a particular problem. Notably, smog and its effects are seldom limited to the boundaries of a city or even a county. Again, solid waste may be disposed of in sanitary landfills outside of a city's boundaries, resulting in the imposition of additional constraints by neighboring communities. Discharging sewage into a commonly used raw water resource may result in pollution that no single discharger can control. As long as each discharger has his own specific waste problems to solve and there is no unity of action, the spoiled resource will continue to be polluted.

Industrial growth of inland areas may be inhibited by the local environment's capacity to assimilate waste. A possible relief of this limit may come from linking the inland area disposal methods to the disposal methods of communities near the ocean. Such an arrangement is feasible if a unified waste management district or region is created.

Thus, the geographic boundaries of a waste management system should be based on the economic and technical aspects of the waste management requirement, rather than on the boundaries of a political entity which may be too small to solve the problem initially or to achieve a low per capita cost system.

Convenient geographical boundaries satisfying these criteria can be defined. Such regions have common topography, weather, and other physical factors that influence the selection of a particular waste management technique. The communities in the regions have common objectives and constraints, and have homogeneous waste composition, concentration, and input rate. The study group defined such regions, using technical criteria principally and social and political constraints only when they were technically acceptable.

4. System Development and Design

Fundamental to the successful design and development of a waste management system is the clear statement of the system output specifications. These specifications consist essentially of a statement of the permissible concentrations of pollutants in air, water, and land for a given area. They will naturally vary with regional requirements. This is especially true for liquid wastes because of regional variations in ground water quality and raw water supply quality. Such specifications do not now generally exist. Until they do, it will not be possible to design in detail a waste management system.

For illustrative purposes, however, the study team sketched four possible waste management systems for the region comprising Sacramento and San Joaquin Valleys and the San Francisco Bay area. The systems were not presented as recommendations, nor were they completely delineated. They were intended as illustrations of method, and as a sample of what could be accomplished in terms of pollution criteria and costs.

Four levels of waste management and prevention were considered: (a) An expansion of existing control measures, using current methods for the next 25 or 30 years, with expanded plant capacity; (b) application of new control measures that are presently within the state of the art; (c) development and refinement of the present state-of-the-art control measures to improve and extend them and reduce their application costs; and (d) the application of advanced control measures to be developed by a full research and development program. System (a) assumes output specifications only in terms of health requirements, while the other three assume specifications in terms of health, aesthetic, and economic costs.

System (a) is merely an expansion of the present waste-handling method in response to increases in population and per capita waste production. With this system, the environment becomes progressively more polluted because of increased waste. The state-of-the-art system (b) is regionally integrated and uses present, fully developed methods to substantially reduce pollution. The development system (c) is an improvement over the state-of-the-art system and shows that savings can be realized by introducing advanced techniques while maintaining the criteria for the state-of-the-art system. Although the development system does not have the many advanced subsystems of the advanced system, it is considerably easier to cost. Meaningful system cost information on the advanced system (d) will not be available until the end of the conceptual phase.

In this brief summary, we will not try to describe the systems. Four major conclusions were reached, however:

> High-quality environmental air, water, and land can be obtained for the region at expenditure levels far less than the social costs associated with a low-quality or "least acceptable" environment.
>
> Acquisition of a high-quality environment requires long-term planning and system development on a regional basis.
>
> Acquisition of a high-quality environment will require an organized effort directed to that objective. A piecemeal, "after-the-fact" operation will not produce the desired results.
>
> A significant portion of total costs required to attain a high-quality environment is attributable to gaseous waste prevention.

Costs were also developed for these hypothetical systems. The costs were not intended to be highly accurate; however, they are indicative. Two types of costs were considered: Only health effects were considered in system (a) specifications, but health, economic, and aesthetic effects were considered in establishing system (b) specifications. One is a least acceptable environment, whereas the other is the highest quality environment that is likely to be requested because of cost.

The annual system costs for the expanded existing system (meeting only specification (a)) will be approximately $500 million by 1990. Specification (b) conditions will increase to approximately $1,250 million by 1990. This figure may be substantially reduced, however, by research and development and improvements in the state of the art. The estimate for this approach is, in 1990, about $800 million.

Social costs were also developed; that is, the hidden costs of pollution to people and industry in the polluted environments, or conversely, the value to them to have no such pollution, were also included in recognition that hidden costs exist, and to show that they can be substantial.

Estimated social costs will continue to increase with the specification (a) system, approaching (in 1990) $2,500 million. Specification (b) will force these costs below their present $600 million to approximately $300 million by that date.

Although the cost estimates were highly tentative, they clearly verify the substantially lower cost of waste management by an overall systems approach and the cost saving potential from development of methods. In fact, the study results strongly suggest the cost of not using an overall system approach may not be meaningful at all, since the increase in the scope of the problem will eventually force an overall approach. Therefore, the pertinent question is not whether to establish a waste management system, but when.

5. Recommendations

The recommendation of the study was for a 3-year program based upon the work done to date and aimed at completing the conceptual design phase. The following steps comprise the program:

1. Obtain additional critical data, or specify the necessary assumptions required to use the environmental and socioeconomic models in completing the overall system analysis.

Although the study team made the first statewide projections of wastes to be generated through 1990 and summarized relevant available data on the effects of pollution, waste generation rates are required in greater detail, and additional relations between effects and pollutants must be developed.

2. Catalogue community objectives that are relevant to waste management, and translate these objectives into initial, overall system criteria and subsequently into preliminary engineering design specifications. The cost implications of alternative objectives or criteria must be calculated.

3. Evaluate all major available technical alternatives. The analysis already performed must be expanded to include available alternatives that are not used now and to suggest new alternatives to available methods and techniques of collecting, processing, and disposing of waste.

4. Complete the overall analytical computer models required to represent and measure all of the main actions and reactions of wastes with the natural environment. These models will augment the simple models developed for the Sacramento area and will incorporate the numerous known physical and physiological effects of wastes upon human health; aesthetic values; the composition of air, water, and soil; resulting effects on plants, animals, and marine life; and the deterioration of products and equipment.

5. Develop a socioeconomic model: This model will supplement the waste-environment models discussed above. It will incorporate definable legal, political, and institutional boundaries placed on the system by society and will simulate the principal direct and indirect financial ramifications of current and potential changes in objectives, technologies, or constraints.

6. Construct a scaled, operating model using the most promising waste-handling techniques in a simulated natural environment, approximating the conditions and waste-loading prevailing in the State's most critical region. This model can be used to study complex reactions that cannot yet be computerized. It should contribute to the formulation of system specifications and will potentially demonstrate the feasibility of the system and its principal components.

7. Through continuous reappraisal, evolve the conceptual design of an overall waste management system and, thereby, establish the initial component specifications and guidelines for the subsequent hardware research and development phase.

To ensure that the above activities are undertaken in the most logical and effective manner, a State coordinator should be designated to assume the necessary planning, coordinating, and supervisory functions and to consider the ways and means of developing and implementing an operational system for the benefit of the State as a whole.

The study to date and the recommended program would, it was felt, directly contribute to Federal programs that are already underway and others that are being studied by Congress and the administration.

APPENDIX C

Prevention and Control of Crime and Delinquency

The Space-General Corp. undertook to perform a systems analysis and cost/effectiveness study of the California system of criminal justice: Local law enforcement, the courts, probation, juvenile and adult institutions, and parole. The avowed objectives of the study were to present a critical evaluation of the present system of criminal justice and to recommend a program directed to more effective prevention and control of crime and delinquency in the State.

The study showed that crime in California will increase almost twice as fast as the population increases during the next 10 years; that Californians currently are paying $600 million annually to support the State's criminal justice system; and that this figure is expected to increase to $900 million per year by 1975. This surge is due to a continuing tremendous increase in the number of persons in the 14- to 29-year age group, where most of the crime occurs.

Thus, California can expect to pay more for criminal justice each year just to maintain the current system with no special efforts for improvement. The study showed, for example, that despite dramatic improvements in communications technology, California law enforcement officers have no way of sending fingerprints from one end of the State to the other, other than by mail or messenger.

And as the cost of crime goes up, related costs not included in the $900 million figure also go up. Bad-check writers and thieves cost the citizens thousands of dollars each year which are not reflected in the taxpayers' costs for criminal justice. In addition, the State now pays $1.2 billion per year on welfare costs, and the study showed that there is an interrelationship between welfare recipients and crime rate.

The study recommends an additional expenditure of 3 percent of the cost of criminal justice or some $20 million per year for an extensive improvement program in a systems approach to reducing the crime rate, thus reducing the long-range cost of crime. The program places heavy emphasis on crime prevention among juveniles, making it more difficult for persons of all ages to commit crimes, and improved methods of information transfer among criminal justice agencies.

1. Analysis of the Current System

The initial effort of the study team was devoted to the construction of a flow diagram of the criminal justice system. The independent functions of law enforcement, adjudication, probation, institutionalization, and parole were studied, and detailed flow diagrams were prepared of their interrelationship. These diagrams showed the ways in which an offender might pass through various agencies involved, how he might eventually leave the system or be cycled through again. Each possible path through the system, from apprehension to release, was identified and defined as a "system flow path."

With this basic conceptualization accomplished, the study team concentrated its attention on a particular aspect of the diagrams: The points at which an offender might move in one of several directions, depending on a decision he or some other individual would have to make. They constructed diagrams emphasizing this aspect of the system, which they called "decision diagrams." There are associated with this decision network objectives which may be unique for each decision. A set of options is available to the decisionmaker; information is available to aid in the decisionmaking process; and various decision rules and constraints govern the use of this information and the range of decision options. Thus, in describing the decision network, an associated information system starts to evolve.

The objectives of a definition of this information system is not to provide detailed specifications for information processing requirements in competition with the information systems study. It is rather to generate a comprehensive review of information flow and access—both current and desirable for the future—for all the pertinent agencies involved in apprehension, judicial, and correctional functions.

The information system analysis indicates, for example, at each decision node in the system, what information is and is not available to the decision-maker. In some cases, information exists which would be helpful but is not available at the time when it is needed. In other cases, there is an unwarranted delay in obtaining information. For example, presentation of recidivism statistics and correlations in a convenient manner may be highly desirable in probation and parole administration; again, rapid definition of program and facility availability within the Department of Corrections may be desirable for more effective reception and guidance center recommendations.

A second technique was employed to uncover the inherent structure of the criminal system: The preparation of a "taxonomic matrix" of society and institutional populations. Essentially, it consisted of tables defining the statistical characteristics of the California population in general: Age, education, race, income, etc., and the same characteristics of those individuals who are currently in correctional institutions. A comparison of the two profiles showed relationships between the various group characteristics, thus aiding in identifying the criminal candidate type, and permitting estimates to be formed of the future criminal candidate group.

Many interesting facts were discovered from this study of criminal typology. Geographically, for example, most offenders come from the southern California area, with Los Angeles County supplying almost half the prison population for both the adult (41 percent) and juvenile (42 percent) groups. (Los Angeles County contains 38 percent of the total California population.) In prison society, the Negro and other minority groups are overrepresented by a factor of five relative to total California population representation.

These techniques were extended and applied in more detail as a specific study was made on Los Angeles County. The county was broken down into groups of census tracts which showed a high degree of homogeneity with respect to population characteristics. Various significant population characteristics were charted on the map, and so was the crime rate. Analysis of the data indicated that relationships exist among many of the social variables in the Los Angeles area. It was found that in nearly all of the study areas having high dependency and delinquency problems, other serious social problems existed.

Some of the social characteristics which appear to show a high correlation with crime rates are these:

1. Median family income less than $5,500.
2. Negro population 75 percent or more of total population.
3. Density of 10,000 or more persons per square mile.
4. High school-dropout rate.

A map of Los Angeles was included in the report of the study showing the areas of the county where these four characteristics were present and where the crime rate was high. This map achieved some notoriety after the Los Angeles riots. Watts is the only area in the county where all four characteristics are present.

Another disclosure of the analysis was in the area of crime statistics. Upon reviewing all aspects of the statistics from the past 5 years, it became apparent that a substantial percentage of the committed group was between the ages of 14 and 29 years. It was reasonable then, in an attempt to learn as much as possible about the phenomenon of crime, to form a new crime rate statistic based not upon the total population but upon population in this age group. The result of this analysis was a relatively constant crime rate for both juvenile and adult groups over the past 5 years. This was true in spite of the fact that the 14-to-29 age group in the overall population had increased by more than 35 percent. If the crime rate calculated in this way remains constant over the next 10 years, the number of crimes will show an increase in that time of 55 percent. In fact, from 1960 to 1975, this crime susceptible age group in California is expected to increase 110 percent, almost twice the expected 60-percent increase of the total population. Crime is indeed increasing faster than is population, but primarily as a result of the increase in the number of members of the crime susceptible age group.

2. The Mathematical Model

In the process of conducting these studies, and particularly in preparing the decision diagrams, considerable numerical information was collected: The number of individuals passing through the various paths and subpaths; the time it takes offenders to move from one decision point to another; the costs incurred by the system for different kinds of offenders at different decision points; and so on. With a schematic diagram of the system and the interrelation of all its parts and numerical data on the flow of offenders through the system, it was possible to apply one of the classic tools of systems analysis. The study team constructed a mathematical model or computer simulation of the system.

The primary purpose of the model was to assist in cost/effectiveness studies. One of the most interesting results was the ability to calculate career costs for the various offense groups. These are defined as the estimated lifetime cost of individuals in particular offense groups to the various justice and correctional agencies with which they will be involved. One of the more surprising results of these calculations was the apparent discrepancy existing between the seriousness of the offense and the system expenditures relative to it. The career cost for a forger or check offender, for example, is significantly greater than the career cost of homicide offender ($16,900 as opposed to $5,800). It should be pointed out that this cost represents the cumulative costs of processing and incarcerating these individuals as they move through the system, not only for the first time, but also for all subsequent returns over the lifetime of the individual. The cost does not include any costs that society might incur as a result of the criminal activity.

Another result from the simulation is the effect on system costs of various parameter changes, or changes in policy. If, for example, the fraction of the sentence which is served in prison before parole is changed from its present value of 50 to 80 percent, the cost to the system would increase from $4,000 to $4,400 for the average offender. Also, other parameters can be perturbed, and their effects on the system can be seen.

As a side effort undertaken to aid in the conceptualization of the system, the analysis has produced some rather interesting mathematical abstractions which illuminate certain system characteristics. For example, in the past there has been a very great tendency to evaluate the effect of prison rehabilitation programs on the basis of parole violations. The results of a theoretical and analytical study clearly indicate the intimate relationship existing between parole violation and probation rate. An increase in probation rate results in an increase in parole violation rate. Since probation rate has been increasing over the past few years, and since it is expected that programs will be implemented which may further increase this rate, it is to be expected that the rate of parole violation will increase also.

Another interesting mathematical abstraction has appeared. Observations have been made by several prison wardens that overall prison population seems to be exhibiting less desirable behavior as time passes. From a mathematical point of view, prison population will, on the average, show tendencies toward less desirable behavior. This does not mean that the noninmate population is changing significantly but rather that the individuals who are entering prison each year on the average have less desirable behavior patterns. This is a direct result of the systematic way in which those individuals with unacceptable behavior are returned to prison, while those whose behavior is acceptable are eventually released.

The systems engineering results described above—career costs, results of system perturbations, and examples of increased understanding of the interrelations between functions of separate jurisdictions—provide a basis for future programs and perhaps even initial policy changes on the part of the State. However, information is still lacking regarding the relationships between system expenditures and ultimate effectiveness. It would be eminently desirable if the State could allocate its expenditures in criminal justice so as to both reduce crime and reduce the damage to society caused by crime. But knowledge of the relation between expenditures within the system and the damage caused by crime is not presently known. The systems engineer cannot effect an optimization of the system, and the State cannot properly allocate resources until these effects are better understood. For example, we might consider the expansion of two functions which certainly have an affect on crime: causing all offenders to serve full terms rather than being paroled, and doubling police patrol capability as a deterrent measure. This action would represent an increase in expenditures of almost 75 percent. However, we do not know the effect on crime rate of eliminating parole, although we do know that the number of parolees within the State is less than 10 percent of the number of felonies which occur in a given year. And we do not fully understand the relation between crime rate and police visibility. It is clear from this that we must explore new and perhaps less costly functional relations, especially in the areas of prevention, so that no alternatives which might show promise of increased effectiveness in the reduction of crime rate are left unexplored.

In the analysis of a system, it is always necessary to trade performance and costs in such a manner as to provide the maximum utilization of resoures. It is interesting that the efforts of society have been largely concentrated on correction rather than prevention. If a susceptible crime group could be identified early, the amount spent could be used to prevent individuals from entering the system. The identification of this group and the effectiveness of the expenditures are difficult and complex, but in light of projected system costs based on present policy, the need for such an evaluation is clear.

3. The Proposed Program

The program which is proposed as a result of the analysis contains recommendations for further work which will complement the progress made in this study. The implementation of an information system and a more adequate analytical model will increase the knowledge of the operation of the present system as well as provide a comparison of effectiveness for any proposed alterations. The program suggests individual programs in certain major areas. Almost all serve a dual purpose—a systematic attempt to determine what functional relationships exist between expenditures and results, and the complementing of existing programs and techniques designed to produce results by the most efficient means available.

Eight groups of programs are recommended:

- System engineering programs.
- Crime reporting programs.
- Potential offenders identification programs.
- Prevention programs.
- Apprehension programs.
- Case management programs.
- Manpower development programs.
- Community relations programs.

A brief description of the purposes of these programs and how they fit into the overall system concept is given below, as well as an additional significant suggestion for a joint coordinating organization.

The Joint Organization. These recommendations cross many jurisdictional boundaries and will require extensive coordination among State and local agencies. The required cooperation and authority necesssary to implement these programs are beyond what could be expected of a typical coordinating committee. It is proposed, therefore, that an organization be formed under mutually agreeable executive control, made up of representatives from State and local agencies which potentially will participate. This organization will be responsible for both technical and financial management; it should be supported by the group which conducts the systems integration program. The organization will be responsible for contracting work to all participating State and local governments and educational and industrial organizations.

Systems Engineering Programs. The systems engineering group of proposed programs provides the mechanism for the control and technical evaluation of all aspects of the overall program. This group will also maintain an awareness of technical progress made throughout the scientific community in matters relatable to crime and delinquency. Research and pilot studies conducted outside this group of programs will be evaluated for applicability along with studies conducted within this group of programs. Important research activities in all technical disciplines will be monitored so that research progress can be utilized as soon as it becomes available.

This group of programs also makes provision for a systematic evaluation of the decision network of the present system of criminal justice. The purpose of this evaluation is to synthesize and improve the system from the standpoint of decisionmaking and to establish the requirements for the attendant information system.

Of primary importance from the standpoint of management decisionmaking is the mathematical computer simulation of the system of criminal justice. The construction of this model provides the mechanism for evaluating costs and effectiveness, and provides the decisionmaker with a method of determining the effect of policy changes and predicting future requirements, as well as enabling ultimate system optimization.

Crime Reporting Programs. The programs proposed in the crime reporting section are primarily directed toward improvement in the quality and quantity of crime statistics. It is the purpose of these programs to give increased attention to the problem of uniform and accurate reporting, including the content and format of this information. These reports not only will form the basis for investigation regarding the character and extent of crime but also will be used as the primary source of data for the potential offender identification program.

A program is included whose objective is to develop methods for obtaining more complete and standardized data relating to the characteristics of offenders.

Potential Offender Identification Programs. The overall objective of the prevention of crime leads to a particularly significant point: If we are to prevent crime, we must first learn the character of the susceptible crime group. The results of the initial study program have shown that it is possible to use a first rough-selection process—the application of an age criterion. There are, of course, many characteristics which might conceivably be used to reduce the size of the predictably susceptible group from all persons within a certain age group to persons within a subgroup which is of a statistically manageable size. Only after this selection process has been made can effective prevention programs be developed.

The characteristics utilized in this selection process cover the complete range of the technical disciplines. Demographic, sociological, physiological, psychological, and other criteria and measurements may be utilized. These new data are designed to enable the decisionmakers to act more effectively by supplying them with information regarding the characteristics of past successes and failures.

Prevention Programs. Crime prevention programs have for the most part been neglected in the past. From the standpoint of continued effort to optimize the system of criminal justice, prevention programs have a vital importance. They must aid in the determination of whatever functional relations exist between prevention expenditures and the number of criminals.

These programs are very closely related to the programs designed to fight poverty and provide opportunity for the youth of this country. Perhaps the most important difference between these proposed programs and other youth opportunity programs is that these programs have as their function the prevention of individuals from entering into and cycling through the system of criminal justice. Therefore, it follows that the selection process in these programs will be directed toward those individuals who do not show promise in our social system, rather than those who do.

Programs will include population planning, improved parental guidance programs, youth assistance, and juvenile placement.

Apprehension Programs. The group of apprehension programs have two fundamental purposes. The research aspect of these programs has as its objective the determination of functional relations which may exist between the rates of crime and delinquency and apprehension programs expenditures. This information is of significant concern to the optimization studies envisioned for the overall system of criminal justice.

The second aspect of these programs deals with the operational system benefits available. These are treated by the proposed programs according to two separable goals—offender identification and apprehension aids. As the crime-susceptible age group increases in the next few years, the number of individuals who must be positively identified will increase rapidly. Since this identification system is already in need of improvement, it is clear that a considerable effort must be made if the system is to serve its function.

There is also a large range of technical devices and aids which can be made available to law enforcement personnel. Before programs to develop these devices are initiated, however, an examination of the utility of each device should carefully be made in terms of its overall effectiveness. Therefore, the proposed programs provide for the pilot model field evaluation of such devices.

Case Management Programs. The case management programs have dual objectives. In relation to the overall systems approach for the State system of criminal justice, these programs must supply information regarding the functional relationships which exist between management program expenditures and the rate of recidivism. This information is of utmost importance to the optimization studies of the systems engineering programs.

The programs themselves are inherently important in their own right. Some of them are aimed at increasing the range of supervision available which can meet the needs of society with a minimum of expense and yet accrue the maximum operational benefit. Others are directed at increasing the effectiveness of parole and probation by providing various techniques designed to enhance the chances of success.

Manpower Development Programs. The manpower development programs are designed to provide the capability of meeting the numerous problems relating to the training and allocation of manpower resources for the overall program complex. It is to be expected that the implementation of the great variety of programs which have been proposed will lead to critical requirements for the availability of trained personnel when and where they are needed. These programs are intended to coordinate closely with the overall program management so as to anticipate manpower needs. The programs also propose to accept responsibility for seeing that all requirements are fulfilled.

Community Relations Programs. The community relations programs are designed to establish a communication liaison between the State system of criminal justice and the general public. Recognizing the high degree of emotionalism associated with many of the State programs in this area, these community relations programs will be responsible for the dissemination of pertinent information designed to keep the public informed of progress and to be receptive to additional public requirements for information.

4. Cost Estimation

The study included cost estimates for the first 5 years of the program. These are shown in the table below, with total system expenditure estimates for the present policy for comparison purposes.

Year	In millions	
	Program costs	Present system
1966	$13.2	$652
1967	24.0	677
1968	29.0	708
1969	28.5	737
1970	26.6	766
5-year total	121.3	3,540

The costs beyond these 5 years were not estimated, since any program proceeding past the pilot stage would be funded from the present policy costs by replacing an existing program. It is expected that the future costs of the complete full-scale implementation together with all other future operating costs will not exceed present policy costs.

APPENDIX D

California Integrated Transportation Study

The contract with North American Aviation was to study the total transportation planning problem of the State. Its job was to examine the scope of the problem and to specify a program of work for solving it; it was not to undertake the study and design of the integrated system of transportation itself.

"The demand for transportation," the body of the final report begins, "is a derived demand. Thus the amount of activity in the transportation industry depends on the amount of activity in the economy at large." This sets the tone of the study. In order to consider the demands for transportation and the possibilities for new kinds of transportation, one must begin by looking at the economy of the community at large.

Even a cursory study will show that there are dramatic new possibilities for new kinds of transportation, that new technologies will have drastic effects on the requirements for transportation in the future, and that the growth of California's population and economy will create severe transportation problems in the future unless they are foreseen and dealt with now.

The study outlines the planning device needed to provide the quantitative measurements that will support the human judgment and decisions in the transportation study. It calls for the application and development of appropriate mathematical models, coupled with the use of computer simulation procedures.

Six submodels will be used, including three basic submodels—population, econometric, and land use. The basic three feed a fourth model which is used to allocate demand to transportation modes and define the flow patterns. This information passes into a fifth submodel used to simulate existing or possible transportation systems and networks.

Development and use of the models will assist in finding solutions to the problems transportation planners face, and will provide the means to assess and choose among several candidate networks and combinations of modes.

Completely new modes of transportation as well as improvements in existing modes can be placed into competition with other projected services, and their capabilities, conveniences, feasibility, timeliness, and cost compared.

The report estimated that to construct and initially exercise such a planning device would require approximately 52 months. The various submodels, however, would be completed and operative at various intervals throughout this period and could be used to analyze specific types of problems unrelated to transportation.

1. California Today and Trends

The study began with an overview of certain aspects of the California economy, including broad considerations of total population, labor force and employment, total personal income as well as per capita personal income, and industrial sources of income.

In the course of this examination it was found that the population of California is expected to grow from 18 million inhabitants in 1965 to 28 million in 1980. The growth in the total population will be accompanied by an even greater relative growth in the labor force. The civilian labor force in California is estimated to increase from 7.4 million to 11.5 million in 1980. The age composition of the labor force is expected to change, with the change consisting of an expansion in that segment of the labor force which will be less than 35 years old in 1980.

In the recent past industrial sources of personal income have changed. Since 1950 the relative importance of manufacturing as a source of income has increased. This is also true of the government sector, whereas farming has declined in importance. Compared to the rest of the United States, the per capita personal income of Californians is considerably higher, and California's share of total personal income has been increasing.

Using value added by manufacture as an indicator of economic activity, it was noted that California's share has increased since 1958. During this period California has been growing at a greater rate than the United States.

Foreign trade moving through California customs district exhibits a general upward trend. In terms of both weight and value, the ports of Los Angeles and San Francisco account for nearly all the activity in this field.

Land usage was briefly examined. It was revealed that the big land holder in the State is the Federal Government which holds nearly 44 percent of the total land area in California. The State of California holds roughly 1 percent of total land, and the rest is privately held. In recent years there has been a decrease in the number of farms and in total farmland. At the same time the number of incorporated communities has increased.

In examining the existing transportation network in California it was found that, measured by annual operating revenues, the bulk of truck transportation is carried out by private and not-for-hire carriers.

The review of California transportation revealed that 36 railroads are operating in the State over nearly 7,500 miles of intercity road. The Southern Pacific Co. and the Atchison, Topeka & Santa Fe Railway Co. are the two predominant railroads in the State. Together they account for approximately 70 percent of the total miles of road. Freight is the principal source of revenue for railroads operating in the State, passenger revenues being rather insignificant in that they make up only 5 percent of the total. Most of the railway freight revenues are derived from interstate traffic. The most important commodity groups moved by the railroads (based on carloadings) are farm products and lumber and wood products.

In the area of air transportation, the bulk of intercity service in California is carried out by 12 operators. The Los Angeles-San Francisco segment is by far the largest air passenger market in California. This market is served by several interstate carriers plus one intrastate carrier. Measured in terms of the number of passengers carried, the intrastate carrier is the largest on this particular segment. Many other California communities are linked by air service, and in 1962 there were at least 18 city pairs with the number of outbound plus inbound passengers exceeding 1,000.

Maritime commerce between California points is a small industry, with most of the activities being localized in the Los Angeles and San Francisco port areas.

As is true in many other areas in the United States and abroad, portions of the transportation industry in California are heavily regulated. The regulation is performed primarily by the Public Utilities Commission, although other agencies, such as the California Highway Patrol and the Department of Motor Vehicles, have regulatory powers.

Within the framework of economic regulation, the State has the power to fix maximum and minimum rates, as well as the exact rate to be charged. The number of carriers in operation at any one time is controlled through the requirement that carriers must have certificates of public convenience and necessity or permits in order to have legal operations. The power of the State to regulate also extends into the area of service, route, and schedule regulation, and the commodities which carriers may haul are prescribed. Carriers in California are subject to limitations on the size and weight capacity of their equipments, and they must observe rigid safety standards.

2. The Impact of New Technologies on Transportation

Technological progress in a number of areas will affect future modes of transportation. New types of aircraft, hydrofoils, high-speed trains, all loom in the future as possible ways of improving the transportation system.

But the transportation system of the future will be affected by technological developments in another way, by affecting the demands for transportation. Therefore, such areas as new techniques in energy conversion, automation, and communication must also be considered.

New population pressures will lead to increased production in California, and even to the establishment of industries which do not now exist. This will be reflected in a rapidly increasing demand for all kinds of transportation—more highways, higher railroad traffic, increased coast and inland waterway traffic, and more transportation by air.

Nationally, air transportation accounts for about 55 percent of the total common-carrier passenger intercity traffic. By 2000, air transportation is expected to account for 85 percent. Helicopter service and, at a later date, VTOL transportation should carry much of this increased traffic in California. Surface transportation is visualized to be integrated with air transportation and to develop in a regional form which ultimately might be tied into a statewide system. Because of its regional nature and the availability of air transport for longer distances, the surface system need not have a speed in excess of 80 m.p.h. The technology will be available for surface speeds which compare to the airplane's, but geography and economics appear to be against such a development.

Developments in communications will tend to reduce the need for travel and, combined with the application of computers, could cause the characteristics of cities to tend toward the "command post" concept. Computers and automation will also lead to a shorter workweek, with resulting increase in recreational time.

An ample supply of energy should be available through the use of nuclear power, particularly after the breeder reactor has been thoroughly developed. If fusion reactors become a reality, energy resources will be practically limitless. The technology to support an increased population and increased production will be available. The technology to provide for the transportation needs which these increases engender will also be available. The greatest limitation is likely to be economic.

3. Future Transportation Problems

Many aspects of potential transportation problems in the future seem reasonably certain from examination of California today and of the impact of major trends. Other equally important possibilities, however, are less certain. The major influencing factors must be recognized and understood if planning for future transportation needs is to be effected. A number of significant current transportation problems can be pointed out. The most evident of such problems is certainly that of home-to-work commuting in the major metropolitan areas. Many sections of new freeways operate at maximum loads during rush hours, practically from day of opening.

A second important problem is that of traffic congestion on major arteries—not only highways but major airports as well.

A third significant problem is the lack of efficient public, local, and metropolitan transportation. This is particularly a problem between airports and business centers. Other problems include: Modal coverage limitations, outdated load and unload transfer procedures, imbalances in the use of various modes, and the complexity of rate regulation, taxation, and subsidies.

These problems are responsible for a number of economic and social losses, loss of time, inconvenience, and increased costs resulting from traffic congestion. Inefficient transportation is responsible for a loss of mobility and business.

California's future problems in transportation will stem from growth in population and the economy generally, changes in distributions of land use, technological advances, and evolutions in governmental control practices. The effect of these is less certain. Population growth, for example, may proceed in various ways. A continuation of the current trend may be hypothesized where the population will be concentrated in high density megalopolism in the San Francisco Bay area and the Los Angeles/San Diego area. However, the development of improved communications which would permit dispersed working areas may result in a dispersed low-density population.

In the first case, we will obviously have a magnification of today's metropolitan problems. In the second case, the problem will be of interurban flow. Another major problem resulting from population growth will be a ceiling on land availability and competition for land use. Further, as the size of the system increases the complexity and severity of interface and interference problems also increase. New modes of transportation which may be introduced will generate new integration and control problems. The need for central coordination and for public education will grow and become more pressing.

4. A Systems Approach to Problem Solutions

The study thus produced an image of transportation as a subsystem embedded in the larger structure of the California economy as a whole. It is not possible to consider transportation without considering the mutual interactions between it and other spheres of socioeconomic interest and development in the State. The study further indicated that transportation would present problems in the future of unparalleled magnitude and complexity. The uncertainties in problem definition coupled with the almost limitless range of possible developments create a particularly difficult analysis and planning problem.

The technique proposed by the study team for handling this complex of problems is simulation. The intimate relationship between transportation and the other affairs of the State indicates that the simulation must be of the entire State system. The State's major internal activities, or subsystems, must be represented along with transportation.

Examination of the representation of California as a system suggests several implications. The broadly defined transportation subsystem is seen to be a central, vital element of the overall State system upon which the functioning of every other subsystem is dependent. This suggests the important possibility that the transportation subsystem may be used to influence many aspects of the State's functioning, ranging from the level of the economy to population distribution and land use. Furthermore, any attempt to solve transportation problems based on independent studies of the population and economy would not allow for investigation of such a possibility. For these reasons, it is necessary to simulate most other aspects of California activities when studying transportation.

Evaluation of future transportation systems must incorporate as an integral part projections of the economy, population, land use, and their interactions. In such a simulation, these projections would be used to form a projection of the future "profile" of the State in order to derive transportation demands. Various submodels in the aggregate comprise the simulation. Three basic submodels, population, econometric, and land use, develop possible future transportation demands. These feed a fourth, which is used to allocate demand to transportation modes and define the flow patterns. This information passes into a fifth submodel used to simulate existing or possible transportation systems and networks. The results of this simulation are fed into a sixth submodel for evaluation.

It should be noted that within the operation of the model, the analysis proceeds incrementally: A projection of conditions at some future point in time is not made in a single step, but rather is reached through a progression of incremental time periods chosen at will but usually representing 5 to 10 years. This procedure permits the resolution of many problems which plague planning activities by producing the sequence of occurrences, allowing the point of divergence from desired results to be identified.

Population Submodel. The population submodel activates and drives the entire California model through the development of population projections from the base year, 1963. An initial projection to the desired point in time is made for each of three nonoverlapping entities: California, the rest of the United States, and the rest of the world. From a profile of expenditures by the projected populations, the demand for goods can be developed and is interpreted in terms of dollars distributed over sectors of the economy, including purchases of consumer goods produced by industrial sectors.

Econometric Submodel. The demands discussed above form the driving functions for the econometric submodel, the heart of which is a rather complex analysis which accounts for interindustry activity. The objective is to establish the total output of every sector of the economy as well as the final fund flows between industries. The results of this analysis have many uses. For instance, productivity trends for each of the industrial sectors can be utilized to derive the labor force necessary to achieve the output required by the final demand. Any increment change in output is eventually utilized by the land use submodel and converted into new requirements for land use. In addition, changes in the work force can be checked against the initially projected population growth and characteristics within the State.

Land Use Submodel. Conversion of economic activity into land use is the next step in the analysis, representing an interplay between the econometric submodel and the land use submodel. This is done by allocating the increase in economic activity to basic land units or zones on the basis of relative attractiveness of the zone to the activity considered. In application, a descending order of priorities segments the land use: Manufacturing, residential, retail and services, and finally wholesale locations. The final product of the land use submodel is the geographic specification of centroids of origins and destinations of personal trips and of those where commodity flows are generated (sources) and absorbed (sinks).

Transportation Demand Submodel. The analysis then proceeds to the development of the transportation demands generated by a given placement of people and other activities. This is done in two distinct elements, commodity flow and people flow.

Commodity flow is established on a yearly basis adjusted for seasonal variations. Joint operation of the land use and econometric submodels allows all sources and sinks to be geographically situated and the total flow between them determined. Within the transportation demand submodel, a market allocation process is applied to measure the flow between each source and sink. The result is the specification by commodity of the strength of desire, or demand, for flow.

The desire for personal travel is developed from information provided by the population, land use and econometric submodels. The generation of desire to travel between zones is dependent upon the number of people and their economic status within the origin zone and the accessibility and attractiveness of the destination zone. The distance and/or cost of travel between zones is employed as a resistance factor.

Transportation Simulation Submodel. Information derived from the transportation demand submodel is fed into the transportation simulation submodel, which simulates movement (the handling of the demand) over a transportation network. Initially, the transportation demands for the year under study are applied to the transportation networks which exist or are firmly planned in the base year. This permits, for example, assessment of the growth potential of a given transportation link of an existing network in terms of how long and well it will service future demand as influenced by several variable factors.

Evaluation Submodel. The transportation simulation submodel furnishes information to the evaluation submodel describing the deficiencies, link overloads, revenues collected, etc., of alternative transportation networks. In turn, the evaluation submodel determines, through an iterative process, the network (mix of modes, routes) which should be applied to best serve the overall transportation demands and requirements of the periods under consideration. Technological changes related to new modes of transportation are reflected directly into network changes in the transportation simulation submodel. In the iterative process, network changes are reflected back into the population, econometric, and land use submodels, with the principal effect being a change in attractiveness of the geographic zones with respect to their accessibility—one of the factors which determines the growth of a zone.

This then completes one major cycle through the submodels, resulting in a new description of the land use, population, economy, and transportation networks which might exist at the time under consideration. The model can again be cycled in the same fashion to obtain other descriptions of the total California system for the same time period.

Other uses of the California transportation model are anticipated, one of which is to measure the impact of contingencies. For instance, changes in transportation demands induced by floods, earthquakes, or fires are immediately reflected. In addition, technological advances likely to have a persuasive influence on the economy or on the distribution of the population would be incorporated in the economic submodel.

5. Program Plan

A plan to accomplish the research analysis and simulation model development was also developed. The suggested program spans a 52-month period. The cost estimates range from a low figure of $5.9 million to a more expensive (but higher probability of success) figure of $9.2 million.

The estimated schedule for the completion of the six submodels is as follows:

Basic Submodels

1. Land use: Developed and checked out at the end of the 10th month. Can be used independently to investigate landuse trends and their attendant effects upon industrial and population distributions.
2. Population: Developed and checked out at the end of the 11th month. Can be used independently to investigate population growth and demand trends.
3. Econometric: Developed and checked out at the end of the 15th month. Can be used independently to project interindustry flow, productivity, and employment trends, and gross state product.

These basic submodels would be integrated with each other and with the data base at the end of the 21st month, and could be exercised to measure and project in a number of areas.

Transportation submodels:

4. Transportation simulation: Developed and checked out at the end of 25th month. Using independently generated inputs, can be used to assess adequacy of links by mode and to examine new or proposed transportation schemes.
5. Evaluation: Developed and checked out at the end of the 26th month. Can be used to evaluate the outputs of the independently operated transportation simulation submodel as well as the information generated by simultaneous operation of the population, land use, and econometric submodels.
6. Transportation demand: Developed and checked out at the end of the 29th month. Serves as the bridge between the basic and transportation submodels.

All models would then need to be fully integrated and validated as a functional unit against an actual situation. This should be accomplished by the end of the 42d month. Initial analyses on the validated model and final reporting are estimated to require an additional 10 months.

A seventh task is included, in addition to the six submodels: "Supporting studies, system integration, and validation and program reporting." This will include continuing investigations into advanced technology. This effort is intended to provide insight into the impact of new technologies on transportation and also valuable background material to evaluate proposed new transportation systems. Other studies recommended are a government study (of regulations, subsidies, taxes, planning, etc.) and a contingency study.

TRANSFERABILITY OF RESEARCH AND DEVELOPMENT SKILLS IN THE AEROSPACE INDUSTRY

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PREFACE

Spurred by what many consider an unduly pessimistic outlook for the aerospace industry and apparently optimistic about the transferability of the industry's research and development capabilities, the State of California has moved to stimulate diversification and, at the same time, solve a number of its own difficult and long-standing problems. The State has paid public tribute to the industry's scientists and engineers and asserted its confidence in their ability to apply the "systems approach" to questions of State and local interest. Whether such optimism is warranted is a significant but hardly decisive issue. The hypothesis is still unproved that scientific and engineering skills, focused for many years almost exclusively on problems of national defense and space exploration, can be oriented easily to other fields of public concern.

This hypothesis has been examined in some detail for this report: By interviews with public and private individuals to gain a better insight into the questions surrounding such a transfer; by a reasonably extensive, although far from complete, review of related writings; and by an analysis of the scientific and engineering activities throughout the phases of a large-scale system program (with an attempt in the process to relate the activities to the relative transferabilities of identifiable groups of scientists and engineers associated with each phase). Four aerospace contractors for the State of California provided case examples of the aerospace industry's attempt to apply some of its research and development skills to civilian public projects. Therefore, their studies were also used in helping judge the ease with which aerospace scientists and engineers could transfer their talents to the early phases of a public system program. While open to debate, as all such issues must inevitably be, the conclusions reached as a result of the examination are based on an honest and, hopefully, objective appraisal of the information available to the authors.

This document also presents results of work sponsored jointly by the Directorate of Operational Requirements and Development Plans, DCS/Research and Development, Headquarters U.S. Air Force, and Analytic Services Inc., as part of its independent research program. These results do not necessarily represent the opinion of anyone other than the authors.

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Transferability of Research and Development Skills in the Aerospace Industry

Summary

The suggestion that the aerospace industry be used to help solve complex domestic problems raises two closely related questions:

1. Will civilian public projects become important as diversification opportunities for the aerospace industry?
2. How well do the aerospace industry's research and development capabilities match those needed in civilian public projects?

Both questions are important, and both bear on the more general issue of the transferability of research and development capabilities in the aerospace industry. One asks whether the capabilities will be transferred; the other, how difficult the transfer would be.

Civilian Public Projects: New Market for the Aerospace Industry?

The public is apparently placing increased importance on a number of difficult and long-standing domestic problems. Moreover, interest is being expressed in attempts to solve some of the problems by drawing on new techniques and industries formerly identified with advanced technological endeavors. California, for example, in an almost unique situation favoring the adoption of novel methods, has asked its large aerospace industry to study four of its most urgent problems: Waste management, crime and delinquency, transportation, and information storage and handling. This action may be the first step in a trend toward the use of a process that has been noticeably lacking at the State level; i.e., utilization of science and scientific research in the type of policy-supporting role used on the Federal level since the beginning of World War II.

Because of the growing complexity of domestic problems, this trend may continue. However, there seem few reasons to assume that other States will necessarily follow California's example in turning to aerospace companies. A number of other kinds of organizations appear equally capable and useful.

Undoubtedly, the aerospace industry will become more aggressive in its attempts to diversify into new product areas if the defense-space market fails to grow as it has in the past. Some company officials believe that the market has already lost its former growth characteristics and, consequently, they are starting to look seriously at possibilities offered by civilian public projects. This contrasts rather markedly with the limited management support and interest often given past attempts to diversify into the consumer products market.

The advances needed to solve most domestic problems lie more in the fields of social, political, and economic science than in the technological areas identified with the aerospace industry. Therefore, the undertaking of civilian public projects would be a reversal in the aerospace industry's historical trend toward products of increasing technological complexity. In a market in which its advanced research and development capabilities would be less important and where a number of other companies are already actively engaged, the aerospace industry would face a more competitive situation than it has in the past. Then, too, existing institutional obstacles, long-standing legal restrictions, and vested interests of individuals and groups, both public and private, could lead to other forms of competition for the industry.

Aerospace R. & D. Skills: Important Characteristics

Some think that the aerospace industry's experience with the "systems approach" is the unique quality that it can bring to bear on complex domestic problems. While attractive in its simplicity, this point of view obscures the true characteristics of the industry. What it actually has to offer is an almost unique combination of specialized industrial experience, overall capability, and individual scientific and engineering skills.

There are a number of essential differences between the experience of the aerospace industry and that of others:

1. The industry is accustomed to working with a customer that identifies its needs and establishes objectives toward which specific programs can be directed. Thus, the mar-

keting function is frequently a joint endeavor.

2. In the past, at least, the objectives have usually led to programs requiring major technological gains.
3. Owing to the magnitude of weapon system programs, the customer has assumed the initiative (and the risk) and has financed the development of the products it wants to buy. As a result, the customer controls, to a rather significant extent, not only the approach the industry takes in developing a system, but also the internal operations of the company.
4. Most weapon and space systems require the development of advanced subsystems by associate or subcontractors working in different technological fields and under various degrees of technological uncertainty. As an integrating contractor contractually obligated to deliver a working system, an aerospace company must work to ensure the performance and compatibility of all elements under development.
5. The industry has had to learn how to meld the efforts of large numbers of scientists and engineers.

These five differences add up to an "industry experience" almost wholly confined to the development and production of large-scale systems for the Federal Government, where inherent technological uncertainties in development and large procurement expenditures are characteristic of the acquisition process.

Aerospace firms have developed broad capabilities in at least four functional areas:

1. Aerospace companies customarily engage in activities concerned with determining needs, establishing policy and objectives, estimating future technical possibilities, synthesizing and analyzing system concepts, and conducting studies to determine efficient resource allocations.
2. The aerospace industry carries out system engineering and technical direction functions which are somewhat analogous to the more traditional architect-engineer functions.
3. The industry has developed capabilities based on its experience in designing, developing, and manufacturing what amounts in a technological sense to progressively advanced models of similar end products.
4. From time to time, aerospace companies have demonstrated their capabilities for operating large-scale, Government-owned systems.

Thus, the aerospace industry possesses the experience and ability to carry out a number of different functions, each of which has some potential utility for civilian public projects.

Scientific and engineering activities vary as a large-scale system program progresses through its life cycle. Therefore, the skills, work backgrounds, and educational attainments of scientists and engineers in one program phase tend to differ from the corresponding characteristics of those employed in other phases. Or, at least, some characteristics are apparently much more predominant in one phase than in another.

Important contributions in the public-projects area may be made in the future by scientists and engineers regularly assigned to earlier program phases. However, the scientific and engineering skills of the industry seem overwhelmingly oriented toward development and development test functions. One suspects, then, that more attention needs to be given to the transferability of those who spend their time almost wholly on development and development test activities. This is especially true because the latter group, consisting principally of engineers holding undergraduate degrees and those with no degrees, is probably not in short supply now, nor is it likely to be in the foreseeable future.

As the aerospace market is constituted today, the overall distribution of scientists and engineers throughout the industry probably approximates fairly well the technical profile of an "average company," for there is substantial homogeneity among large aerospace programs. To speak of a typical public program in this sense, however, is very likely misleading. The distribution of technical fields of specialization within one public program frequently will vary markedly from those in another.

Conclusions

Studies such as those performed by the aerospace industry for the State of California may be useful in helping identify possible solutions to complex domestic problems. However, as indicators of the ease with which the research and development capabilities in the aerospace industry could transfer to civilian public projects, they are inconclusive, testing as they do only a very small sample of the seemingly most transferable industry scientists and engineers.

Just as its success in performing any function in large domestic projects will depend on its ability to compete with other interested public and private instrumentalities, so will the future success of the industry in conducting studies of this sort. Then, too, how capable and resourceful governmental jurisdictions will prove to be in overcoming individual and institutional barriers will determine to a large extent the importance of civilian public projects as diversification opportunities.

To assess the degree of mismatch between the industry's scientific and engineering skills and the skills needed to design and develop large-scale civilian systems is extremely difficult without reference to specific public programs. Nevertheless, some insight into the relative transferabilities of industry's scientists and engineers can be gained by analyzing activities in each of the weapon system program phases. Based on such analyses, the following conclusions were reached:

1. Scientists and engineers in the early phases should have the least trouble in transferring their skills.
2. Scientists and engineers in the design and development phase would very likely encounter the most difficulty in transferring their skills.
3. Scientists and engineers in the production and acquisition phases would probably find a situation somewhere between 1 and 2, above.

Thus, the largest group of scientists and engineers in the industry, those engaged in design and development activities, may prove to be the least transferable. Still, whether the scientific and engineering skills in the aerospace industry could be transferred easily may not be a conclusive issue. For, after all, other problems surrounding industry diversification appear much more difficult than the problems accompanying the transfer of its scientists and engineers.

Introduction

A fairly substantial body of opinion holds that civilian public projects offer new and potentially profitable opportunities for the aerospace industry—opportunities that may afford offsets to cutbacks or intraindustry shifts in defense and space spending. Whether such views have merit depends largely on the nature and extent of the cutbacks or shifts, the probable growth of the civilian market, and the characteristics of the industry as they relate to its ability and desire to move into new product areas. The purpose here is to examine these factors, trying in the process to clarify their relationships to the objectives of this study.

The Aerospace Market

Many profess to see in the move to diversify into the civilian public-projects area a similarity to an earlier pattern of diversification within the aerospace industry—a pattern that began with the shift from aircraft to missile development and production and continued with the shift into the space program. The relative ease with which these shifts were accomplished is taken by some to be an indication that a shift into the new market, should the market develop, could be brought about just as readily. While at least some surface indications support this point of view, there are also a number of questions which can be raised in opposition. To adopt either view would be premature without an understanding of the earlier diversification efforts of the industry and, in particular, how it has historically responded to past changes in the defense-space market.

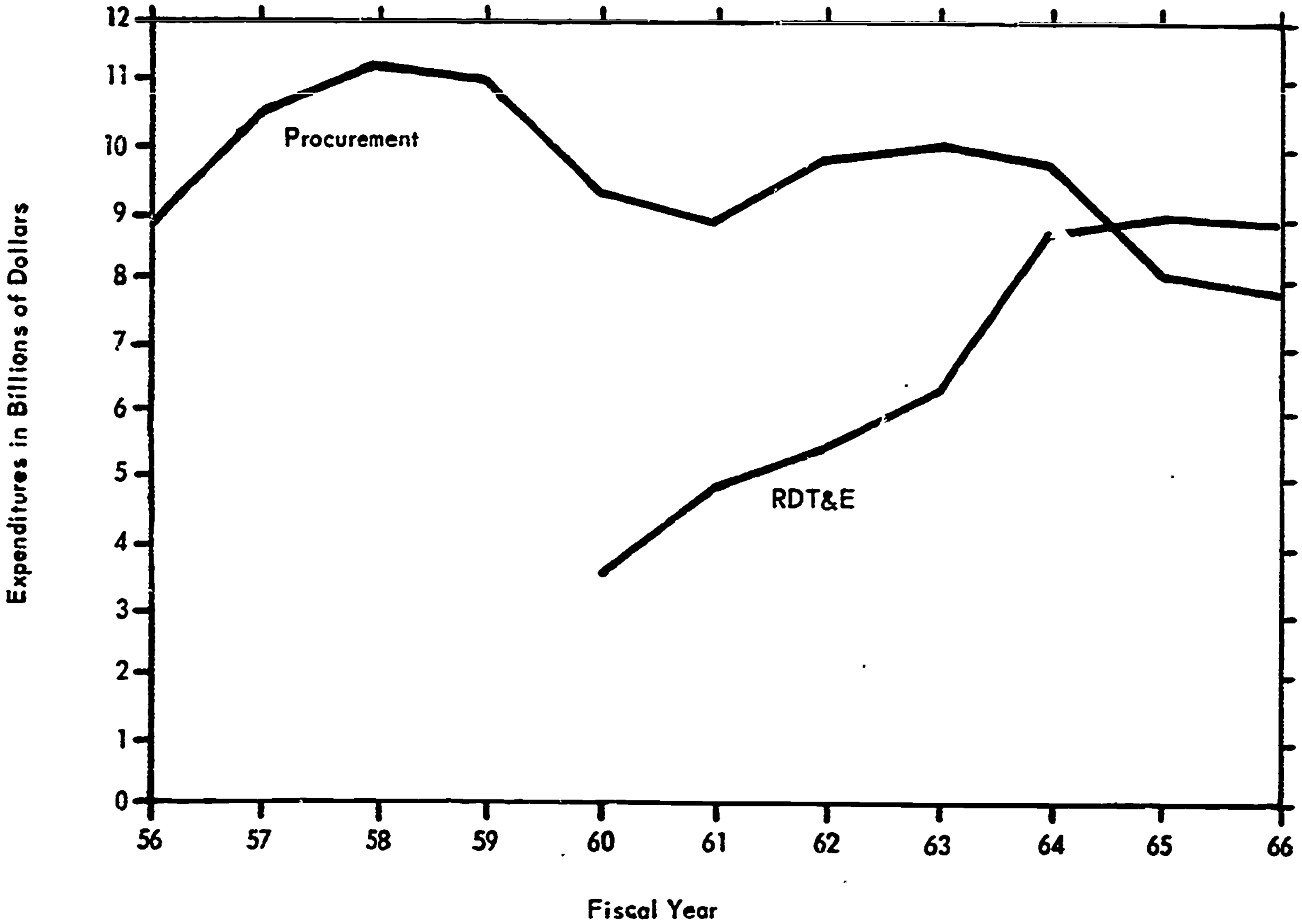
Perhaps the most significant trend which has emerged in the aerospace industry during the last two decades is the progressive increase in the ratio of research, development, test, and evaluation (RDT&E) to procurement of hardware. Figure 1 illustrates this trend over the last several years, showing an expenditure crossover point in fiscal 1964, where RDT&E expenditures became larger. While a part of this change in the military budget can be attributed to an actual decline in procurement, the increased complexity of modern weapon systems has undoubtedly played a role as well. For example, according to the Department of Defense (DOD) Comptroller, while aircraft RDT&E costs since 1960 have run about one-tenth of aircraft procurement costs, missile RDT&E has approximately equaled missile procurement costs. And because of the research and development character of most space activities today, the budget of the National Aeronautics and Space Administration (NASA) can be almost wholly classified as RDT&E funds. What this says, of course, is that the aerospace industry, as it merged its missile and space programs with the development and production of aircraft, has more and more undertaken programs of increasing scientific and technological complexity.

Effects stemming from the greater emphasis on research and development have touched almost every aspect of the industry's operations. Capital outlays have increased, new subsidiaries have arisen, the ratio of technical to total employees has increased, and the product mix of the industry has broadened.

In the last decade, as revealed in figure 2, capital expenditures sharply increased in the period 1954–57 and again from 1960–63. While the increased rate of expansion in the first was occasioned by

(1) the need to modernize what were essentially World War II plants; (2) the divesture of many Government-owned facilities and a considerable decrease in Federal expenditures for industry's operation of such facilities; and (3) the almost concurrent advent of the ballistic missile programs, which required increased manufacturing capacity and novel test facilities,

FIGURE 1. *Aerospace Procurement and RDT&E Expenditures (Fiscal Years 1956–64, Actual; 1965–66, Estimated)*



SOURCE: R. Dean George and Edmund M. Phelan, "Analysis of Aerospace Funding and Employment—Fiscal Years 1956 to 1966," 1965 (information from Office of the Secretary of Defense Comptroller and annual budget documents).

the second resulted from the buildup associated with the advent of the National Space Program.[1] As a result, new R. & D. facilities accounted for a major portion of the capital expenditures of these companies from 1954 to 1963. What this meant in terms of floor space utilization is shown by data developed by Shapero and Vollmer in their analysis of 19 major aerospace contractors (see table 1). These data show a predictable and unmistakable response to the shift toward products of higher technological complexity.

Even before 1954, however, the effects of market changes were being felt on the management of a number of aerospace firms. Miller has described North American Aviation's experience as follows:

> North American Aviation was one of the first companies in the aerospace industry to recognize the importance of new technical fields and act upon it. In 1945 it proposed a program of missile research and development to the Air Force which later became the NAVAHO intercontinental cruise missile program. As part of this effort, North American developed a liquid-fuel rocket engine which was a considerable improvement over the German V-2. This development was the origin of the Rocketdyne Division, which supplied rocket engines for most of the ballistic missile and NASA booster programs. During this same period, the former North American Aviation Technical Laboratory acquired a pioneering competence in inertial guidance systems which later enabled it to be established as the Autonetics Division, the largest component of NAA for several years.[2]

TABLE 1. FLOOR SPACE ALLOCATION IN SELECTED AEROSPACE ACTIVITIES FOR 1955 AND 1961

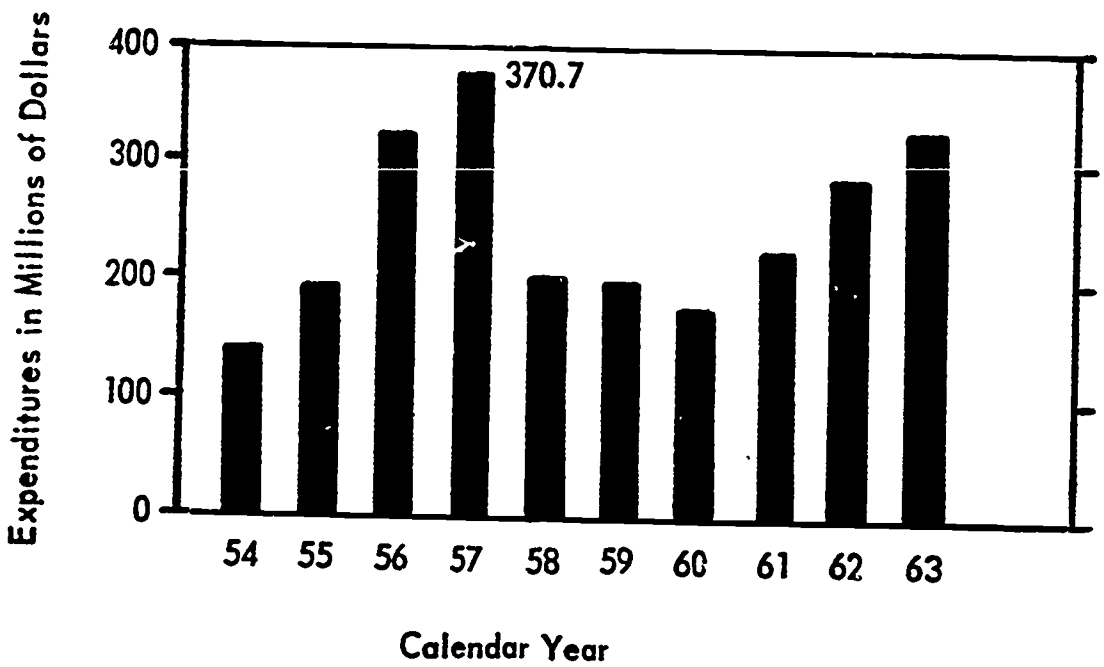
Allocation	Percent of total floor space used	
	1955	1961
Manufacturing	51.7	39.9
Laboratory and office	17.9	28.4
Storage	14.6	14.4
Other uses	15.8	18.3

SOURCE: Albert Shapero and Howard M. Vollmer, "Technical Profile of the Industry," *The Industry-Government Aerospace Relationship*, vol. II (Menlo Park: Stanford Research Institute, 1963), p. 288.

[1] Thomas G. Miller, Jr., "Strategies for Survival in the Aerospace Industry" (Cambridge: Arthur D. Little, Inc., 1964), p. 17.

[2] *Ibid.*, p. 31.

FIGURE 2. *Aerospace Plant and Equipment Expenditures*



SOURCE: R. Dean George and Edmund M. Phelan, "Analysis of Aerospace Funding and Employment—Fiscal Years 1956 to 1966," 1965 (information from Bureau of the Census).

This tendency to establish separate divisions or subsidiaries in new areas of company competence has become a fairly common practice in the industry, as further illustrated by Aerojet-General Corp.'s establishment of Space-General in 1961 "to undertake research, development, and production in the broad fields of electronics and space technology," and the Lockheed Aircraft Co.'s establisment of the Lockheed Missiles and Space Co. in 1954 to manage a number of growing systems programs.

The increase in corporate entities in the industry has not been matched by a corresponding growth in employment, for, as shown in figure 3, the total number of employees has steadily fallen off since a peak in 1957. Employment of production workers has followed a similar decline, and while the reduced number of cost-plus-fixed-fee contracts entered into by the DOD since 1960 may have discouraged stockpiling of employees,[3] it is probable that the decline in production contracts and possibly a wider use of automated manufacturing tools are principally responsible for the work force reductions. In contrast, as shown in figure 4, the increase in RDT&E contracts has resulted in the steady growth in the employment of scientists and engineers, almost doubling over the 8-year period since 1957.

A broadening of the technological base of the aerospace industry accompanied the rise in employment of scientists and engineers as many companies moved into new fields and attempted to gain inhouse research and development capabilities in a number of areas formerly dominated by non-aerospace firms. And so the picture of the industry during almost the last two decades has been one of steady movement toward increased scientific and engineering participation—from which products of increasing technological sophistication have resulted.

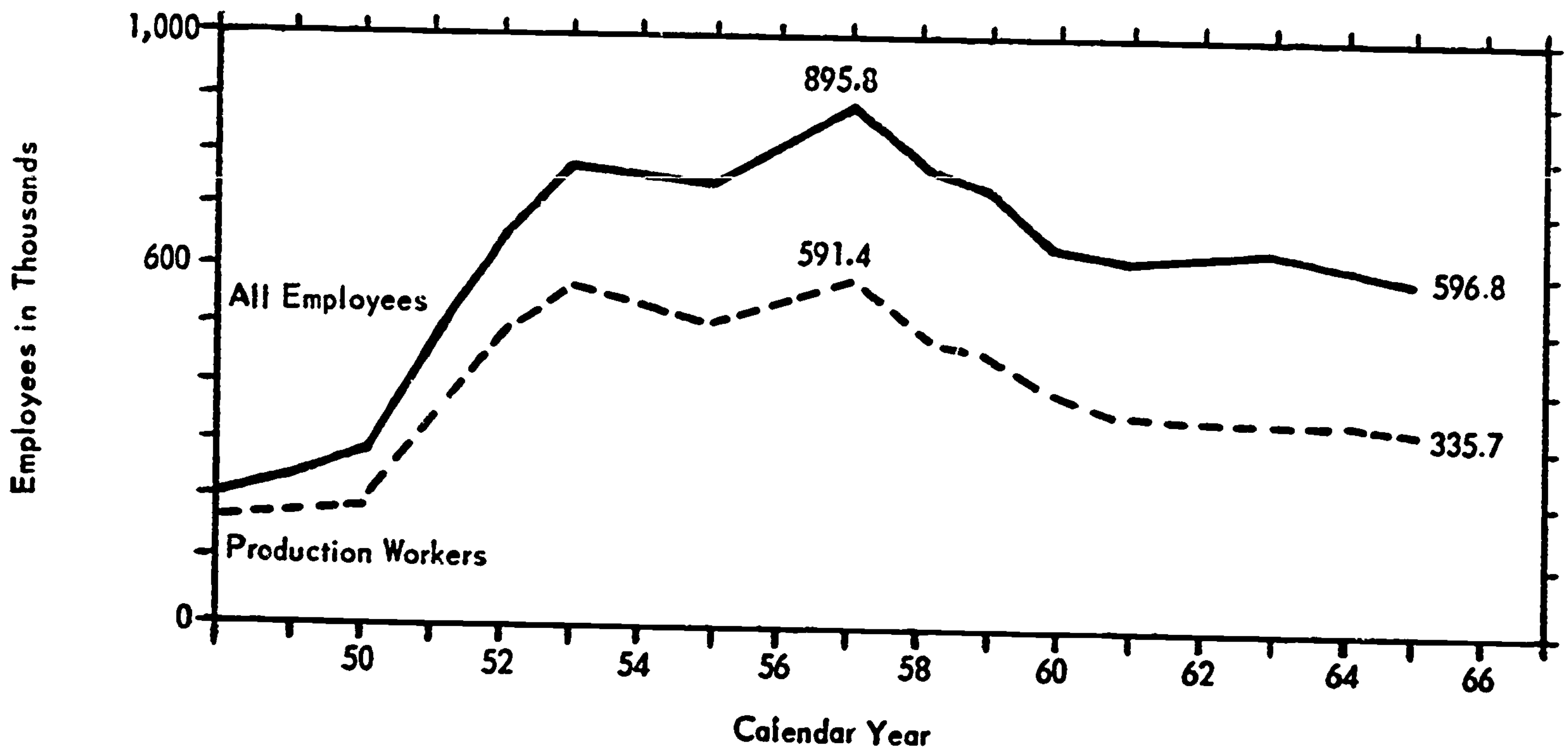
But would a move into the civilian public-project area be a continuation of this trend? Probably not, for many would agree that most domestic problems facing the Nation today could be substantially alleviated, if not solved, by the application of technology much less advanced than that found in the aerospace industry today. And while there are certain exceptions, such as the application of nuclear technology to civilian needs and the development of supersonic passenger liners, the major advances needed probably lie more in the fields of social, political, and economic science and less in the technological areas identified with the aerospace industry. Still, this is not to say that the scientific and technological capabilities of the aerospace industry could not be usefully employed in applying present-day technology to domestic areas or that improvements in these areas would not be valuable and far reaching.

Growing Importance of Civilian Public Projects

Whether civilian public projects actually represent even a potential market for the aerospace industry depends to a great extent on the importance the public places on satisfying domestic needs at the Federal, State, and local levels. A number of authors have described how the aero-

[3] Joseph D. Mooney, "Displaced Engineers and Scientists: An Analysis of the Labor Market Adjustment of Professional Personnel," (Massachusetts Institute of Technology [thesis], 1965), p. 21.

FIGURE 3. *Aerospace Employment—Total and Production Only*



SOURCE: R. Dean George and Edmund M. Phelan, "Analysis of Aerospace Funding and Employment—Fiscal Years 1956 to 1966," 1965 (information from Bureau of Labor Statistics).

space industry might assist in meeting such needs.[4] Most have generally described them as urgent and important, although their importance, as viewed by the general public, cannot be measured quantitatively. There are, however, a number of indicators, ranging from increased coverage in the press to more and more attention to the subject in statements and addresses by local, State, and national leaders. For example, Julius A. Stratton, president of Massachusetts Institute of Technology, in a June 1964 commencement address remarked on the need for solutions in many problem areas in this fashion:

> And so, too, our society—the body politic—is subject to old, chronic disorders and to new ailments. These diseases of the system are emerging in increasing number; and we must be courageous in recognizing that they are themselves the byproducts of our high technological environment. . . . We can no longer afford to nibble away piece by piece at the problems of the modern city—of transportation—of underdeveloped economies—of automation—or of disarmament.[5]

Then, too, the importance that the present Administration places on these problems was pointed out in President Johnson's 1965 state of the Union message.[6]

But the actions of Congress, perhaps more than any other single indicator, are a forceful exhibit of the public concern for domestic needs, for, after all, congressional appropriations are necessary to transform words into meaningful programs to alleviate the problems now before the country. Table 2, in its overview of Federal spending, suggests that during the last decade Congress has tended to ascribe an increasing importance to public needs, spending 15.2 percent of total Federal payments in fiscal 1956 for health, labor, welfare, education, housing, and community development; 23.4 percent in fiscal 1961; with 29.3 percent estimated for fiscal 1966.

TABLE 2. COMPOSITION OF FEDERAL PAYMENTS

Functions	Percent of total by fiscal year		
	1956 (actual)	1961 (actual)	1966 (estimate)
Health, labor, welfare; education; housing, community development	15.2	23.4	29.3
National defense, space, interest	63.5	55.9	52.2
Other	21.4	20.7	18.5
Total	[1] 100.0	100.0	100.0

[1] There appears to be a discrepancy here of 0.1.

SOURCE: *The Budget in Brief, Fiscal Year 1966* (Washington: U.S. GPO, 1965), p. 18.

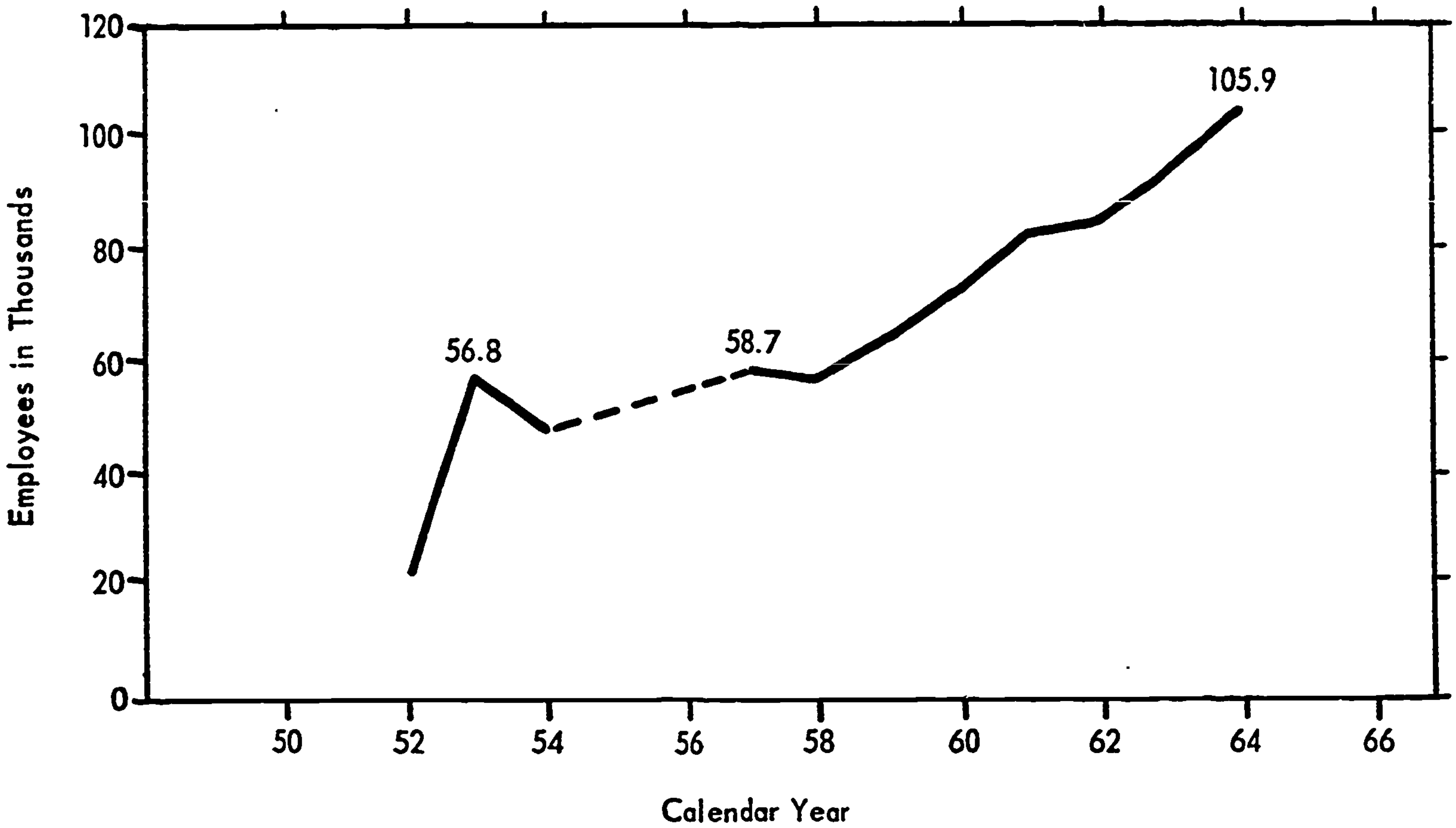
There are, then, some indications that the public is placing greater importance on meeting its domestic needs. Furthermore, there is a great deal of interest in attempting to solve some of the problems which Stratton calls "old, chronic disorders and new ailments," by drawing on techniques and industries formerly identified with ad-

[4] See Murray L. Weidenbaum, "Defense Cutbacks and the Aerospace Industry," *Astronautics and Aeronautics* (June 1964), p. 63, for a description and factors a company should consider before attempting a move into one of these areas.

[5] Julius A. Stratton, commencement address (Massachusetts Institute of Technology, June 12, 1964; later published in *Daedalus*, fall 1964).

[6] *The Washington Post* (Jan. 5, 1965), p. A10.

FIGURE 4. *Aerospace Employment—Scientists and Engineers*



SOURCE: R. Dean George and Edmund M. Phelan, "Analysis of Aerospace Funding and Employment—Fiscal Years 1956 to 1966," 1965 (information from National Science Foundation).

vanced technological endeavors. Until now, however, the work of these industries in this area has been limited primarily to the provision of services—i.e., conducting studies and operating training centers. Moreover, only a small fraction of the money being spent today to satisfy domestic needs is being spent for new and unconventional solutions of the type the aerospace industry might have to offer. Thus, from the point of view of the industry, the public-projects market now is more potential than real.[7] Whether it develops and becomes a significant factor in the later growth of the aerospace industry depends in large part on how actively the industry pursues the emerging opportunities in the area and on the interests and abilities of individuals occupying present and future key positions in local, State, and national governments.

Characteristics of the Aerospace Industry

One of the reasons frequently cited—and possibly the principal one—for believing that the industry can successfully diversify into the public projects area rests in the experience of aerospace companies in applying the systems aproach to development and production of large-scale systems in which significant technological advances are required. Just what the "systems approach" implies in relation to the experience of the industry and why this should ease its problem of entry into the public-projects area are not always made completely clear by the proponents of this view. Nor is there full agreement among them on what constitutes this experience. This lack of consensus was amply evident during interviews with various members of industry and government. When queried, for example, on what they understood industry's past experience with the systems approach to be, they expressed a number of different opinions:

> The "systems approach" is the process of solving functional problems.
>
> It is the methodology employed in the design of a system; a methodology that is basically always the same.
>
> The "systems approach" is the method used by industry in contracting with the government in a single-customer market.
>
> Integrating subsystems into working systems is what is meant by the "systems approach."

While all different, each of these statements describes some characteristic—or what appears to be some characteristic—of the total industry experience in developing and supplying military and

[7] In the remainder of the report, the term "public-projects market" refers to an aerospace industry market.

space systems to the Federal Government. And undoubtedly it is the overall experience, rather than some nebulous experience in applying the "systems approach," that should be examined when assessing the likelihood that the aerospace industry could successfully diversify into the public-projects area.

In terms of overall experience, there are a number of essential differences between the experience of the areospace industry and that of others. These have to do with (1) the marketing function; (2) technological innovation; (3) program size; (4) subcontracting practices; and (5) the ratio of scientists and engineers to total industry employment. Specifically, the important differences are:

1. In contrast with other product areas, the industry is accustomed to working closely with a customer who identifies his needs and establishes objectives toward which specific programs can be directed. Thus, the marketing function is largely carried out as a joint undertaking of the customer and the supplier, the initial contact between industry and the DOD usually being made long before a specific system program can be identified.

The factors underlying a decision to initiate a new weapon system program can be partially deduced from Boyd's [8] and Cherington's [9] discussions of the decision to undertake the Titan II missile program. While the Titan I was considered a "backup" missile for the Atlas, some among the scientific community thought the Titan should be a more advanced missile. For one, George B. Kistiakowsky, then a member of the von Neumann Committee (this committee was composed of scientists and occupied a key position in the long series of recommendations which culminated in the Titan II decision), ". . . felt the original Titan I program was too close a parallel to Atlas" and that it should be abandoned for the Titan II approach.[10] Industry became involved in helping decide on the future of the Titan II primarily as a result of its experience on the Titan I program, and it is interesting to note that three of the eventual four larger Titan II associate contractors had held equivalent contracts on the Titan I program. Moreover, of the key persons in industry and the Air Force who were later involved in the development program, Cherington, in his case study of the Titan II program, found that the bulk had prior experience on the Titan I program.[11]

2. The objectives usually lead to programs in which major technological gains are a necessity, often requiring the acquisition of new scientific knowledge and almost always depending on difficult engineering achievements. Consequently, the activities of the aerospace industry, more than those of most other industries, have been characterized, in the past at least, by major technological uncertainties and innovations. The Titan II, for example, incorporated a number of technological innovations never before used in a missile system; e.g., the use of a storable liquid propellant and an all-inertial guidance system. Innovations of this sort, coupled with reliability problems stemming from the exceedingly large number of component parts (ICBM systems may contain as many as 40,000 individual parts) complicates the development of most products produced by the aerospace industry.[12]

3. Aerospace companies regularly manage programs much larger than those found in most industries, programs that very often run into billions of dollars. To illustrate, the development of the Atlas ICBM cost $2.3 billion, Titan $2.6 billion, Polaris $2.5 billion, and Minuteman I $2.1 billion,[13] while Peck and Scherer found that the median cost system still runs about $400 million.[14] The result has been that the customer has taken the initiative (and the risk) and has financed the development of the products it wants to buy, but in so doing, it has demanded a greater control over the internal operations of the industry. As Weidenbaum has pointed out, this control

> . . . covers such aspects as financial reporting systems, industrial engineering and planning (the compulsory use of PERT/COST systems, for example), limitations on the use of overtime, purchases from abroad, restrictions on charitable contributions, patents, and pay rates.[15]

Thus, the customer controls to a rather significant extent not only the approach which the industry takes in developing a system, but also the internal operations of a company.

4. The size and complexity of most weapon systems usually require the development of advanced subsystems by associate contractors or subcontractors working in different technological fields and under various degrees of technological uncertainty. As an integrating contractor contractually obligated to deliver a working system, an aerospace contractor must work to ensure the performances and compatibility of all elements under development.

[8] Harwell L. Boyd, Jr., "The Titan II Decision," Defense Policy and Administration Seminar (Harvard University, May 3, 1963).

[9] Paul W. Cherington, "Case Studies of Titan II and NTDS," *Toward Better Utilization of Scientific and Engineering Talent: A Program for Action,* James R. Killian, Jr., committee chairman (Washington: National Academy of Sciences, 1964), *passim.*

[10] Boyd, *op. cit.*

[11] Cherington, *op. cit.*, p. 129.

[12] Merton J. Peck and Frederic M. Scherer, *The Weapons Acquisition Process: An Economic Analysis* (Harvard University, 1962), p. 43.

[13] Robert S. McNamara, Secretary of Defense, testimony before House Armed Services Committee (Feb. 1965).

[14] Peck and Scherer, *op. cit.*, p. 58.

[15] Murray L. Weidenbaum, "Some Observations on the 'Semi-Nationalized' Industries" (unpublished paper, Washington University, 1965), p. 10.

On the Titan II program, Martin Co.'s Denver Division was the integrating contractor responsible for design and development of the airframe, integration of subsystems, and testing of the complete weapon system. The primary difference in the role played by Martin and that of industries in the commercial consumer market is this: The subsystems or products needed to complete a system very often have to be developed in large-scale weapon development projects with all their accompanying uncertainties. In contrast, the subsystems or products normally used in consumer systems are usually "off the shelf" items with little or no uncertainty about their performances.

5. Because of the characteristics of its products, the industry has had to learn how to mold together the efforts of large numbers of scientists and engineers, a situation rarely encountered in most other industries.

For example, in the development of the Titan II, Martin Co. alone reached a peak employment of 16,500 man-months equivalent in October 1962, of which approximately 20 percent were scientific or engineering personnel.[16] Table 3 further illustrates the magnitude of the scientific and engineering manpower buildup on large-scale weapon system programs, showing the buildups for three of the major companies working on the Titan II program from January 1960 to November 1963.[17]

These five differences add up to a "company experience" almost wholly confined to the development and production of large-scale systems for the Federal Government, where inherent technological uncertainties in development and large procurement expenditures are characteristic of the acquisition process.[18] Thus, the nature of the products has given rise to a Government-industry relationship that has led Weidenbaum to suggest that the industry could be justifiably called a "seminationalized industry."[19]

While some may question whether the relations between the aerospace industry and the Federal Government are this close, one suspects that they have influenced to a large extent industry's past attempts to diversify. Many companies have exhibited a reluctance to move outside the aerospace market—partly, perhaps, from a fear that to do so might impair their capabilities to carry out the programs of their principal customers, the DOD and NASA. Consequently, faced, just as any other industry, with a presumed need to expand, the aerospace industry in the past has generally tended to confine its growth either to previously untried areas within the defense and space markets or to new areas where it could easily employ its existing capabilities while giving precedence to its aerospace endeavors. Recently, however, by buying up firms in unrelated fields, a number of companies have demonstrated an interest in markets totally alien to their inhouse capabilities and existing product lines. Should this practice continue and become even more widespread, it could reflect a greater interest at the top management levels in diversification designed to decrease the industry's dependence on Federal spending for defense and space purposes.

In contrast to this pattern of deliberate diversification resulting primarily from top management decisions, the more normal pattern has been one of natural diversification stimulated mostly by management at the operating level and stemming largely from two types of motivations. In the first place, a declining market, such as the aircraft industry faced in the early 1950's, generates pressures within a company to modify its make-or-buy policy to permit inhouse development and production of a greater proportion of a total system.[20] To enable a company to do this requires the development of new technological capabilities in product areas formerly reserved for subcontractors. Diversification resulting from this form of motivation is typical of the pattern historically followed by most aerospace companies and undoubtedly represents the diversification activities at which the industry has been most successful.

In the second place, existing technological capabilities present opportunities to market newly developed products or to apply products developed for one purpose to needs in other areas. This situation has from time to time led several companies to make attempts at entering (1) the con-

TABLE 3. TITAN II SCIENTIFIC AND ENGINEERING MANPOWER

Date	Manpower		
	Space technology laboratories [1]	Martin (all divisions)	A.C. Sparkplug Division of General Motors
Jan. 1, 1960	178	100	300
July 1, 1960	225	1,200	400
Jan. 1, 1961	238	2,000	525
July 1, 1961	243	2,500	500
Jan. 1, 1962	248	2,700	500
July 1, 1962	257	3,300	400
Jan. 1, 1963	235	3,300	350
July 1, 1963	230	2,750	300
Nov. 1, 1963	218	[2] 2,600	240

[1] Includes Titans I and II.
[2] September.

SOURCE: Paul W. Cherington, "Case Studies of Titan II and NTDS," *Toward Better Utilization of Scientific and Engineering Talent: A Program for Action*, James R. Killian, Jr., committee chairman (Washington: National Academy of Sciences, 1964), p. 113.

[16] Cherington, *op. cit.*, p. 113.
[17] Letter (Paul W. Cherington, Graduate School of Business Administration, Harvard University, to Ronald P. Black, Analytic Services Inc., Sept. 8, 1965). Cherington noted that the data reproduced in table 3 are actually shifted 6 months behind the actual manpower loading; e.g., the loading given for Jan. 1, 1960, actually occurred July 1, 1959.

[18] Peck and Scherer, *op. cit.*, p. 17.
[19] Weidenbaum, *op. cit.*, p. 13.
[20] Peck and Scherer, *op. cit.*, p. 388.

sumer products market; and (2) the nonconsumer, specialized applications market. On one hand, as noted by a number of authors, the aerospace industry has usually been unsuccessful in its penetration of the consumer products market. And it might be noted that in these past attempts management normally exhibited only mild interest and rarely gave them more than limited support. Weidenbaum noted that this situation

> . . . is evidenced by the very small investments made in comparison with military and airline projects, and also the reluctance to commit full-time senior management or top technical personnel to [this] area of diversification.[21]

On the other hand, when industry has undertaken the marketing of specialized products and services—supplying instrumentation for oceanographic research, designing automated warehouses, developing and producing equipment for oil drilling purposes—it has usually met with considerably more success.

[21] Murray L. Weidenbaum, "Adjusting to a Defense Cutback: Government Policy Toward Business," *The Quarterly Review of Economics and Business*, vol. 4 (1964), p. 8.

The California Experiment

Justified or not, the mounting concern over future growth prospects in its large aerospace industry and a growing suspicion that new, and perhaps unconventional, approaches were needed to solve many of its long-standing problems prompted the the State of California to undertake a program that has attracted nationwide interest. In deciding to initiate the program, California embarked on the largest and first organized attempt to solicit help from the aerospace industry in studying complex domestic problems seemingly far removed from the technological difficulties of developing and manufacturing military and space systems.

Whether this attempt will set a pattern for seeking solutions in similar areas of public need is a question that interests not only California and the aerospace industry, but other governmental jurisdictions as well. But, regardless of the success California may achieve as a result of its innovative approach to its problems, the answer is not at all straightforward. In a number of respects, at least, the almost unique situation in California favored the adoption of fresh and out-of-the-ordinary measures. The principal factors accounting for this situation were the important position the aerospace industry holds in the economy of California; the personal dependency of a large part of the State's population on the health of the aerospace industry; a reluctance to let the well-paid, well-educated industry personnel move from the State; the financial capacity of the State that permitted it to move ahead on the program without legislative delays; and, possibly, a degree of professionalism within the State government that recognized the need for novel approaches in such areas as waste management, transportation, criminal and delinquency control, and statewide information handling. Probably in no other State in the Union will all of these factors be found to the same degree.

Importance of the Aerospace Industry in California

Of the factors contributing to California's decision to explore new problem-solving techniques, undoubtedly the most influential was the importance of the aerospace industry to the well-being of the State's economy, particularly in view of the apparent leveling off of Federal spending for defense and space purposes. That a lower defense and space budget bears a greater significance for California than other States is evident from statistics of this sort: In 1962, California received $5.993 billion in prime contracts of $10,000 or more, while New York, ranking second in the receipt of such awards, received only $2.669 billion—less than half the amount California received.[22]

Furthermore, by breaking the contracts down into the 11 program categories shown in table 4 and ranking the States receiving the contracts according to their dollar volumes, Roswell Gilpatric recently demonstrated the relative magnitude as well as the variety of military prime contracts which went to California in 1962.[23] Missile and aircraft prime contracts accounted for approximately half of the total dollar volume in the 11 categories. Of the dollar volume awarded to California companies, missile and aircraft contracts constituted about 70 percent. Moreover, 47 percent of NASA's prime contract funds in 1962, or $441 million, went to California firms.[24] Thus, of all the States, California has by far the largest stake in the aerospace procurement activities of the Federal Government.

And to those whose livelihoods depend on the health of the aerospace industry, the stake is a very real one indeed. For in California in 1962, the combined wage and salary disbursements to employees in five defense- and space-related manufacturing industries[25] and to military and civilian

TABLE 4. CALIFORNIA'S RANKING IN PRIME CONTRACT AWARDS

Program	California's rank
Missiles	1
Aircraft	1
Electronics	2
Ships	4
Vehicles	3
Ammunition	1
Weapons	3
Miscellaneous hard goods	1
Soft goods	1
Services	1
Construction programs	1

SOURCE: Based on data from Roswell L. Gilpatric, "Five-Year Trends in Defense Procurement, 1958–62," *Convertibility of Space and Defense Resources to Civilian Needs: A Search for New Employment Potentials* (Subcommittee on Employment and Manpower of Committee on Labor and Public Welfare, U.S. Senate, 88th Cong., 2d sess., vol. 2, 1964), p. 607.

[22] Roswell L. Gilpatric, "Five-Year Trends in Defense Procurement, 1958–62," *Convertibility of Space and Defense Resources to Civilian Needs: A Search for New Employment Potentials* (Subcommittee on Employment and Manpower of Committee on Labor and Public Welfare, U.S. Senate, 88th Cong., 2d sess., vol. 2, 1964), p. 605.

[23] *Ibid.*, p. 607.

[24] *Doing Business in California* (Bank of America National Trust and Savings Association, San Francisco, Feb. 15, 1965).

[25] Ordnance and accessories, communications equipment, electronic components and accessories, aircraft and parts, ship and boat building and repairing.

personnel in defense- and space-related Government agencies[26] were $5.684 billion. Since the total income received by residents of California from all sources was just over $49 billion, this amounts to 11.6 percent of the total State wage and salary disbursements.[27]

The economic effects of defense and space spending on the economy of California is further reflected in employment figures of its defense and space industries. In March 1965, for example, employment in the aircraft, ordnance, electronics, and instrument firms was reported at 473,000 (a continuation of the declining trend—from a high of 510,200 in 1963—evident in table 5). The 1965 figure corresponds to 35 percent of all manufacturing employees and 8 percent of the total nonagricultural wage and salary workers in California. Adding to this figure the number of persons directly employed in Government installations, private shipyards engaged in Government work, and in research and development firms under service classification, gives a total employment figure of 650,000 for defense and space activities in California. Furthermore, some have estimated that two jobs are created in the consumer industries to meet the requirements of each defense and space worker for goods and services.[28] If these figures are approximately correct, then 28 percent of the total civilian employment in California is employed either directly or indirectly in the Nation's defense and space efforts[29]—a figure that compares favorably to a recent estimate by one of California's banks that "from one-third to one-half of total personal income generated in Southern California stems from defense and space-related activities."[30]

Governor Brown's statement in his second annual economic report pointing out that "the giant defense-aerospace sector of our economy, which had advanced spectacularly and steadily for a decade and a half, leveled off and declined somewhat . . ."[31] reflected a concern that had been mounting in the face of reductions in aerospace

TABLE 5. CALIFORNIA'S AEROSPACE EMPLOYMENT

Year	Number of aerospace industry employees
1950	131,400
1951	201,700
1952	274,500
1953	311,500
1954	322,400
1955	347,700
1956	403,800
1957	448,400
1958	417,800
1959	462,800
1960	460,800
1961	469,400
1962	509,400
1963	510,200
1964	483,900

SOURCE: Edmund G. Brown, Governor of California, "Economic Report of the Governor, 1965" (1965), p. 65.

employment. These reductions (shown in table 6) were caused partially, perhaps, by automation, technological change, and alterations in DOD contractual policies, but more directly by two roughly simultaneous occurrences: (1) A reduced Federal defense budget; and (2) a smaller share of the prime defense contracts to California firms. California's percentage fell from 23.2 percent in the first three quarters of fiscal 1963 to 21.4 percent in the corresponding period in fiscal 1964 (during the third quarter of fiscal 1964, the percentage had fallen to 18.7).[32]

The outlook at the time for the California defense and space industries in fiscal 1965 did not appear any brighter. As the First National Bank of Los Angeles put it,

> In the defense sector the problem is heightened [in 1965] by the fact that the categories within the budget of greatest importance to Southern California—procurement, and research and development—are among the very areas scheduled to receive a lesser portion of the budget total. Further, there is a strong probability that increasing competition from other sections of the country—particularly Texas and the Deep South—will result in the entire State's obtaining a

TABLE 6. CHANGES IN CALIFORNIA'S AEROSPACE EMPLOYMENT

Industry	Peak period	Employment drop by Dec. 1964 from peak	Percent change 1963-64
Total aerospace	Dec. 1962	53,900	−5.2
Electronics	Dec. 1962	32,100	−7.7
Aircraft	1957	122,600	−4.2
Ordnance (missiles)	Jan. 1964	13,900	−2.5
Instruments	Nov. 1963	1 100	1 −1.4

1 There is some doubt as to the correctness of these numbers, since the source says the −1.4 percent change from 1963 to 1964 corresponds to a drop in employment of 400, yet indicates in a table (p. 66) that the drop in employment from the period of peak employment to December 1964 was only 100.

SOURCE: Edmund G. Brown, Governor of California, "Economic Report of the Governor, 1965" (1965), pp. 8, 9, 66.

26 DOD, NASA, AEC, Selective Service Commission, and Office of Emergency Planning.

27 U.S. Arms Control and Disarmament Agency, "The Impact of Defense on the National Economy," *Convertibility of Space and Defense Resources to Civilian Needs*, op. cit., p. 594.

28 Southern California Associates, Committee for Economic Development, "Defense in the Southern California Economy," *Convertibility of Space and Defense Resources to Civilian Needs*, op. cit., p. 731. This factor of 2 includes, in addition to personal goods and services for defense and space employees, supplies purchased by the aerospace industry.

29 Other data sources indicate that 39 percent of the total California employment is either directly or indirectly employed in defense and space activities. It should also be noted that this is a very crude calculation. On one hand, all of the 473,000 employed in the defense and space industries are not working on defense/space projects. But, on the other hand, the defense and space industries subcontract to other firms, not included in our "defense/space" classification. Knowledge of subcontractor tiering, however, is very tentative and quite scanty, although more sophisticated attempts to gain such data have been made. The results of these attempts, however, are consistent with the estimates used above.

30 *Southern California Report, A Study of Growth and Economic Stature* (Security First National Bank, Los Angeles, 1965), p. 61.

31 Edmund G. Brown, Governor of California, "Economic Report of the Governor," 1965, p. II.

32 *Southern California Report*, op. cit., p. 60.

smaller share of defense-space contracts than it has in the past.[33]

Conclusions of this sort, together with a recognition that new approaches were needed to combat many of its long-standing problems, reinforced the State's decision to turn to the aerospace industry for assistance in studying ways to solve not only its own, but also the potential problems of a significant sector of its economy.

Background of the California Experiment [34]

As with most Government programs of importance, the evolution of the California study program was a complicated and sometimes obscure process involving interactions with other studies and with other ongoing and proposed programs. The actual decision to proceed with the program was based on numerous formal discussion, informal contacts between members of the aerospace industry and the State government, and activities of a number of individuals, corporations, and other interested groups at the national, State, and local levels. The cross relationships responsible for the State's actions were so many and so intertwined with those of other programs and interests that to trace all the factors leading to the undertaking of the study program would be impractical, if not impossible. Still, a number of actions can be followed and certain individuals identified as having contributed either to the creation of an environment which eased the conception and initiation of the program or, more directly, to the formulation of the program itself. But, in an attempt to do so, there is an inherent problem which Harvey Brooks has described when suggesting how a number of themes from the physical and biological sciences have found their way into our general culture. Brooks pointed out,

> Even in a subject like history, a sort of analog of the uncertainty principle is found. It lies basically in the fact that the historian knows what happened afterwards and therefore can never really describe the "initial conditions" of his system in a way which is independent of his own perspective. In seeking to discern the underlying causes of events, he inevitably tends to stress those factors which demonstrably influenced events in the way they actually came out, minimizing factors or tendencies which did not develop even though the relative strengths of the two tendencies may have been very evenly balanced at that time.[35]

Various groups have been concerned for a number of years over the economic effects of arms control or disarmament on the defense-related industries. In view of the importance of defense spending in California, it is not surprising that a great deal of this concern was centered on the aerospace industries in that State. The concern was heightened with the signing of the limited test ban treaty in August 1963, and its ratification by the U.S. Senate in September 1963. President Kennedy's cautiously worded statement, in the same year, that security expenditures would start leveling off and perhaps even decline in the years ahead,[36] and Defense Secretary McNamara's similar remarks,[37] gave rise to further questions about the outlook for the aerospace market. Partly in response to this public concern, Senator Joseph S. Clark's Subcommittee on Employment and Manpower (under the Committee on Labor and Public Welfare) began hearings in 1963 on the Nation's manpower and employment problems. As an outgrowth of these hearings, the Subcommittee published a document entitled *Convertibility of Space and Defense Resources to Civilian Needs: A Search for New Employment Potentials*. This important reference source did nothing to allay the fears of those who had been studying the problems of adjustments to defense cutbacks.

During the same period, Senators Hart and McGovern and then Senator Humphrey were putting forward similar bills, directed toward the implications of the changing patterns of defense procurement. Then in December 1963, President Johnson gave formal status to an interagency committee that had been informally started during the summer of 1963 ". . . to survey the present state of knowledge of the impact of defense spending, and to encourage the additional analytic studies and data collection that were needed."[38] This committee was established as the Committee on the Economic Impact of Defense and Disarmament with Gardner Ackley as its chairman. It had become apparent by this time that the Federal Government, while reluctant to appear unduly alarmed, was taking an increasingly serious view of the economic import of arms control and disarmament.

The progress of the activities on the national level were being closely followed by representatives of the State government in Sacramento. Moreover, individuals in a number of California's defense and space companies (essentially those in the aerospace industry, since it constitutes the major portion of the defense-space industry in Cali-

[33] *Ibid.*, p. 60. Data supplied by the DOD Comptroller's Office indicate that while the dollar value of California's prime DOD contracts declined from $3.7 billion in the first three quarters of fiscal 1964 to $3.6 billion in the similar period of fiscal 1965, the percent of the prime contracts procured by California firms rose to 23.2 percent. Thus, though the value of prime DOD contracts apparently continued downward, the trend is perhaps not as bad as some reports have feared.

[34] This section is largely based on conversations held with Arthur Barber, Governor Edmund G. Brown, Jack Halpin, Daniel M. Luevano, William F. Lipman, Allan H. Muir, Julian M. Smith, Carl F. Stover, and Murray L. Weidenbaum.

[35] Harvey Brooks, "Scientific Concepts and Cultural Change," *Daedalus*, winter 1965, p. 75.

[36] Joseph S. Clark, "The Impact of the Defense and Space Programs upon National Employment and Economic Growth," *Convertibility of Space and Defense Resources to Civilian Needs*, *op. cit.*, p. VII.

[37] Robert S. McNamara, speech delivered to the Economic Club of New York (Nov. 18, 1963).

[38] Gardner Ackley, statement before Senate Committee on Commerce, hearings on S. 2274, proposed "National Economic Conversion Act" (June 22, 1964).

fornia) and in several nonprofit corporations were trying to determine the effects that changes in defense and space expenditures would have on the aerospace industry and what the chances were that it could successfully diversify into new market areas. The efforts of these persons were assuming a new significance about this time, for studies by the State Office of Planning were beginning to show some discouraging conclusions.

The State Office of Planning was established in 1962 within the Department of Finance to carry out a State development plan program. One of the first objectives of this program had been to develop an econometric model, partly to examine more quantitatively how Federal spending influenced the California economy. By 1964, results of the model were apparently disclosing a startling dependency on military and space contracts. Reactions to these results, particularly within the Department of Finance, led to a period of searching inquiry into possible ways to moderate the unfavorable effects of a downard trend in defense spending. This inquiry was responsible for increased discussions between State and industry activists.

During this period, a number of individuals from aerospace companies and nonprofit corporations began to meet periodically in informal groups to discuss the changing defense budget. In June 1963, one of the groups in northern California, meeting under Carl Stover's[39] chairmanship, established itself formally as the Seminar on Industry Planning to Meet Shifts in Government Demand, and expanded to include other representatives, not only from local aerospace and nonprofit research corporations, but also from other industries, State and regional governments, local banks, labor organizations, and universities. After several meetings, the seminar recommended to Governor Brown that he appoint a high-level industrial commission to serve him in an advisory capacity on policy matters relating to possible actions the State might take to alleviate any adverse economic effects of changes in the Federal budget. In December 1963, Governor Brown called together a group to discuss the proposal, and shortly thereafter, in January 1964, he formally established a Governor's Advisory Panel on Aerospace and Electronics Industries.

In parallel with these activities, a second seminar was formed, this one meeting in southern California under Julian Smith of the Douglas Aircraft Co. Called the Southern California Industry Planning Seminar, the group also included representatives of local aerospace and electronic industries, nonprofit research corporations, State and regional governments, local banks, labor organizations, and universities. Its stated goals were:

> to seek a better understanding of the problems associated with reductions in military contracting in this [Southern California] area; to attract speakers from agencies concerned with arms control, economic development and industrial conversion; to investigate applicable legislation and policies; to review the effects of international treaties; and to [illegible]ne those weapon system characteristics which [illegible] toward military stability.[40]

William Lipman of the State Office of Planning was a representative to both seminars. At this time, Lipman reported directly to Daniel Luevano, then chief deputy director of the Finance Department in California; and to a large extent, through Lipman's contacts with personnel in the aerospace industry, both he and Luevano acquired a greater sense of urgency about the problems that could arise from cutbacks or shifts in defense spending. In the spring of 1964, Luevano left office. Before leaving, however, he conveyed to Jack Halpin, his successor, his thoughts about the adverse effects of a declining Federal defense budget on the State's economy and the necessity for broad integrated planning to circumvent them.

In April, Halpin became aware of the high unemployment level in areas heavily dependent upon the aerospace industry. And, about this time, the econometric model in use by the State Office of Planning revealed in more detail what the future effects would be on California's employment picture should President Kennedy's earlier prediction prove correct. The results were somewhat gloomy. Perturbed by these indicators, the State decided to impose closer checks on future defense expenditures in the State. Hoping to gain a clearer picture of DOD's planned expenditures, Governor Brown contacted Secretary McNamara and received an impression that confirmed his earlier fears that defense spending in the State would at least level off and possibly decline slightly. Knowing that the expanding aerospace industry had provided employment for a significant part of the large population increase in California over the last decade and a half, he found the possibility of a contracting aerospace industry especially disquieting.

In light of this discouraging picture, attempts were made to determine what the Federal Government would do to assist the State in the event of major cutbacks in California's defense contracts. The information obtained gave little apparent encouragement, seeming to suggest either that the Federal Government would do little to assist the State or else that it was reluctant to say what it

[39] With the Stanford Research Institute at that time and now executive director of the National Institute of Public Affairs.

[40] Julian M. Smith, "The Defense Dollar Dilemma: Current Trends in Aerospace Planning" (presented at 10th Annual and 1st International Meeting, Western Section, Operations Research Society of America, Honolulu, Hawaii, Sept. 17, 1964).

would do. To compound further what seemed by this time to be a bleak outlook indeed, an Air Force official came to the State in June and disclosed the results of a survey relating to California's future aerospace employment. Based on the survey, the predicted level of employment was even lower than the State had predicted; and when the Air Force estimate was used in the State's econometric model, the results showed the possibility of an unemployment figure as high as 10 percent.

Meanwhile, other events were occurring which were to have an eventual influence on the California experiment. The Committee on the Economic Impact of Defense and Disarmament, mentioned earlier, had formed three subcommittees. One was headed by Arthur Barber, Deputy Assistant Secretary of Defense/Arms Control, and was to be "concerned with the prospects and possibilities of industrial conversion . . . with special attention given to the highly developed research and development resources."[41] To assist in this task, Barber, in April 1964, organized a group of industrial consultants, mostly Californians, several of whom were active in one or both of the California seminars, to work with several Federal departments and agencies to identify new technical areas that might serve as offsets to cuts in defense spending. They were to create a list of several hundred projects in the national interest that might require the types of R. & D. resources and skills possessed by the aerospace industry.

Halpin, during this period, had been carrying on conversations with Carl Stover, William Lipman, and Daniel Luevano regarding the aerospace industry. Partially as a result of these associations, Halpin's contact with industry personnel began to increase. After the work with the Barber subcommittee was completed in the summer of 1964, two of the industry participants suggested to Halpin that the State of California use the advanced systems-oriented technology of the aerospace companies by having them undertake a program to help solve some of the State's domestic problems. Halpin—aware that the fiscal year 1966 Federal budget might provide for the State to supplement specific programs with Federal funds—discussed with Lipman and others the notion that California could conceivably finance the initial phases of such a program, hoping to obtain Federal assistance in later stages.

Satisfied that the ideas had some merit, a small ad hoc group from industry and the State began in July to meet under the auspices of the Department of Finance to discuss specific steps. Approximately 30 problem areas in which the aerospace industry might make significant contributions were delineated, and Halpin narrowed these down to 8 possibilities.

At this point, Hale Champion, Director of the Department of Finance, asked his budget officers to determine whether $100,000 could be made available for each of the eight problem areas. (As alluded to earlier, California's State budget, the largest in the Nation, was important in giving California the freedom to experiment with innovative ideas.)

Agreement was reached that the Department of Finance could reallocate funds to six of the eight problem areas if a policy decision was made that this was desirable. Halpin then prepared a paper suggesting the outline of the proposed study program, and he and Champion discussed the proposal with Governor Brown. The possibility that the State could utilize the systems-oriented aerospace industry to assist in solving domestic problems was not new to the Governor. On June 17, 1964, for example, in a speech drafted in close cooperation with his Advisory Panel on Aerospace and Electronics Industries, he had remarked: "The State, too, must help to redirect the great scientific and engineering capacity, now heavily absorbed in defense, into the new markets created by unmet public needs." Governor Brown had said, in describing these unmet public needs, ". . . along the way, you well may discover a potential for redesigning the total transportation systems of this State." Among major needs was the "elimination of environmental pollution, including pollution of air and water."[42] Halpin's proposal therefore met with immediate acceptance, and the Governor authorized them to proceed.

With the assistance of the industry members of the ad hoc group, Halpin developed requests for proposal (RFP's) in the six problem areas. (As it turned out, the Division of Highways wrote the final version of one.) Concern over the possible political reaction to the wording of the RFP in one area (welfare) resulted in its deletion from the study program. Difficulties in actually obtaining funds for the study project in a second area (education), resulted in another RFP being dropped. Finally studies were limited to four areas: Waste management, transportation, handling of criminal and mentally ill populations, and information gathering, processing, storage, and retrieval.[43]

In September, October, and early November, with Governor Brown often in attendance, the program was discussed before the Governor's Advisory Panel on Aerospace and Electronics Industries (where it received the group's concurrence), at various seminars, and in meetings with industrial and other groups. Reactions were mixed, making it difficult at times to tell whether

[41] Ackley, *op. cit.*

[42] Edmund G. Brown, address given at San Francisco International Airport, Board of Directors' room (June 17, 1964).

[43] Contracts were subsequently awarded to Aerojet-General Corp. (waste management), North American Aviation, Inc. (transportation), Space-General Corp. (handling of criminal and delinquent populations), and Lockheed Missiles and Space Co. (information gathering, processing, storage, and retrieval).

the majority was for or against the program. Nevertheless, the Governor and his aides, believing that the positive aspects outweighed the negative, decided to proceed. Thus, on November 14, Governor Brown made public the State's plan:

> Within the next few days, specifically, I plan to call for bids from California's aerospace industry to work out programs in four areas:
>
> First, transportation. We will ask the system engineers to study ways to provide a complete transportation network within the State, efficiently coupled into land, sea, and air transportation from out of State. We will ask them to identify the major patterns of movement of people, merchandise, materials, and food within the State. We will ask them to describe the transportation system which the State will need 30 to 50 years from now to provide efficient movement.
>
> And, finally, we will ask them to tell us how much such a transportation system will cost; who should pay for it; who should run it.
>
> * * * * *
>
> Second, we will ask the system engineers to design new ways to cope with California's criminally and mentally ill.
>
> This is a problem with which it is becoming increasingly difficult for California to cope. Our population is growing and so is the population of mentally ill. There are flaws in any system that involves institutional control and we will ask the aerospace teams to suggest ways in which they might be corrected. Perhaps an entirely new social structure within a hospital is desirable. We would like to know whether the cost of care can be cut and the efficiency of treatment be improved.
>
> The third problem we will pose to the system engineers is that of accurate collection of information on which government and industry can base decisions for years and even decades ahead.
>
> * * * * *
>
> We will ask the aerospace engineers to design systems that will improve our data on diseases and educational requirements. We will ask them to provide information on special needs of some of our population we might now be overlooking.
>
> Finally, waste management. There is a system at present for managing the wastes discharged into the air, soil, and water of California as a result of consumption by men and machines of materials which are necessary to support life or to produce goods. But it is not a system which has been developed by deliberate design to meet the State's needs.[44]

Statecraft by Contract

Recognizing the limitations of its inhouse capabilities for monitoring and evaluating these studies, the State contracted with the Systems Development Corp. (SDC), a not-for-profit organization originally established to assist the Air Defense Command of the Air Force, for technical advisory services. Thus California adopted a course of action which has become fairly commonplace at the Federal level, particularly within the military departments, since the start of World War II; i.e., contracting with a private group for studies leading to policy recommendations in a major problem area in which solutions normally require research and development. In his book on the relationship between government and science, Don K. Price points out in a chapter on "Federalism by Contract" that "from time to time the military services have identified a major problem that requires a new approach, based on a combination of scientific and strategic or tactical thinking" and—finding it easier at the beginning of World War II and less disturbing to all the career relationships involved—they obtained assistance from companies and institutions already established.[45] Price goes on to point out that "only in the United States have such broad studies of crucial importance to national strategy been farmed out to private institutions," and notes, along with several other authors, that this process has continued within the Federal Government since the war.[46]

California has identified four major problem areas which in its view require new approaches based on what it understands to be scientific and systems thinking. And rather than taking the long and, perhaps, impractical route of waiting until an inhouse capability could be developed, the State has contracted where they believe the talent resides—with private profit and not-for-profit corporations.

An innovative program of this sort would have been unlikely without a prior history of constructive planning that paved the way for its public acceptance. And, apparently, both the executive and legislative branches in California have placed unusual emphasis on such activities. On the executive side, as described earlier, these activities were exemplified in 1962 by the creation of the State Office of Planning which was—

> designed: (1) to reveal the present pattern of responsibility for development in California, (2) to describe the State's economic, social, and environmental conditions by regions, and (3) to forecast the population and economic bases of the State for future years, insofar as possible.[47]

[44] Edmund G. Brown, address given at UCLA Extension Symposium Luncheon, Los Angeles (Nov. 14, 1964).

[45] Don K. Price, *Government and Science, Their Dynamic Relation in American Democracy* (New York: New York University Press, 1954), p. 65.

[46] Frederic N. Cleveland in his book *Science and State Government*, a study of the scientific activities of State government agencies in six States (Chapel Hill: University of North Carolina Press, 1959), has noted: "Recalling Price's concept of the policy role that science and scientific research play at the national level, it is evident that these six State governments have tended to underemphasize this policy supporting dimension."

[47] *California State Development Plan Program Progress Report and Summary Interpretation of Phase I Studies* (State Office of Planning, California Department of Finance, Feb. 1965), pp. 9, 10.

And on the legislative side, the 1963 general session enacted legislation calling for an annual economic report by the Governor. Growing out of an investigation by a special subcommittee of the Assembly's Committee on Ways and Means, this act provided the enabling legislation for more coordinated policies and plans relating to employment, specifically, and to the economy of California, in general.[48]

The work carried out in 1964 by a steering committee established to conduct a management study of automatic data processing in State government further illustrates the evolving attitude. This study, essentially the inhouse efforts of three separate task forces composed of members from various State agencies, is illustrative of the parallel, although mostly uncoordinated, activities underway during this period—activities that contributed to a climate in which new approaches to the problems of State government were more and more being viewed with favor.[49]

In some respects, the State government's attempt to develop proposals for and an overall statement of policy on utilization of automatic data processing equipment were roughly analogous to those routinely taken by the DOD when establishing overall defense policies and objectives. The outstanding difference, however—and the one that may be the harbinger of statecraft by contract—is the wealth of experience and capabilities that the DOD has found necessary to develop since the start of World War II compared to those to be found in most State governments today. Military departments, particularly since World War II, have brought together—both within the military organizations and through the formation of independent, not-for-profit organizations—specialized teams that carry on continuing programs of technological studies, threat evaluation studies, force structure analyses, and other similar efforts to furnish decisionmakers with needed data. To expect a State to duplicate within the near future, even on the small scale required, inhouse capabilities either to perform or to manage on a continuing basis such an expanded program of studies and analyses may be overly optimistic, if not wholly unrealistic. Nevertheless, California, in drawing on the experience and knowledge of the aerospace industry and on not-for-profit groups such as SDC, conceivably could establish fairly quickly the contractual arrangements needed to offset the current shortage within the State government.

While such a combined State-industry relationship can increase the State's capabilities, possible difficulties with the process have worried some State officials. Some are concerned about possible conflicts of interest and that through its dependency on nongovernmental organizations the State might abdicate its decisionmaking responsibilities (a concern that has often been voiced at the Federal level in relation to the not-for-profit corporations under contract to the military departments). One California official connected with the California program commented, "We haven't got any experience along those lines. . . . Let's face it—we might be completely snowed." He went on to note that SDC "could snow us too, but we've worked with them before on some data-processing problems, and we trust them."[50]

With the experience of the Federal Government as a guide, difficulties with such contractual arrangements can undoubtedly be overcome. The development of improved capabilities within government to evaluate the efforts of its contractors and the encouragement of vigorous competition among contractors are representative steps that would help alleviate future problems. On the assumption that California and other States[51] will expand their use of this type of contractual arrangement, studies to clarify potential difficulties with the process and to help establish useful guidelines for State-industry relationships should probably be undertaken now.

The Four California Studies

Whether the systems approach and the scientific and engineering skills of the aerospace companies can be transferred effectively to civilian public projects is a question of direct concern not only to those responsible for satisfying public needs, but also to those interested in maintaining a prosperous and viable aerospace industry. To the extent that they resemble the normal activities of the aerospace industry and call for the application of similar technological capabilities, California's four study contracts are a first attempt to answer this question.

To evaluate the transferability of aerospace scientists and engineers was only one of several objectives of the studies. Some of the broader objectives have already been mentioned—alleviation of anticipated employment problems resulting from further defense cutbacks, stimulation of the aerospace industry to move into new areas, and prevention of an exodus of highly skilled aerospace employees from the State. Further, there

[48] Letter (William F. Lipman, formerly with California State Office of Planning, to Ronald P. Black, Analytic Services Inc., August 17, 1965); and Edmund G. Brown, "Economic Report of the Governor" (Mar. 2, 1964), p. 87.

[49] In its proposal request for a study of a statewide information system, the Department of Finance directed contractors to use results of the management study as necessary.

[50] Elinor Langer, "Defense: California Planners Try Novel Approach to Problems of Economic Reconversion," *Science* (Apr. 23, 1965), p. 482.

[51] A number of other States have expressed interest in this type of contractual arrangement, including Pennsylvania, Massachusetts, Connecticut, Wisconsin, and Michigan. See Mitchell Gordon, "Down to Earth," *The Wall Street Journal* (June 9, 1965); and Harold Walt, deputy director, Department of Finance, State of California, government-sponsored briefing (Los Angeles, June 7, 1965).

was the fundamental hope that the systems approach as practiced by the aerospace industry could be utilized effectively in helping solve some important domestic problems. Then, too, the prospect of losing a good part of its industrial tax base, should a serious decline occur, added an incentive for seeking new ways to employ the aerospace industry. While these are fairly straightforward goals, the specific objectives that the State had hoped to achieve in each of the four studies cannot be discerned with equal clarity. For while the expected results of individual studies are spoken of by some in glowing terms, at least one State official has complained that "too many people think these studies will come up with substantive innovations."[52]

Parenthetically, it is interesting to note the contrast between the three RFP's which were prepared under the auspices of the Department of Finance and the final version of the fourth which at its insistence was written by the Division of Highways. In all RFP's, except the one in the transportation area, the design of a "system to be activated in the near future" was called for in one section, while other sections seemed to suggest a contradictory and less stringent requirement.[53] In later statements, as one would expect, the specific goal in each of the areas seemed to be less than the development of a system to be put into early operation. Even then, however, with the exception of the transportation study, the actual objectives were never made completely clear and did little to amplify Governor Brown's original remarks.[54] What this may reflect is the experience possessed by the Division of Highways in requesting proposals from contractors in the past. It is interesting to speculate that due to their experience with the contractual process and with the techniques of planning and overseeing the development of large-scale systems, highway departments in most States may be more experienced with the systems approach and better prepared to contract and oversee the development and implementation of such systems than any other State agency.

Despite some uncertainty about the specific objectives of the studies and the likelihood that they might lead to significant market opportunities, a great deal of interest in the program was shown by the companies competing for the studies. One of the losing companies, for example, was reported to have spent approximately $150,000 on the preparation of its proposal alone, while each of the winning companies indicated its intention to spend more than the $100,000 that the State had available for each contract.[55]

Proposals submitted by Aerojet-General, Lockheed Missiles and Space Co., and North American Aviation outlined task descriptions that corresponded closely to the RFP's in the three areas. As an example, the State in its RFP for the waste management study delineated a number of elements that should be included:

1. A long-term construction plan.
2. A long-term equipment plan.
3. A long-term personnel plan.
4. The other pertinent elements of a total system.
5. A schedule for needed research and development.
6. Interfaces with other problem areas, e.g., the anticipated demand for potable water.
7. Estimation of the dollar resources needed to develop the waste management system considering alternative methods of financing the overall system to include participation by Federal, State, and local governments and private users of the system.
8. Implications of the optimal system upon relevant laws and regulatory procedures.[56]

Comparing these with the 12 tasks that Aerojet-General proposed to accomplish (see app. C) reveals a high degree of responsiveness to the study requirements. Without the final study report, however, how closely Aerojet-General followed its original proposal cannot be established.[57]

In contrast, the Space-General Corp. and its subcontractor, Serendipity Associates (a small behavorial-sciences, human-factors research group) concluded that the original RFP on criminal and mentally ill populations was too broad, encompassing an area too large to study in the period of the contract. Consequently, they limited their proposal to the prevention and control of crime and delinquency. Moreover, the study was further modified after it had been underway for sometime. Nevertheless, the following results (described as first-order approximations requiring further study) were obtained and, by Space-General's report at least, were considered new and unusual:

1. New statistical description of crime and criminals leading to more meaningful definitions of the problems.

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[52] Andrew Strain, comment in *The Wall Street Journal* (July 26, 1965).

[53] State of California, *Request for Proposal—Information System* (Nov. 18, 1964); State of California, *Request for Proposal—Criminal and Mentally Ill Populations* (Nov. 18, 1964); State of California, *Request for Proposal—A Waste Management System* (Nov. 18, 1964); and State of California, *Request for Proposal to Design and Develop Specifications for Integrated Study of Transportation in California* (Nov. 17, 1964).

[54] Brown, address at UCLA Extension Symposium, *op. cit.*

[55] Spending in excess of contractual funds is not unusual in industry studies for DOD and NASA. Daniel J. Haughton, president of Lockheed Aircraft Corp., in an address before the 1965 annual meeting of the AIAA, noted that the $6 million in Government funds his firm had received (as had Boeing and Douglas) for contract definition studies on the C–5A military transport program had been more than matched with company funds.

[56] State of California, *Request for Proposal—A Waste Management System, op. cit.*

[57] At the time of writing, California had not released the final study reports.

2. New concepts of system cost descriptions for criminals, and delinquents. Individuals committing offenses assessed by a total system "career cost," accrued over the lifetime of the individual. Numerical values achieved for numerous crime categories.
3. Achievement of system cost/effectiveness results by computer analysis of parametric variations.
4. Modeling of certain types of behavior patterns showing startling results in the areas of prison behavior trends and subsystem parameter interrelations.
5. Complete description relating various functions, showing clearly the requirements for information and feedback which are not presently being met.[58]

The apparent indecision at the outset on the scope of the study, as well as Space-General's use of a subcontractor (the only study contractor to do so, although others used individual consultants) may reflect the exceptionally wide gap between the design of space systems and the development of ways to control crime and delinquency. Still, as pointed out earlier, this blending of subcontractor efforts into an overall product is characteristic of the aerospace industry. To assume, then, that the lack of inhouse capability may have been detrimental to Space-General's efforts would be unwarranted. What can be assumed, however, is that the ratio of social to physical scientists in the aerospace industry would probably increase should the companies become more actively engaged in civilian public projects.[59]

[58] Letter (Norman Solat, member, project team, System for the Prevention and Control of Crime and Delinquency, Space-General Corp., to Ronald P. Black, Analytic Services Inc., July 30, 1965).

[59] A similar conclusion was reached by the Committee on the Economic Impact of Defense and Disarmament. See *Report of the Committee on the Economic Impact of Defense and Disarmament* (Washington: U.S. Government Printing Office, July 1965), p. 30.

Another aspect of the California studies deserving consideration is the comparison between the aerospace contractors' approach and traditional approaches to similar problems in the past. First, the State did not pose problems similar to those given in previous years to other research groups—university research groups, for example. Earlier studies to eliminate smog, ameliorate traffic problems, reduce governmental record storage difficulties, and solve other problems related to the four California studies were initiated and carried out essentially at the city or county level. Had the research and study groups in the prior attempts been given the freedom to approach the problems on a State or regional basis, as the aerospace industry was, there is some question whether their results would differ substantially from those obtained in the California studies.[60] Nevertheless, the techniques used were characteristic of the aerospace industry and represent an important experiment in trying to solve old problems with new approaches.

[60] For example, in the March 1965 *Bulletin of the Atomic Scientists*, John T. Middleton (director of the University of California Air Pollution Research Center) said:

"Acceptance of the principle of resource management for most beneficial use requires that conservation programs be established for naturally definable geographic and meteorologic areas in which the entire population is involved through whatever political device is required. Quality standards, established on a shed or regional basis, provide the management agency with a unit of sufficient size to strike an appropriate balance between input and output. The quality standards adopted must be designed to control the quantity as well as the concentration of materials released, since the adverse effects of water and air pollution result not only from initial concentration but also from the products formed as the material moves from the output site into nearby reaction site areas."

This statement sounds remarkably like some of those made by Aerojet-General on the same subject.

Capabilities of the Aerospace Industry

From a practical point of view, the research and development capability of the aerospace industry is an aggregate of the scientific and engineering skills of many individuals plus the accumulated experience of a number of companies that have grown up and subsisted on technological innovation. What this implies about transferability of this capability, particularly that part commonly thought to be the systems approach, is difficult to assess. For what this approach is and how it is used in the large aerospace companies usually evoke conflicting replies. Nevertheless failure to reach a common understanding has seemingly done very little to influence those who believe that the industry's systems capabilities can be put to effective use on large-scale civilian projects.

Applications of the Systems Approach

If there is fairly wide agreement that the systems approach is the outstanding quality aerospace companies have to offer in helping solve complex domestic problems, considerably less agreement is apparent on what this means in future opportunities for the aerospace industry in the public-projects area. In some respects, this absence of complete agreement parallels and possibly stems from a similar lack of consensus about what is meant by the industry's systems capabilities. A major aerospace company possesses the experience and ability to carry out a number of different functions, each of which can be performed with a systems approach. The direction in which the industry can and will likely grow in the public-projects area, then, largely depends on what capabilities individual aerospace contractors try to apply in the civilian-projects area and how well these capabilities compare with competing ways to perform needed functions; e.g., by the use of inhouse government agencies or more traditional business concerns.

Aerospace firms engage in at least four major activities that could conceivably be used with a systems approach in carrying out large-scale domestic projects:

1. Research and analysis.
2. Systems engineering and technical direction.
3. Development and production of large-scale systems.
4. Operation of large-scale systems.

Understanding how the systems approach relates to these provides a better appreciation of what is involved in applying the systems capabilities of the aerospace industry to domestic problems.

As mentioned earlier, the military departments have been assisted during the last decade or so by systematic analysis performed primarily by not-for-profit research organizations. The Rand Corp., a pioneer in this field, has evolved an approach to the solution of defense problems which it has come to call systems analysis—a method of scientific analysis which "offers a means of discovering how to design or use effectively a technologically complex structure, the components of which may have apparently conflicting objectives." [61] The characteristic that distinguishes analyses of this sort is the extensive participation of practitioners from many fields, including social science, economics, the physical sciences, engineering, and mathematics.

Systems analysis of large-scale problems in this sense refers to activities concerned with determining needs, establishing policy and objectives, estimating future technical possibilities, synthesizing and analyzing system concepts, and conducting tradeoff studies; e.g., cost and effectiveness studies to determine efficient allocations of available resources. Obviously, while analyses of this sort—treating as they must significant social, economic, and political factors—can rarely be made wholly quantitative, they do depend heavily on mathematical techniques and concepts (as well as other forms of scientific and engineering methodology). To a large extent, the method is an outgrowth and extension of operations analysis (or research) techniques developed during World War II. The important elements underlying systems analysis—as well as all system activities—are the adoption of a broad view of the problem, the explicit recognition and treatment of uncertainties, and the examination of how proposed problem solutions change as the assumptions upon which the analysis is based are changed.[62]

While the aerospace companies are less noted than Rand and others for these types of activities, they do have substantial capabilities in applying

[61] *The Role of Analysis in Defense Planning*, Seminar (The Rand Corp., Feb. 15–19, 1965).
[62] *Systems Development and Management (Part 3)* (Subcommittee of Committee on Government Operations, House of Representatives 87th Cong., 2d Sess., Aug. 1962), p. 924.

the systems approach in this way—although they have been less concerned in the past, perhaps, with determining needs and more concerned with synthesizing and analyzing systems that might satisfy a stated need. And, to some degree, it is largely with this aspect of systems analysis that they have been concerned in the four California studies to date. While an aerospace firm could possibly grow in this direction in the public-projects area, by establishing a subsidiary like Rand, for example, the possibility seems slight that it would do so except in support of one or more of the three remaining functions listed above.[63]

An aerospace firm might more likely capitalize on its system engineering and technical direction capability, for, historically, before the inception of not-for-profit organizations such as the Aerospace Corp., the large airframe contractors performed these functions in their roles as prime weapon system contractors. These functions, perhaps, more closely reflect what most have in mind when they speak about applying the systems capabilities of the aerospace industry to civilian public projects.

Defined in this context, systems engineering provides the basis for technical direction and consists of efforts of these sorts:

1. Establishing system design and performance requirements.
2. Integrating the design and development of all elements of a system.
3. Overseeing to ensure that detailed design and development criteria are met.
4. Formulating and revising program schedules and monitoring progress during the course of the program.
5. Preparing system test requirements and evaluating test data.[64]

Technical direction also involves the integrating (and, to some extent, the controlling) of the research, development, test, production, and installation and checkout efforts of all subcontractors on a program. In addition, control is exercised over the preparation of facilities and criteria for test, training, and operational installation of the overall system. At the same time, supporting research and development efforts such as the following are often considered necessary activities of an organization acting as a technical director:

1. Laboratory research and development.
2. System integration and testing.
3. Investigation and correction of system failures.
4. Preparation of work statements and evaluation of technical proposals.[65]

Therefore, in most respects, technical direction and systems engineering as used in this context are closely aligned to programs involving physical systems and are important components of the often-noted ability of the aerospace industry to manage large-scale, complex programs in which major technological considerations are present.

When the decision has been made to initiate the development and production of a large-scale system, the number and diverse nature of the activities tend to obscure the meaning of the systems approach. As indicated, it can clearly mean systems engineering and technical direction, but it also means something else at different hierarchical system levels. Hall, in his analysis of the systems engineering process, points out that system (or subsystem) development entails the same basic steps that are followed in reaching a decision to undertake development; i.e., problem definition, system (or subsystem) synthesis and analysis, decisionmaking, and communication of results.[66] Thus, good engineering practice dictates the use of the systems approach, not only in the overall design of the system, but in the design of the subsystems as well.

To support this view, one has only to examine the organizational structure of a typical large-scale weapon system program conducted by an aerospace contractor. In almost every case, a system function can be identified at the program director's level, at major subsystem levels, and, occasionally, even at minor subsystem levels. The function is most apt to be termed systems engineering, rather than systems analysis or research; it is also carried out using a systems approach.

While perhaps less obvious, the production process is an orderly system and, therefore, lends itself to similar analyses. But here the analysis starts to take the form of operations analysis or research, as distinguished from systems analysis or research. Although both use a systems approach, systems research is concerned with *devising* operational processes (systems) that meet human needs, and operations research with *analyzing* systems either in development or in operation.[67]

Industry operation of large-scale, Government-owned systems has been a fairly common practice in which the aerospace companies have engaged periodically at the request of the military departments. Recently, a number of defense contractors have become interested in similar opportunities in areas far afield from the defense industry, hoping to apply their systems capabilities more

[63] In some respects, the General Electric Co. anticipated a move of this sort when it established its TEMPO division, an activity roughly analogous, in a functional sense, to the Rand Corp.

[64] *Systems Development and Management (Part 3)*, op. cit., pp. 1200–1210.

[65] *Ibid.*

[66] Arthur D. Hall, "A Methodology for Systems Engineering" (Princeton: D. Van Nostrand Co., Inc., 1962), pp. 130–132.

[67] Herman A. Affel, Jr., "System Engineering," *International Science and Technology* (Nov. 1964), p. 19.

broadly—to the operation of Job Corps urban training centers, for example. A number of these companies, notably the International Telephone & Telegraph Corp., General Electric, Litton Industries, and Ford's Philco subsidiary, are already operating training centers around the country and others are taking serious steps to augment their capabilities to handle such programs.[68]

Beyond these types of operations for the Federal Government, it is not too difficult to visualize possibilities at the State, regional, and local levels for industry operation of large, centralized information handling systems, computational facilities, transportation control systems, and the like. Undoubtedly the experience of the aerospace companies in modeling a system to determine its operational characteristics and subsequently analyzing its expected performance under various operating conditions places them in an informed position for applying their systems capabilities to the actual operation of the system. Still, to insist that this activity is a significant part of the aerospace industry's present systems capability seems questionable. More probably, it represents a possible future extension that could utilize a significant part of the industry's technological capability—perhaps the less-advanced portion—in contract operations for Federal, State, and regional governmental jurisdictions.

Which of the four functional activities, then—research and analysis, systems management and technical direction, development and production, or operations—did the State of California have in mind when it assumed that the systems approach would be useful in analyzing proposed solutions to its problems? The wording of the RFP's would indicate that the State was thinking of research and analysis, particularly having to do with systems synthesis and analysis. Still, from an economic standpoint, this function alone would account for only a small fraction of the total current income of the aerospace industry in California and, thus, could not serve as an offset to any significant cutback or intraindustry shift in defense spending. Therefore, it seems likely that both the State and its aerospace companies are looking at the other three functional activities as better possibilities for long-term growth. Thus, the key issue in assessing the applicability of the industry's systems capabilities to complex domestic problems remains: What direction will the eventual pattern of growth follow? For even though a common characteristic of the industry may underlie each function (i.e., the systems approach that depends on taking the broad view of the problem, the recognition of uncertainties surrounding it, and the scientific evaluation of proposed solutions under various assumptions), how well the aerospace companies can bring their system talents to bear on public projects depends on the functions they ultimately undertake in that area.

Transferring Industry Skills to Civilian Projects

Several writers have commented on the similarities between the defense and space markets and what they see as emerging opportunities in the public-projects area. But few have delved deeply into the differences and the concomitant problems these may pose to an aerospace firm attempting to use its existing scientific and engineering skills in applications seemingly far afield from their usual concerns. This tendency to brush aside factors that might weigh against an optimistic view of the growth possibilities in this area may be misleading. For despite the demonstrated adaptability of the aerospace industry to earlier changes in Federal procurement patterns, undertaking some public projects will involve problems significantly different than those the industry had to face in 1955 when it began the transition from aircraft manufacturing to missile development.

Possibly, the two most prominent problem sources are (1) the partial mismatch between the scientific and engineering disciplines needed in many public projects and those possessed by aerospace companies; and (2) the loss, when shifting into alien fields, of the accumulated experience gained from the design, development, and manufacture of what amounts in a technological sense to progressively advanced models of similar end products. How serious these factors prove to be and the extent to which they would hamper efforts to use research and development talents in the public-projects area depend on the direction of growth ultimately taken by the industry. But that they would influence to some degree, at least, how easily the aerospace industry could make the shift ought not be ignored.

Although the purpose here is not to assess the degree of mismatch between the aerospace industry's scientific and engineering skills and those needed to design and develop large-scale public systems—to do this without reference to specific public programs would be difficult—the characteristics of the mismatch may be clarified somewhat by noting that a survey of one aerospace company showed that 22 percent of its 870-man technical staff consisted of aeronautical engineers.[69] How the company would utilize the skills and experiences of these persons in the design and manufacture of a statewide information handling system, for example, is not immediately clear. Nor is it readily apparent just how its 174 electrical/electronic engineers would be employed

[68] "Big Business Sees Profits in Poverty," *The Washington Post* (Mar. 7, 1965).

[69] Miller, *op. cit.*, p. 38.

to devise and build new systems for the incarceration and control of the criminal population of California. Still, in the early stages, where ideas are being formulated and evaluated, difficulties in transferring skills of selected engineers to other technical problems are seemingly not insuperable, as evidenced by the apparently satisfactory completion of the four industry studies.

Whether other scientists and engineers who have spent the greater part of their careers building highly complex, technically advanced aerospace systems can be transferred with equal facility can be seriously questioned. An important trait of much of the industry is its experience resulting from an evolutionary period of technological growth when the skills needed to design aerospace vehicles were gradually developed. Moreover, many of the engineering skills have been acquired from working experience rather than from college training. In a survey of one company, for example, about 23 percent of those classified as engineers and scientists, while having some college training, had not received degrees, and almost 12 percent had not attended college at all.[70] Whether engineers who have gained their knowledge primarily by on-the-job training in one industry can transfer their capabilities to other industries as easily as engineers with academic backgrounds and degrees is a question that has received little consideration in past discussions of the industry's ability to shift into the civilian projects market.

These, then, are the types of questions examined in the following section, questions which in the aggregate are concerned not with whether the aerospace industry can bring its research and development skills to bear on major problems of public concern—for they already are doing so—but rather with how difficult the transfer is likely to be.

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[70] Shapero and Vollmer, *op. cit.*, p. 261.

Scientists and Engineers in Large-Scale System Programs

Past studies of the transferability of scientific and engineering manpower in the aerospace industry have generally failed to distinguish among the many activities the industry's technical personnel engage in; i.e., no distinction has been made between transferability, say, of an engineer whose primary training and experience has been in systems analysis and one whose background has been in production engineering.[71] The approach to the analysis described in this section rested on the hypothesis that the transferability of skills should be examined at each stage throughout the life cycle of a large-scale systems program. This provides a clearer and more accurate representation of the industry's research and development capabilities and avoids the oversimplifying assumption that all scientists and engineers could be transferred with equal ease to civilian public projects.

The Phases of Large-Scale Weapon System Programs

The nature of the scientific and engineering activities and the percentage of the total program effort they represent vary as a large-scale weapon system program progresses through its life cycle. As a result, the skills, work backgrounds, and educational attainments commonly identified with the scientists and engineers in one program phase tend to differ from the corresponding characteristics of those employed in other phases. Or, at least, some characteristics are apparently much more predominant in one phase than in another. The purpose here is to summarize briefly these phases by excerpting from appendix A, "Phases of a Large-Scale Weapon System Program," to establish a framework for the remainder of the discussion in this section.

As illustrated in figure 5, the activities preceding a decision to consider seriously the undertaking of large-scale weapon system program normally span several years. During this time, principally given over to the generation and evaluation of ideas, a number of program opportunities exist, and while many will inevitably be discarded, some eventually become viable choices from which one or more weapon system programs may be selected for accomplishment. As these choices are made in the latter part of the opening phase, some fairly definite objectives emerge in the form of tentative operational requirements and research and development objectives.

Once the decision has been made to examine the desirability of developing a new system, some fairly identifiable phases follow over the next 6 or so years. In the first phase, termed concept formulation by the Department of Defense, attention more and more starts to focus on specific program possibilities, although at the outset of this phase a number of choices are still open to the decisionmaker, including a decision not to proceed with the subsequent phase. After completion of concept formulation, the general features of the future program will have been established with sufficient clarity to permit entering the contract definition phase, where the program is refined and planned in even greater detail.

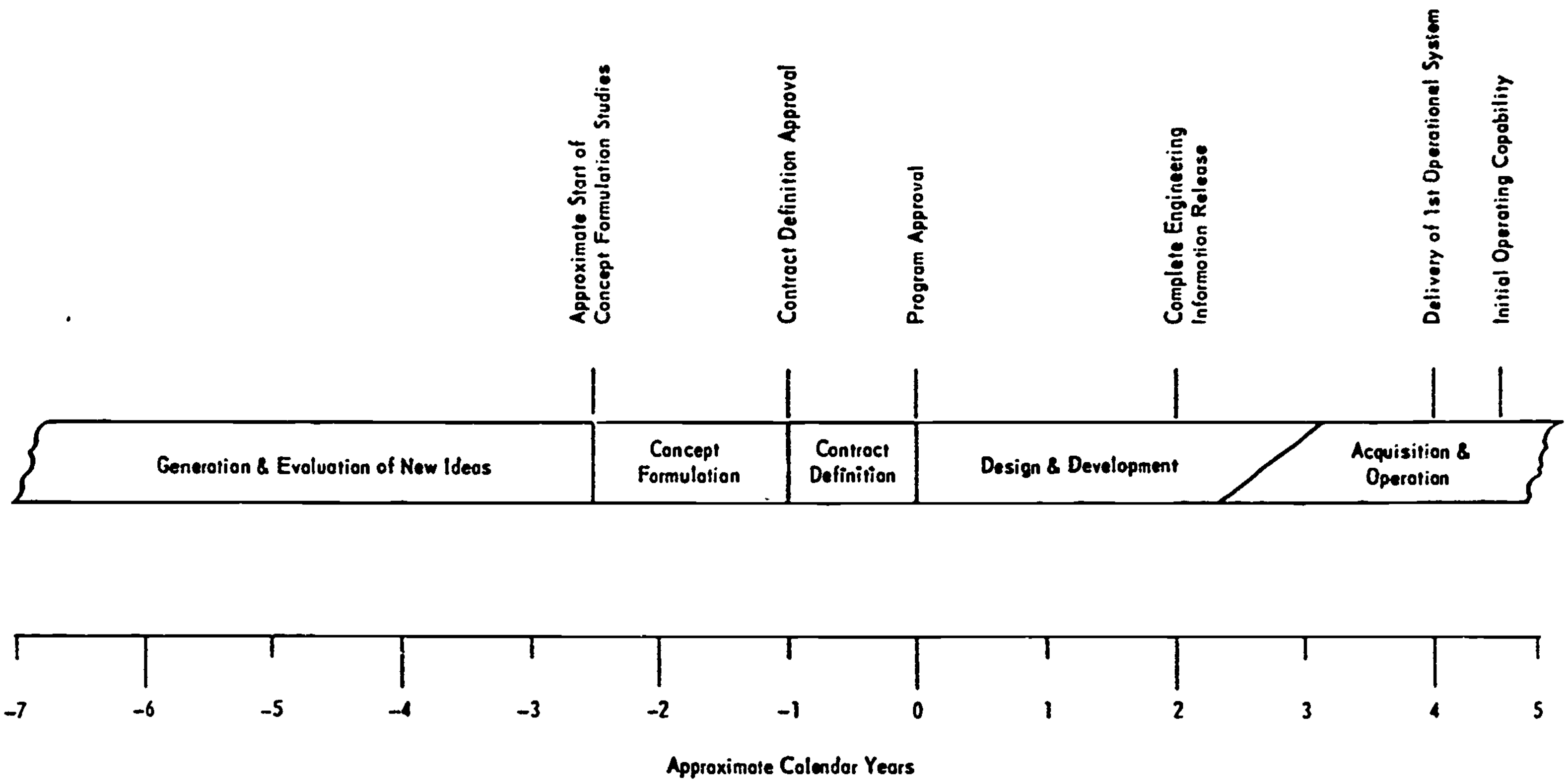
At the conclusion of contract definition, the third phase, the full-scale design and development program, is undertaken. Should the decision then be made to acquire production versions of the system, production commences at a point that normally overlaps development and test. The acquisition and operational phase then follows, overlapping production and, at times, developmental testing. While future improvements may be made to the system and advanced models may come into being, the program as originally conceived is essentially complete at this point.

Early Stages of Large-Scale System Programs

Some may view the conclusion of the four California studies as a demonstration that the aerospace industry can diversify without serious difficulty into the public-projects area. And, in some respects, their optimism may be warranted. Still, comparing the pattern of activities found in the four studies with the overall activity pattern in a large-scale weapon system program tends to moderate such optimism. For as measures of how easily the industry could apply its research and development know-how to a large-scale public system program, the California studies are only partial indicators, testing, as they did on a limited sample basis, only the transferability of a minor (although admittedly important) fraction of the total scientific and engineering capability of the industry. Yet to the degree the efforts in the Cali-

[71] Lawton M. Hartman, "Industrial Practice Affecting the Utilization of Scientific and Engineering Manpower," *Toward Better Utilization of Scientific and Engineering Talent, op. cit.*, pp. 138, 139.

FIGURE 5. *Weapon System Program Phases*



fornia study projects and the characteristics of the participating scientists and engineers resemble those at a similar point in the evolution of a major weapon system program, the studies do furnish some limited insight into how readily that fraction, at least, could be applied in the future to similar study projects.

The background of the California studies and the four State requests for proposals disclose quite clearly the highly indeterminate nature of the activities prior to the time the studies were inaugurated. In the face of uncertain needs and doubts concerning the applications of defense—and space-related—technology to such needs, the period was largely given over to the generation and preliminary evaluation of ideas on possible solutions to loosely defined problems. In this respect, some parallels can be drawn between this period and the period preceding the concept formulation phase of a weapon system program (see app. A)—not only in the nature of the activities, but also in the characteristics of the industry participants. Among these parallels, however, two factors bearing on the transferability of scientific and engineering skills during the embryonic phases of large-scale public programs stand out in contrast. One concerns the reservoir of defense- and space-related knowledge and experience possessed by the aerospace industry; the other, the industry's relations with the Federal Government.

The impetus given defense research and development in World War II has been sustained with only minor interruptions since 1945. Moreover, the National Space Program, in its dependence upon advances in almost all areas of technology, has further stimulated the country's research and development efforts. Because the aerospace industry has been at the forefront of these activities, intensively engaged in research, experimental development, study, and analysis, it has a long-established familiarity with defense and space problems and an intimate knowledge of how advanced technology can contribute to their solutions. But few scientists and engineers in the industry possess equivalent understanding of public problems or a deep awareness of their social, economic, political, and technological implications.

Nor has sufficient time elapsed to form the close relations with State and local governmental bodies that the industry has developed during the last 20 years or so with the military—and, more recently, with NASA. Study groups in the military departments, for example, while trying to identify needed operational capabilities, routinely draw on industry's knowledge of what is technologically possible. And the aerospace companies regularly inform the military of new possibilities opening up as a result of anticipated technological advances. Thus a continuing interplay and a rare degree of understanding has evolved among aerospace scientists and engineers and the military involved in weapon system acquisition. But, as an industry participant in one of the California studies observed, a similar rapport is yet to develop with members of the State government, although the working relations that grew up between some State officials and some industry scientists and engineers were apparently quite close.

From California's point of view, however, neither industry's relative inexperience with problems predominantly social, economic, and political nor industry's undeveloped relations with State and local governments represented any apparent serious or even significant barrier to the transfer of scientific and engineering skills. For when the State issued its four RFP's and thus entered into the equivalent of the early stages of the concept formulation phase described in appendix A, it obviously expected that the approaches and techniques used by the aerospace companies for the DOD and NASA could also be employed effectively in the California studies. Evidently this expectation was borne out, in part at least. The technical approaches and study techniques outlined in two of the four successful proposals [72] are in most respects similar in pattern to those found in proposals to the military departments and NASA. In both proposals, the indicated approaches generally correspond to the steps (listed in fig. 6) normally identified with the systems approach. The planned uses of techniques such as mathematical modeling and computer simulation of systems, functional input-output matrices, econometric models, activity networks (e.g., PERT), quantitative cost and effectiveness analyses, and mathematical optimization techniques demonstrated the intent to employ the methodology of systems research and analysis. The functional block diagram of the operational processes associated with crime and delinquency in California (fig. 7) illustrates how one company went about putting its intentions into practice.[73]

California seems convinced on the basis of the studies that the systems approach can be effectively applied to its problems. Or, at least, so public statements by such people as Governor Brown indicate. On July 22, 1965, the Governor, in testimony before the Subcommittee on Employment and Manpower of the Senate Labor and Public Welfare Committee, stated: ". . . the first question that had to be answered in this program [the four studies] was whether the aerospace engineers could handle it. Their answer now is yes."

In agreeing with this conclusion, however, one would be forced to bear in mind that the Governor was speaking of only a very small percentage of the total scientists and engineers normally found in a large-scale weapon system program, or, for that matter, of a very small segment of the scientific and engineering population in the aerospace industry as a whole. Cherington has estimated, for example, that perhaps 5 percent or more of the industry's scientists and engineers are engaged in what he calls precontract activities,[74] activities which, in many respects, roughly compare to those associated with the four California studies. And

[72] Only two of the four proposals were made available for this study.

[73] "California Reaches for Aerospace Engineering to Solve State Problems," *American Engineer* (May 1965), p. 33.

[74] Paul W. Cherington, "Systems-Acquisition and the Utilization of Scientific and Engineering Manpower (Requirements and Program Determination, Contracts and Grants)," *Toward Better Utilization of Scientific and Engineering Talent, op. cit.,* p. 117.

FIGURE 6. *Steps Usually Associated With Systems Approach*

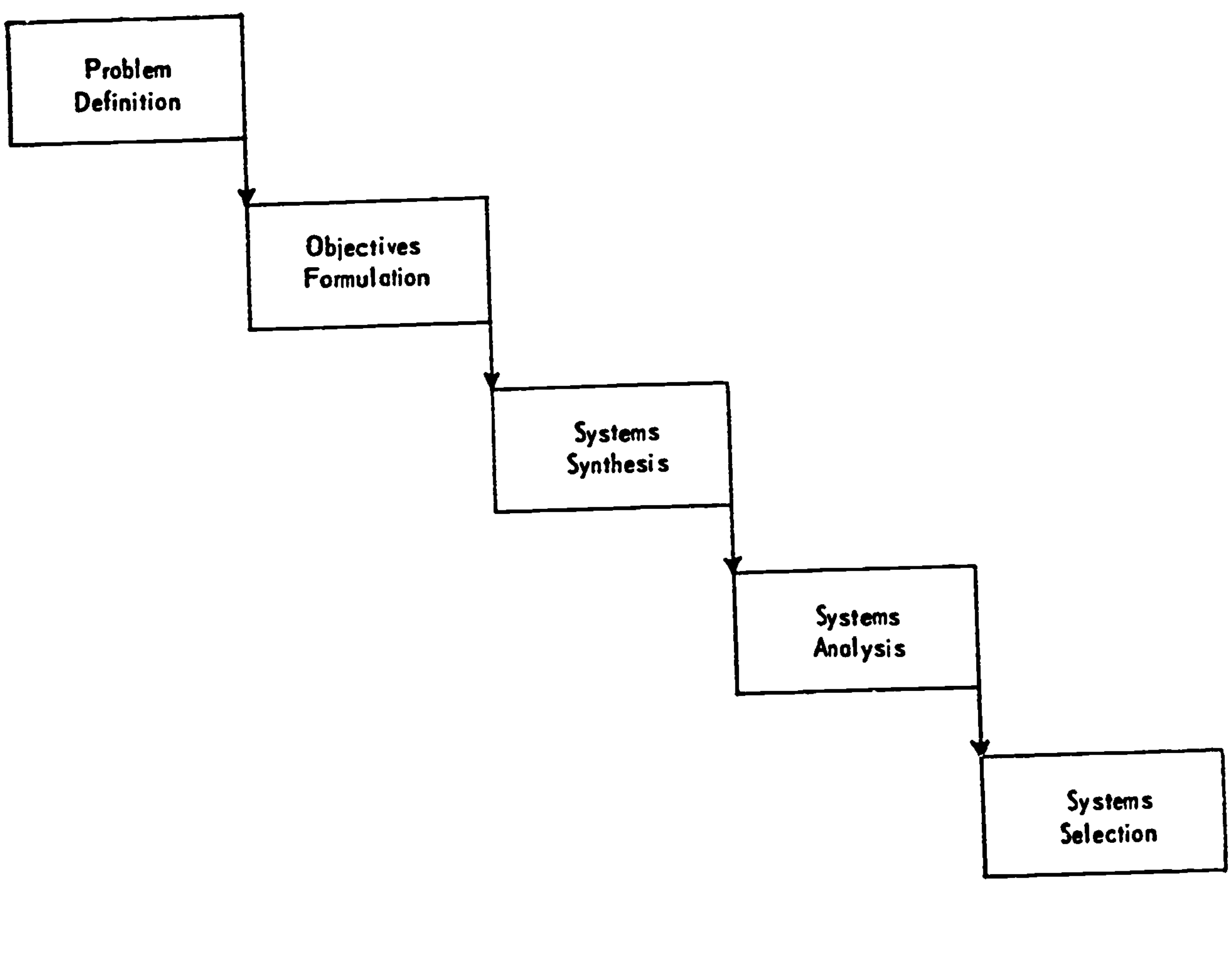
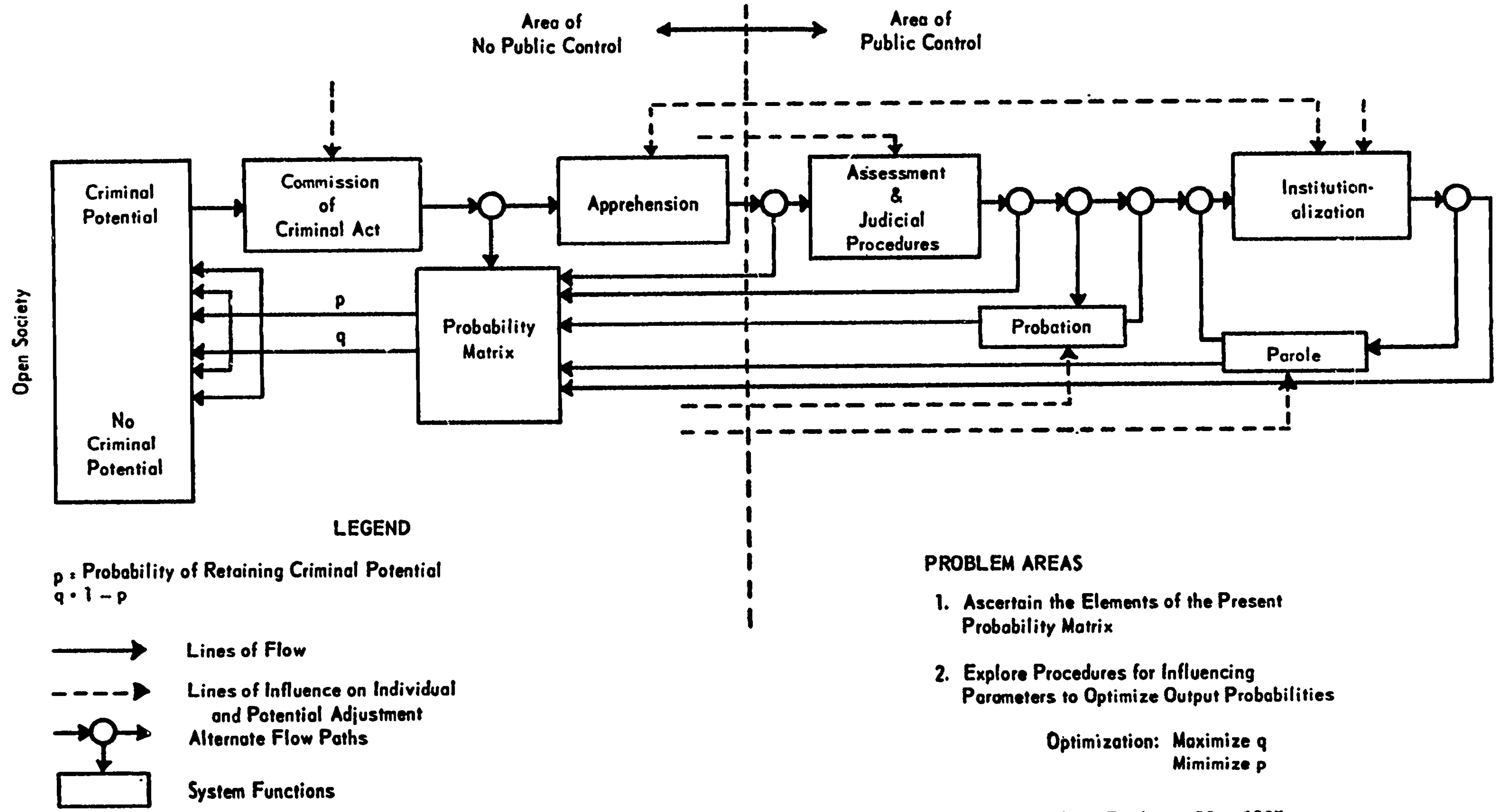


FIGURE 7. *Space-General's Application of Flow Diagram—Processes in Crime and Delinquency*



SOURCE: "California Reaches for Aerospace Engineering to Solve State Problems." *American Engineer*, May 1965.

so while the aerospace scientists and engineers may be able to cope with the early phases of a large-scale public project, what of the other activities which make up the later program phases and, in a weapon system program, occupy the efforts of perhaps 70 to 90 percent of the total scientific and engineering manpower of the industry?

Distribution of Scientists and Engineers

Before analyzing the way the industry distributes its scientists and engineers among the later program phases, it may be well to comment briefly on Cherington's estimate that 5 percent or more of the scientific and engineering manpower in the aerospace industry is utilized in precontract activities.[75] This estimate may be slightly misleading, suggesting as it may to some the existence of a relatively stable group occupied full time with activities of this sort. In practice, while a number of industry personnel with scientific and engineering backgrounds do spend the greater part, if not all, of their time working in the early program phases, an even larger number regularly shift back and forth between precontract activities and tasks associated with later program phases. In one of California studies, for example, interviews with the study participants disclosed several who had only recently been working in one of the company's major design and development programs before its cancellation. (Transferring technical personnel, particularly the more talented and innovative, to proposal and study activities as their efforts are no longer needed on design and development programs may become even more prevalent with DOD's increased emphasis on concept formulation and contract definition studies before program initiation.) What should be noted with respect to Cherington's estimate, of course, is the earlier point that the knowledge gained from the four California studies concerns at best the transferability of scientists and engineers working at the type of activities which accounts for a mere 5 percent or so of the total technological effort of the aerospace industry.

That the profile of the scientific and engineering manpower on the California studies is probably not an adequate representation of the overall technical profile needed in a large-scale public system program is made further apparent: something like 5 percent of the peak scientific and engineering manpower loading on a large-scale weapon system program may also be a fair estimate of the maximum number of scientists and engineers normally employed in the early program phases. Data on manpower utilization in the Titan II ICBM program, for example, show that the manpower loading at the Martin-Marietta Co. reached about 185 at the time DOD approval was given for program go-ahead (see fig. 8).[76] This corresponds to just over 5 percent of the maximum loading of 3,600 scientists and engineers reached well after test and evaluation activities had started to predominate in the design and development phase. On the basis of numbers alone, the technological skills possessed by the aerospace industry seem overwhelmingly oriented toward activities associated with the later program phases. Thus. while future important contributions in the public-projects area may be made by the scientists and engineers regularly assigned to a system development program before the accelerated buildup of personnel begins, more attention needs to be given to the transferability of those who spend their time almost wholly on tasks associated with the later program phases. For this latter group, principally consisting of engineers holding undergraduate degrees and those with no degrees, is probably not in short supply now, nor is it likely to be in the foreseeable future. But as Cherington has pointed out in discussing the breakdown of scientific and engineering manpower in the aerospace industry, there is and probably will continue to be a shortage of technical innovators, managers, and top-quality backup personnel.[77]

At present, little evidence is available on which to base judgments on the likely utilization of scientific and engineering personnel in large civilian projects such as those envisioned as follow-ons to the California studies. But assuming, as most do, that the unusually high ratio of engineers and scientists to other employees in the majority of military and space programs stems primarily from the large technological advances sought in most weapon system developments, some justification exists for thinking that the ratio would be lower in comparable civilian public projects. Nor does it appear unreasonable to expect that the ratio of the peak number of scientific and engineering personnel in later program phases to the number in earlier phases would be smaller than that obtained from data derived from the curve in figure 8. As mentioned earlier, technological advances of the magnitude normally associated with military and space system developments are probably not required today in most public problem areas.

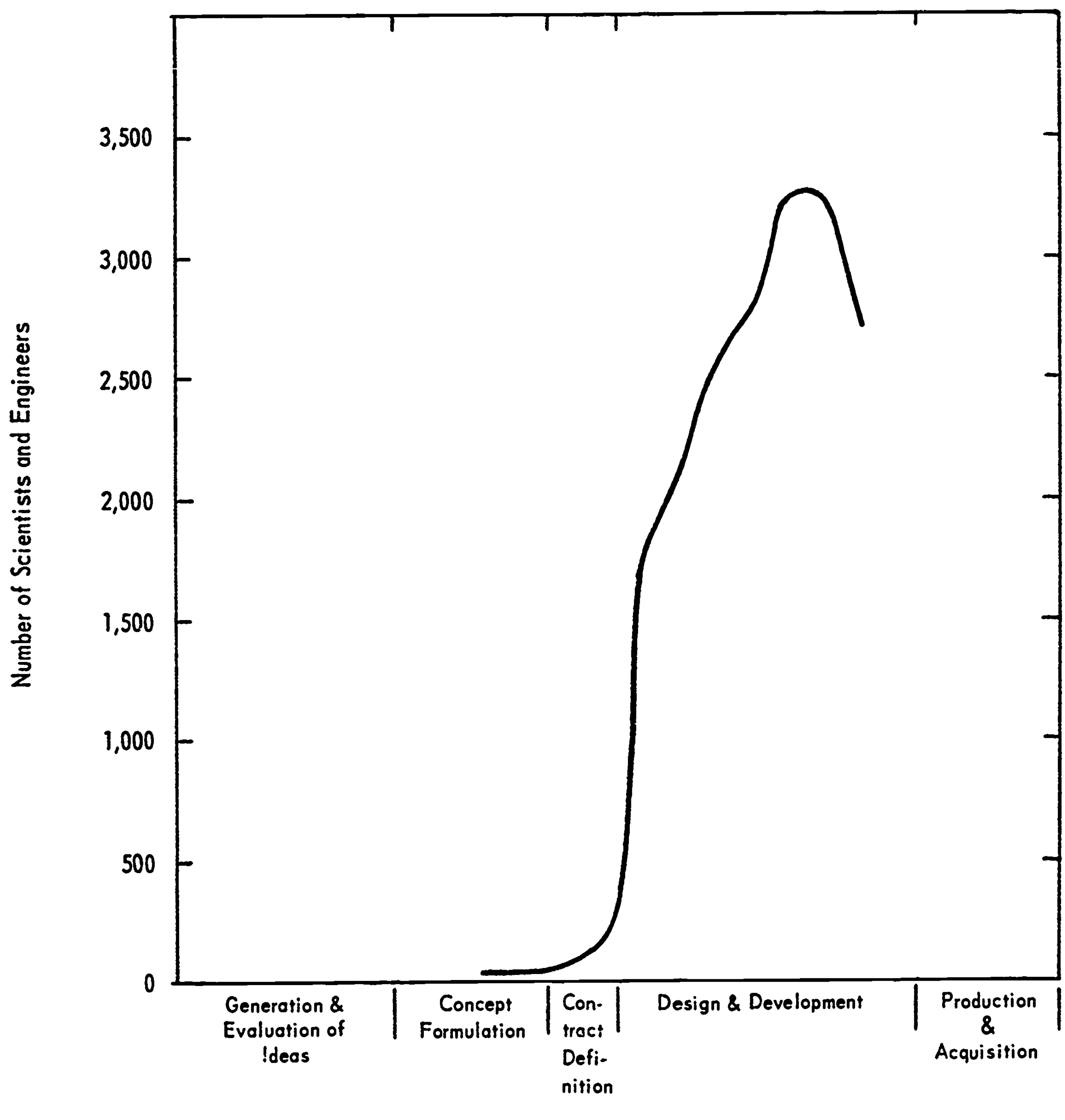
The scientific and engineering manpower component of large aerospace programs, particularly that part associated with the accelerated buildup shown in figure 8, has been the subject of surprisingly little research. Existing data, sparse and largely inadequate for analyzing the transferability of the group, rarely differentiate among the numerous activities of individuals having what appears to be similar backgrounds and skills. For

[75] *Ibid.*

[76] Letter (Paul W. Cherington, Graduate School of Business Administration, Harvard University, to Ronald P. Black, Analytic Services Inc., Aug. 3, 1960).

[77] Cherington, "Systems Acquisition and the Utilization of Scientific and Engineering Manpower," *op. cit.*, p. 113.

FIGURE 8. *Scientific and Engineering Manpower Buildup in Titan II ICBM Program (Martin-Marietta Co.)*



SOURCE: Based on letter from Paul W. Cherington, Harvard University, Aug. 3, 1960.

example, data such as given in table 7 provide very little insight into the diverse tasks in a weapon system program that are performed by technical personnel nominally identified by the same technical discipline. As an illustration, the 20 percent of electronic/electrical engineers in table 7 might be involved in any one of the functional areas shown in table 8 (which, it should be noted, is not a comprehensive listing) and, thus, to draw conclusions about their transferability without considering the nature of their activities seems wholly unrealistic.

Of dubious value, also, in assessing the applicability of the industry's scientific and engineering skills to civilian projects are data on the distribution of academic degrees in the aerospace industry. Providing data of this sort, as one company did in its study proposal to the State of California, helps very little when judging how difficult it would be for the company to utilize its technologi-

TABLE 7. DISTRIBUTION OF TECHNICAL DISCIPLINES IN ONE AEROSPACE COMPANY

Technical discipline	Percent of all disciplines
Electronic/electrical engineering	20
Mechanical engineering	22
Aeronautical engineering	22
Physics	10
Mathematics	7
Other engineering and sciences	19

SOURCE: Thomas G. Miller, Jr., *Strategies for Survival in the Aerospace Industry* (Cambridge: Arthur D. Little, Inc., 1964), p. 38.

TABLE 8. ELECTRONIC/ELECTRICAL DEVELOPMENT ENGINEERING AREAS

Flight controls	Flight test instrumentation
Feedback control systems	Flight test operations
Navigation and guidance	Flight test data processing
Fire control systems	Test engineering
Radar technology	Production testing
Radomes	Service engineering
Antenna systems	Project engineering
Hydraulic and electrical systems	Technical writing
Armament systems	Operations analyses
Electronic countermeasures	Support equipment

SOURCE: Based on descriptions of professional employment opportunities contained in various periodicals.

cal capabilities in the follow-on phases of the program.

Without additional data on the individuals substantive background characteristics and their relationships to future requirements posed by public projects, what observations can be made on the projected distribution of scientists and engineers in the design and development, production, and acquisition and operating phases of a typical, large-scale public program? Very few, certainly. Perhaps only the following point can be usefully made at this time: To speak of a "typical" public program in the sense that a single technical profile could be constructed as a model for distributing scientific and engineering skills in future public programs is very likely misleading. As the aerospace market is constituted, the overall distribution of scientists and engineers probably approximates fairly well the technical profile of an "average" company, for there is substantial homogeneity among large aerospace programs. But the potential market in the public-projects area, ranging in the four California studies alone across such disparate fields as the control of criminal delinquency and the problems of waste management, strongly suggests that the distribution of technical fields of specialization within public programs will vary markedly. Therefore, while insufficient data are available to project the utilization of particular skills, individual companies might be faced with some rather difficult problems in maintaining a proper match between their inhouse technical mix and the heterogeneous requirements of a civilian market should they attempt to work in several of these fields.

Potentially a much more useful approach to determining a workable profile of scientific and engineering manpower in large aerospace programs seems to be that adopted by Shapero and Vollmer.[78] They sorted systematically into nine activity categories the job titles of all scientists and engineers in one aerospace company and then related these activities to representative organizational functions. Using this approach, they developed the data shown in table 9 for one major aerospace company.

But, as Shapero and Vollmer note, determining whether the data are representative of the industry at large would depend on additional analyses of other firms—although the earlier assumption of homogeneity among large aerospace programs argues for the generality of the overall technical profile represented by table 9.

Even though the nine categories employed by Shapero and Vollmer are not sufficiently detailed to reveal the fine-scale activities in each aerospace program phase, an imperfect approximation based on table 9 has been made of how the effort

[78] Shapero and Vollmer, *op. cit.*, p. 235.

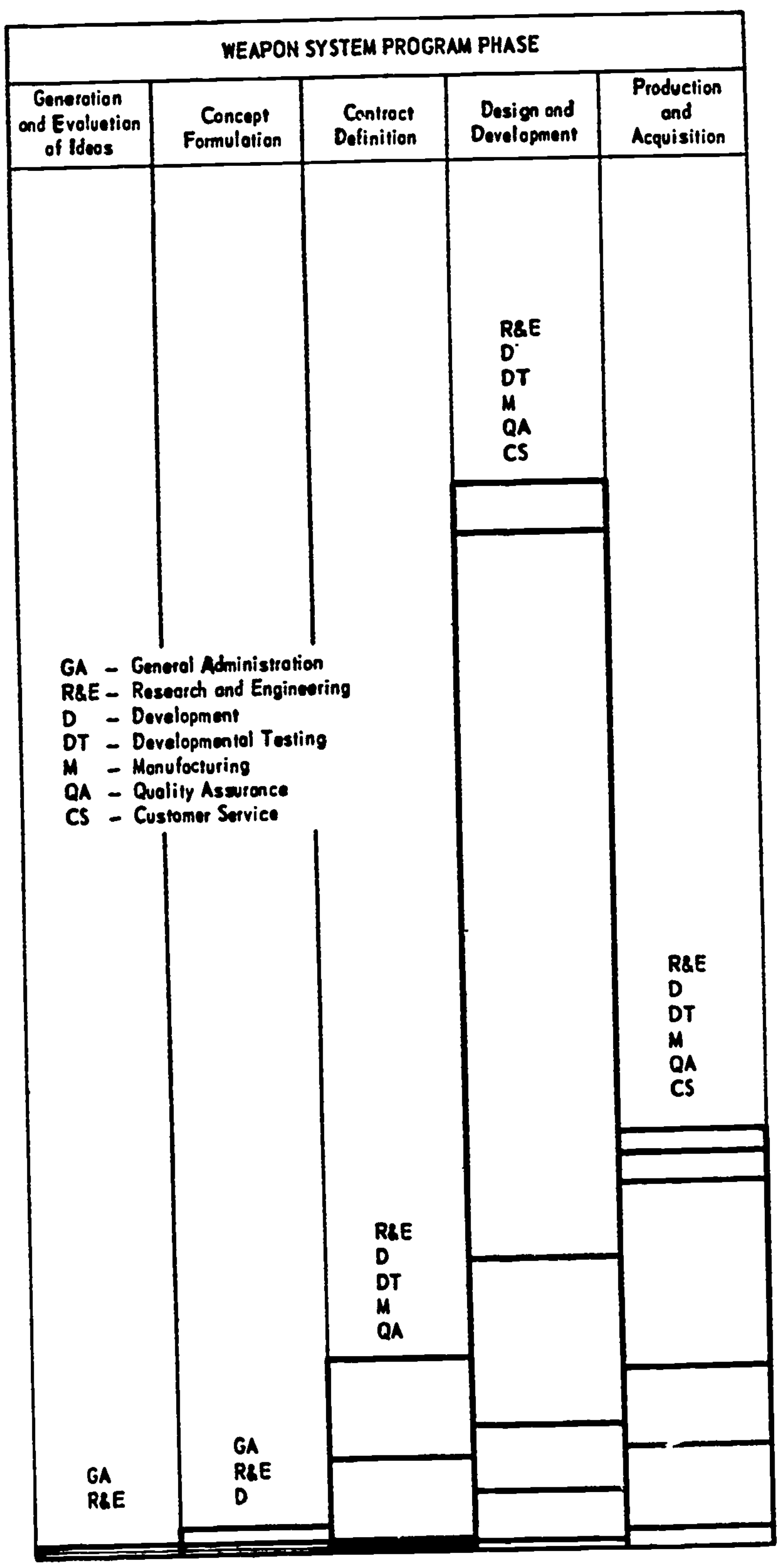
TABLE 9. DISTRIBUTION OF ENGINEERS AND SCIENTISTS BY ACTIVITY PERFORMED IN DIFFERENT ORGANIZATIONAL FUNCTIONS IN ONE MAJOR AEROSPACE COMPANY, 1962

Organizational function	Percent distribution by activity performed									
	Scientific research	Product design analytic	Product design hardware	Test engineering	Technicial snpport	Facilities design	Manufacturing and facilities design	Quality assurance	Customer service	All functions
General administration	0.1	0.1								0.2
Research and engineering	5.0	6.4	1.1	0.4	0.9		0.1		0.5	14.4
Development	1.4	10.6	28.1	.9	2.6		.3	0.1	1.8	45.8
Development test	.5	1.9	3.0	13.7	.6	0.6			.5	20.8
Manufacturing		.6	1.5			1.0	5.5		.1	8.7
Procurement										
Quality assurance		2.0	0.7	.2	.1		.1	5.0	.1	8.2
Customer service			0.2			.1			1.0	1.3
Total	7.0	21.6	34.6	15.2	4.2	1.7	6.0	5.1	4.0	99.4

SOURCE: Albert Shapero and Howard M. Vollmer, "Technical Profile of the Industry," *The Industry-Government Aerospace Relationship*, vol. II (Menlo Park: Stanford Research Institute, 1963), p. 235.

in each organizational function is distributed. This somewhat crude distribution, shown in figure 9, was developed by judging for each organizational function what percentage of its related activities was normally performed in each program phase. While based partly on subjective judgments, the results are thought to be generally valid. For example, the percentage distribution between phases is fairly consistent with the manpower loading distribution described earlier. Also, while the distribution within phases may be somewhat more uncertain, the additional uncertainty does not invalidate the basic conclusion to be drawn; i.e., that based not only on numbers of personnel alone, but also on an analysis of how the activities are distributed, the technological capabilities of the aerospace industry seem overwhelmingly oriented toward activities associated with the later program phases.

FIGURE 9. *Scientific and Engineering Manpower Distribution by Program Phases*



Specialization of Scientists and Engineers in the Aerospace Industry

Problems which have stemmed primarily from the magnitude and complexity of the tasks involved in major weapon system programs, and to a lesser extent from the characteristics of the defense market itself, have compelled aerospace companies to develop techniques and approaches which, in some cases, have given rise to certain areas of technical specialization within the industry.[79] This situation, summarized in table 10, generally prevails throughout the industry and lends support to a hypothesis that most aerospace engineers and scientists tend to specialize in fields frequently bearing only incidental relationships to their academic backgrounds.

On the surface, specialization centering on defense and space problems seems inconsistent with ease in shifting research and development skills to new and complex problems in the public-projects area. But a conclusion of this sort may be premature, or at least too general. Two or perhaps more of the approaches listed in table 10 were

TABLE 10. AREAS OF TECHNICAL SPECIALIZATION

Problem	Technique or approach	Technical specialty
Technical sophistication of products.	Employment of technical personnel in proposal and sales efforts.	Technical entrepreneurship.
Single-customer market.	Establishment of independent group to monitor cost versus performance.	Value engineering.
Large number of complex, technical decisions at program director's level.	Assignment of strong technical staff to program director.	Project engineering, system engineering.
Complex program interrelationships.	Use of computer techniques for program monitoring.	Program planning, PERT analysis.
Large number of complex system concepts and parameters.	Use of mathematical models and computer simulation.	Systems synthesis and analysis.
Complex interrelationships among system elements.	Assignment of control over int[illegible] of major s[illegible]ems to independent group.	Configuration control.
Interactions due to design changes.	Establishment of formalized change control procedures.	Liaison engineering.
Stringent reliability requirements.	Institution of reliability programs, vendor qualification programs, incoming parts inspection and test programs.	Reliability engineering, parts engineering

[79] For further discussion of this trend, see Allen O. Gamble, "Proposal for Development of an Improved Manpower Related Information Program," *Toward Better Utilization of Scientific and Engineering Talent, op. cit.*, p. 103.

employed successfully by the aerospace companies in the California studies: First, in accomplishing the studies, some, if not all, used mathematical models and computer simulations of systems; and, second, all used technical personnel in their proposals and sales efforts to obtain the study contracts. In fact, there is some justification for thinking that this latter approach, more than any other single factor, is responsible for the leading role California is playing today in trying to adapt the technical resources of the aerospace industry to domestic problems.

It is interesting to note that the use of technical resources to carry out what are essentially sales and marketing functions has often come under attack, usually on the grounds that technical talent was being wasted on "brochuremanship," i.e., the preparation of elaborate, and often costly, proposals. While there may be some basis for such criticism, there are also reasons to suspect that it is overexaggerated. Many believe that partly because of the technological complexity of its products, the aerospace industry has had little recourse but to devote a significant portion of its scientific and engineering capability to the preparation of technical proposals and the promotion of ideas constantly generated in response to known or presumed military requirements.

In 1962, C. F. Horne estimated that 18 percent of the industry's top scientists and engineers were occupied in this manner.[80] Although not all of the 18 percent—or all of the 1965 equivalent percentage—are either fully or permanently engaged in these activities, there has emerged in most aerospace companies what some have called the "technical entrepreneur," i.e., the scientist or engineer who spends a majority of his time in managing proposal efforts, briefing top management, and trying, usually in concert with the firm's customer relations department, to arouse Government interest in the company's latest proposal. These individuals, normally articulate and reasonably well informed in several technological areas, have evidently found very little difficulty in interpreting the scientific and engineering capabilities of the aerospace industry to a new, and apparently highly receptive, audience. Without this type of technical entrepreneurship, one wonders whether the California study program would have been conceived and undertaken.

[80] Quoted in *The Industry-Government Aerospace Relationship*, vol. I (Menlo Park: Stanford Research Institute, 1963), p. 19.

Industry's Experience With the California Studies

If it has done nothing more, the California study program has focused the attention of a large number of responsible Government officials on a potential source of help in unraveling the complex, usually interrelated problems facing modern society. It has failed, perhaps, to provide any conclusive clues to the future role the aerospace industry is apt to play in domestic projects at the Federal, regional, State, and local levels. But it would have been unrealistic to have expected the four studies to furnish more than an initial impression of a trend that could develop and the likelihood that it would. The studies do provide some insight into the market possibilities for the aerospace industry and the effect a move in this direction might have on the manpower composition of individual companies.

As a part of this study, a number of interviews were held with members of aerospace management—both those primarily concerned with broad corporate objectives and those customarily involved more directly with company operations (including project managers of the California studies)—and with the participants in three of the four California studies.[81] The objectives of the interviews were (1) to gain management's observations and impressions of any problems associated with the California studies and their views of future possibilities in the public projects area; and (2) to gather background data for use in making some predictions about the likely manpower composition of similar study teams in the future.

Management Observations

Talks with company officials responsible for overall corporate growth quickly reveal a correspondence of views that was almost completely absent among managers at the operating levels. For example, that the DOD and NASA were the industry's principal customers was invariably made clear at the upper corporate levels. Furthermore, in responding to questions about the future of the aerospace market, the almost uniform reply was that while the DOD and NASA would continue to be good customers, the market was unlikely to grow as it had in the past. Principally for that reason, aerospace companies are interested in new marketing opportunities, one of which could conceivably be presented by civilian public projects. Should a market eventually develop in this area and grow to an appreciable annual volume, the industry would be interested in obtaining a reasonable share. This would be accomplished slowly although steadily on a selective basis as a logical extension of present business. Slightly inconsistent with this view, perhaps, is the apparent consensus that large-scale participation in the domestic projects market would result in either the formation or acquisition of new companies to undertake and carry out the activities.

How quickly this potential market develops, if it does, depends to a very great extent on actions of the Federal Government—or so corporate management believes. The magnitude of the Government's efforts and how broadly it sets out to attack the Nation's domestic problems will largely determine not only the rate of growth, but the overall market potential as well. That corporate officials believe this potential to be real and likely to result in significant business for the aerospace industry has been demonstrated over the last 2 or 3 years by the increased time they and some of their upper level scientists and engineers have devoted to this area. They believe, however, that under the best conditions, it would be unrealistic to expect that civilian public projects will account for a very significant percentage of the aerospace industry's business within the next 5 years or so.

In contrast to the apparent unanimity described above, management views at the operating level range from extreme skepticism if not disbelief in the likelihood that a market will develop, to the conviction that the market has already developed and that the industry is even now actively and successfully participating in it. Not surprisingly, the two extremes correspond to the views held respectively by a group that has its future apparently tied inextricably to the defense and space markets and by a substantially smaller group that has evidently become almost wholly occupied with diversification—often through an earlier interest in arms control and disarmament. Between these two are many managers engaged in the day-to-day activities of the company who embrace a variety of views between the two extremes.

The managers who have been active in diversification efforts tend, as expected, to emphasize the potential of civilian public projects, while at the

[81] Questionnaires were used for the participants of the fourth study. These data, together with those collected in face-to-face interviews with participants in the three other studies, are summarized in app. B.

same time to discount the problems of creating and shifting into the new market. Those who identify closely with DOD and NASA programs do just the opposite. Which group is nearer to reality is difficult to say, particularly without a better understanding of what would constitute industry success in the civilian public projects area. Very likely the two groups have different ideas about this aspect as well.

Of the management personnel directly or closely connected with the California studies, most expressed views which generally leaned toward the diversification group, although on further questioning, they acknowledged the existence of difficult problems. Moreover, when asked for more explicit descriptions of where the California studies might lead, they conceded that the future was quite hazy. They would rarely admit, however, that the aerospace companies would be unsuccessful should they decide to undertake future domestic projects. Whether this represented their real views or merely an adopted attitude to strengthen their chances of success is, of course, difficult to say.

In speaking of the California studies specifically, the study managers indicated that their principal problems centered largely on obtaining essential information. Accustomed to dealing with DOD and NASA personnel who try more or less as a matter of course to ascertain their information requirements and furnish the data in a suitable form, they had some difficulty in adjusting to some State personnel who, at best, would provide them with only the specific documents or data requested. Moreover, it was not unusual to find that required information just did not exist. The study participants also found that many State employees were skeptical and lacked understanding of what they were trying to do, although members of one industry team thought that State government employees lost most of their doubts about halfway through the project. While none found that he was seriously hampered by a lack of background knowledge, most study managers generally thought that more detailed information would be desirable should they continue working in the field.

Of the future directions their companies might take with respect to civilian public projects, the study managers seemed to think that "research and analysis" and "systems engineering and technical direction" functions offered the best possibilities, although some thought that "development and production" might be a good possibility. Very little support was given to the idea that the companies might assume an operating role. A number expressed interest in obtaining from the State additional studies in the areas of their current efforts.

Backgrounds of Study Personnel

Assumptions that significant differences would appear in the scientific and engineering makeup of teams performing space and defense studies and those conducting the California studies were fairly well borne out by the personal data collected on the industry participants. As illustrated by figure 10, the educational backgrounds of personnel described in one industry study proposal to NASA show a predominance of physical scientists and engineers, whereas aggregating the educational backgrounds of all participants for whom data were available in the California studies reveals a higher percentage in a classification other than physical science and engineering. Moreover, past experience with industry studies for the DOD and NASA indicates that the composition of the one aerospace study shown in figure 10 may include a larger number of physical scientists and other disciplines than are found in most such efforts.

As mentioned earlier, scientists and engineers associated with the earlier phases of aerospace programs usually hold higher academic degrees and are probably more transferable, in general, than those engaged in the later phases. Comparing the educational levels of the California study team members shown in figure 11 with those found by Shapero and Vollmer [82] for the overall industry provides some small support for this view, in that

TABLE 11. WORK BACKGROUNDS OF STUDY PERSONNEL

Organizational function [1]	Percent study personnel in function just before this study
General administration	11
Research and engineering	57
Development	26
Developmental test	0
Manufacturing	0
Procurement	0
Quality assurance	0
Customer service	6

[1] Categories developed by Albert Shapero and Howard M. Vollmer, "Technical Profile of the Industry," *The Industry-Government Aerospace Relationship*, vol. II (Menlo Park: Stanford Research Institute, 1963), p. 256.

[82] Shapero and Vollmer, *op. cit.*, p. 260.

FIGURE 10. *Educational Background of Personnel Found on One Aerospace Study and on California Studies*

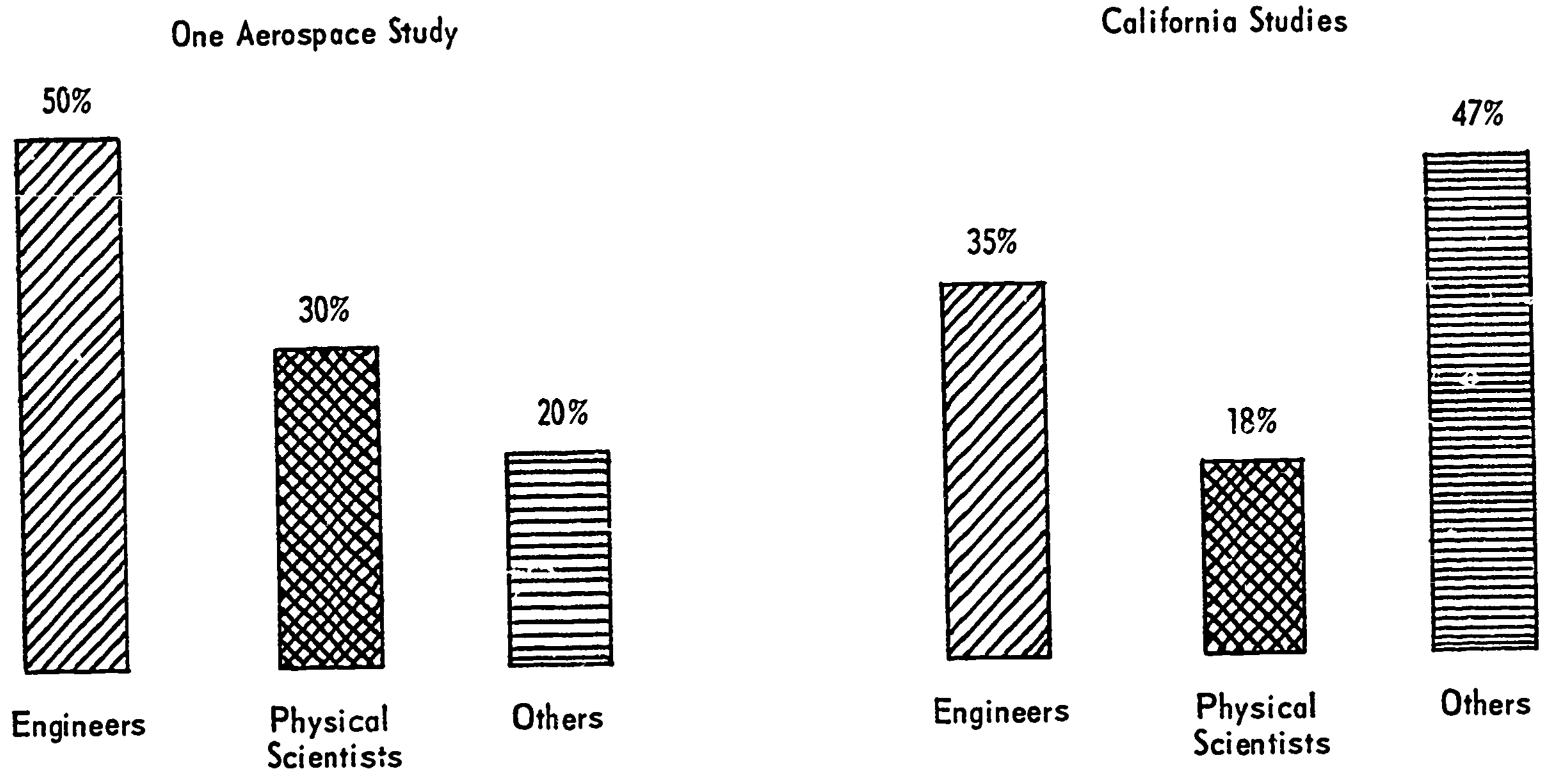
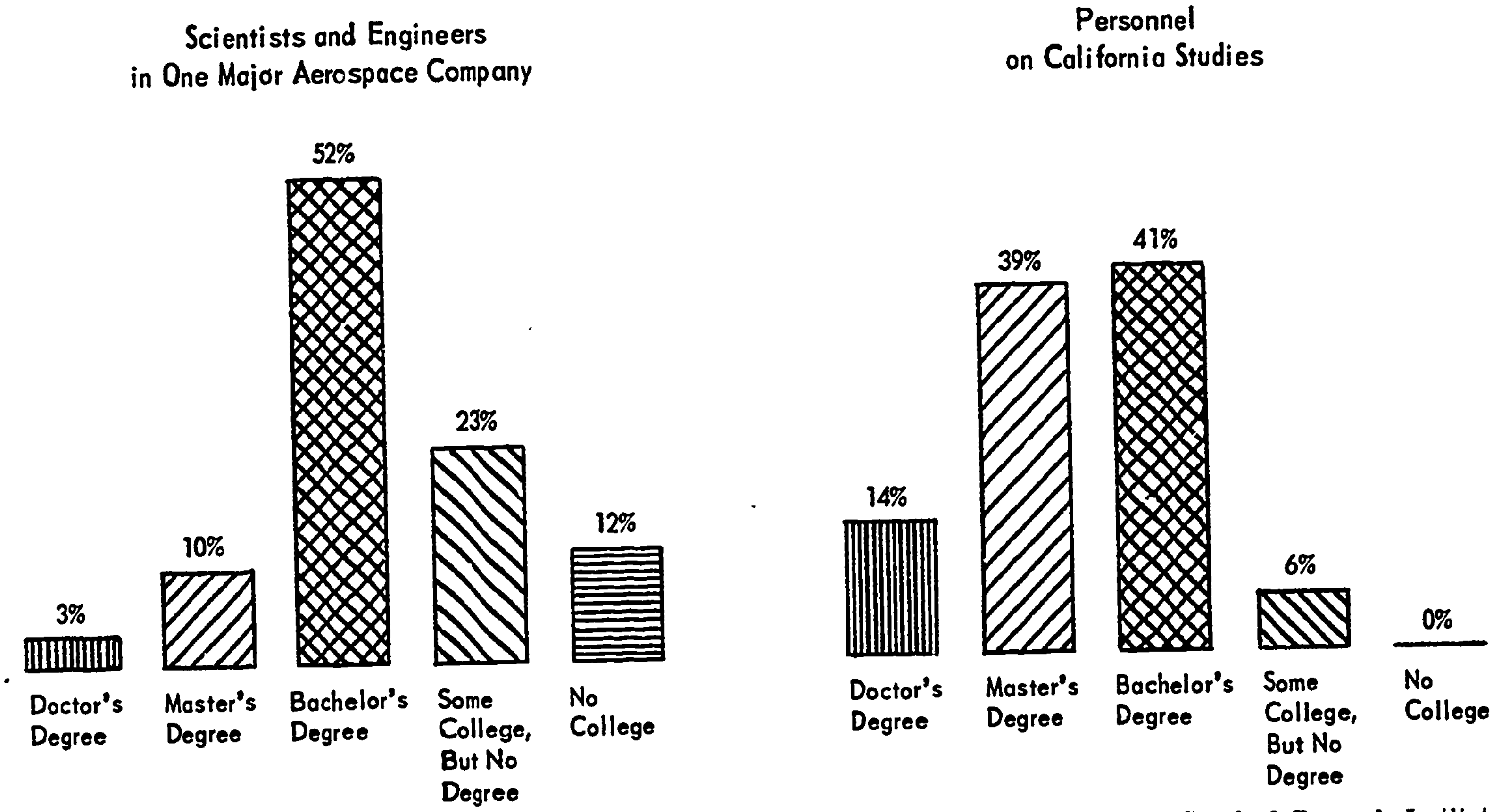


FIGURE 11. *Highest Educational Level of Scientists and Engineers in one Major Aerospace Company (1962) and of Personnel on California Studies*



SOURCE for scientists and engineers in one major aerospace company: Albert Shapero and Howard M. Vollmer, "Technical Profile of the Industry," *The Industry-Government Aerospace Relationship*, vol. II (Menlo Park: Stanford Research Institute, 1963), p. 260.

the median educational level in the California study corresponded to a master's degree, in comparison to a bachelor's degree for the industry.

Table 11 provides data on the work backgrounds of the study personnel immediately preceding their assignments to the California's studies. The indication that 57 percent of the scientists and engineers had been involved with the research and engineering function is roughly comparable to estimates on the composition of study teams during the concept formulation stages of weapon system programs (see fig. 9).

Other personal data were obtained on the participants that may illuminate the makeup of the study teams. The average age was 39 years and the average time with the company was 7 years. (This length of employment dispels any idea that the companies hired new personnel for the studies.) On the average, the primary reason given for being selected to work on the study was possession of past experience, although this was usually not in the actual area of the study. The principal problems were nontechnological, although most felt that to continue working in the area would require study in a technological area. Before the study, the average team member knew 20 to 30 percent of the other members and had worked with 10 to 20 percent. Queried about the prospects for the aerospace industry in the public projects area, most indicated that they thought they were good.

Conclusions

The systems approach is neither a new technology, as some seem to think, nor a methodology reserved for the exclusive use of scientists and engineers in the aerospace industry. It is a way of looking at questions, of analyzing issues, but not a technology in the sense of an applied science or a methodology dealing with the tools of analysis. From this point of view, it is not even a form of analysis, such as systems operations or research. In another sense, however, it is a methodology, for it deals with the principles of intellectual procedure; i.e., the systems approach as an idea or concept prescribes that a subject under consideration be examined in a particular way—by taking account of all factors that seem relevant, noting the uncertainties, and investigating the effects of variations in the relevant factors. In most respects, all of this adds up to very litle more than the application of commonsense, a trait not solely the possession of any single group in our society.

Still, to conclude that the so-called "systems capabilities" of the aerospace companies are more imaginary than real would be erroneous. In their accustomed use of operations and systems research to analyze complex questions of choice and in their systems engineering experience with large-scale systems, selected personnel and organizational units in most aerospace companies are able to apply some highly developed, sophisticated analytic techniques that can often provide more quantitative, less subjective data on which decisions can be based.

Certainly, today's society and its problems are incalculably more complex and interrelated than those in past years; consequently, they require not only the adoption of the systems approach, but also the increased use of the advanced analytic methods which some have identified with the aerospace industry. Extrapolations of present trends indicate that factors such as higher population densities and greater reliance on machines will undoubtedly compound these problems in the future. It seems reasonable, therefore, to expect that State and local governmental jurisdictions will be required to turn more and more to the types of analyses that have come to be associated with defense and space endeavors. The State of California under a somewhat unique set of circumstances has taken steps to strengthen its capacity to handle some of its urgent and more pressing problems by utilizing private firms. These actions may indicate a trend toward the use of a process that has been noticeably lacking at the State level; i.e., the utilization of science and scientific research in the type of policy-supporting role evident on the Federal level since the beginning of World War II. If other State and local governments plan to retain their present policy-making roles in the Federal system, they will have to demonstrate their ability to cope with the difficult problems which face them now and in the future. Thus, it seems reasonable to conclude that they will more and more incline toward the pioneering direction established in California's novel experiment.

But there seems no reason to assume merely because the aerospace companies may have been successful in using the systems approach to assist California in its innovative activities that other States will necessarily turn to the aerospace industry. After all, there are few reasons to think that other organizations would not be equally successful, should they be given the opportunity. The future success of the aerospace industry in conducting studies of the sort carried out for California will depend, therefore—much as it will with other functions it might consider performing in large domestic projects—on the ability of individual companies to compete with other interested public and private instrumentalities having capabilities to examine questions of public policy. Of perhaps equal or greater importance to assessing the difficulties apt to confront the aerospace industry when it attempts to establish at the State and local levels the relations it has with the Federal Government are questions raised by existing institutional obstacles, longstanding legal restrictions, and the vested interests of individuals and public and private groups. How capable and resourceful State and local governing bodies will prove to be in overcoming such barriers remains to be seen.

Probably the single, most innovative—and possibly most important—contribution of the scientists and engineers in the California studies was their attempt to model explicitly, and to some extent quantitatively, the social, political, economic, and technological factors in the systems under consideration and to define the optimum relationships within the total systems under various assumed conditions. Yet to conclude from these studies that aerospace scientists and engineers as a group are uniquely fitted to study questions of public policy involving technological issues seems a premature and unwarranted conclusion. Granted that they possess the training and experience that could permit valuable and far-reaching technological contributions, there seems little evidence that the scientific and engineering skills of the aerospace industry are better suited to making technological contributions to domestic projects than those possessed by other scientists and engineers having comparable backgrounds and academic attainments.

By necessity, the aerospace industry has continued to reach for new technological advances, and, as a result, the scientific and engineering component of its work force has steadily increased. In some respects, this situation has tended to feed on itself, with new scientific and engineering talent bringing forth new ideas which, in turn, have resulted in requirements for additional scientists and engineers. Whether this self-sustained innovation proves an important factor in easing the entry of the industry into the domestic projects market depends on the need for major technological improvements in the area. While a fresh and less conventional approach to some problems should be beneficial, there are a number of persuasive reasons for believing that solutions exist for the technological aspects of most current domestic problems.

The characteristics and abilities of aerospace scientists and engineers vary—and, therefore, their transferabilities vary. In this study, how difficult the transfer would be has been examined by hypothesizing that the scientific and engineering activities associated with the definable phases of a large-scale weapon system program provide some significant indications of the transferabilities of those involved in the activities. Based on this analysis, the conclusions reached are that, in a rough sense at least, the transferability of aerospace scientists and engineers is inversely proportional to the manpower loading curve for a large-scale weapon system program; i.e., scientists and engineers normally occupied in the early phases should have the least trouble in transferring to civilian public projects, those in the design and development phase would very likely encounter the most difficulty, while those principally associated with the production and acquisition phases would probably find a situation lying somewhere between the two extremes. And so the largest group of scientists and engineers in the industry, those engaged in design and development, may well prove to be the least transferable.

To an aerospace company that becomes deeply involved with the civilian projects market this may mean that a small group normally identified with the early program phases would form a nucleus that could evolve into a separate division or subsidiary. (This does not say, of course, that others who have been accustomed to working in the later program phases could not also transfer. The transfer would merely be more difficult and less natural for them.) The practice of forming new organizational units could develop during a period of reduced defense spending. If it does, it could result not in the preservation—as some have hoped—of an industry "team" that could be recalled quickly when needed to the problems of defense, but rather in the eventual growth of separate corporate entities remote from the defense- and space-based parts of the parent company. As time goes on, these would possess fewer and fewer capabilities to undertake large-scale weapon or space system programs.

Contrary to some opinion, for the aerospace industry to move into the civilian projects market would likely be a departure from its historical trend over the last two decades, i.e., toward products of increased technological complexity. While there is a similarity between what may become a new market for the industry and the defense and space markets, it stems primarily from the use in each of contractual arrangements for solution of very large and complex problems. Once this correspondence has been noted, the similarity rapidly decreases. What seems more important from a marketing point of view is that the undertaking of civilian public projects would be a reversal in direction. Because the aerospace industry, in its defense and space programs, has consistently worked at the fringes of new technology, its advanced research and development capabilities have placed it in an exceptionally good competitive position in a market almost totally dominated by the industry in the first place. In the civilian public projects market, however, where new technological advances seem less important and a number of other companies are already actively engaged, the aerospace industry will undoubtedly meet with a much more competitive situation.

In summary, then, three points need to be emphasized: First, as indicators of the ease with which the research and development capabilities in the aerospace industry could be transferred to civilian public projects, the four California studies are inconclusive, testing as they did only a very small sample of seemingly the most transferable industry scientists and engineers. Second, whether the scientific and engineering skills in the aerospace industry could be transferred easily may not be a conclusive factor in examining the question of industry diversification. For after all, the magnitude of other problems surrounding industry diversification appear much larger than those associated with the transfer of industry scientists and engineers. Third, while there are indications of a growing interest in public projects and while there are components of the scientific and engineering capability of the industry that could be usefully applied to the solution of specific problems, it seems unlikely that civilian public projects will become in the next 5 years or so a significant part of the industry's total business. Then, too, future changes in the defense and space markets, brought on by world events, for example, will alter the industry's interest in this market.

Appendixes

APPENDIX A

Phases of a Large-Scale Weapon System Program

Introduction

The nature of the scientific and engineering activities and the percentage of the total program effort they represent vary as a large-scale weapon system program progresses through its life cycle. As a result, the skills, work backgrounds, and educational attainments commonly identified with the scientists and engineers employed in one phase of the program tend to differ from the corresponding characteristics of those employed in other phases. At least, some characteristics are apparently much more predominant in one phase than in another. A number of difficult problems are encountered, therefore, when attempting to aggregate the variety of scientific and engineering disciplines and skills found in the aerospace industry into a single, homogeneous entity.

Moreover, trying to judge how easily these skills could be transferred to a major civilian public project without accounting for this lack of complete homogeneity oversimplifies and, in many respects, tends to obscure the question of transferability. The problems can be at least partially circumvented, however, by adopting an alternate approach, i.e., by analyzing the relative transferability of the skills associated with each program phase rather than by constructing an analytic model approximating a composite cross section of the scientific and engineering skills of the industry. The purpose of this appendix is to provide the background for an analysis of this sort by delineating the distinguishable phases of a large-scale weapon system program and describing the general pattern of activities in each.

Life-Cycle of a Weapon System Program

A large-scale weapon system program, in the complexity of its organizational structure and in the diverse range of its activities, is an undertaking of substantial proportions whose successful conclusion comes about only after large quantities of resources have been consumed and sometimes created. Quite often, for example, a major missile or space program will result in the expenditure of several billions of dollars,[1] depend on the efforts of 15,000 to 20,000 persons in one aerospace company alone (of which there may be several in the program), and require 5 to 10 years to bring the new system to full operational status as an element of the Nation's military force structure. Entering into a program of this size and complexity is thus a decision of considerable magnitude and import that is made only after much prior deliberation and study.

The activities preceding a decision to consider seriously the undertaking of a large-scale weapon system program normally span a period of several years. During this time, principally given over to the generation and evaluation of ideas, a number of program opportunities exist. While many inevitably will be discarded, some eventually will become viable choices from which one or more weapon system programs may be selected for accomplishment. Because of the nonspecific character of these embryonic activities, directed as they are toward a number of separate and distinct possibilities, it may be slightly incorrect to describe this early period as the opening phase of one particular program. Nevertheless, to the extent that the formulation and analysis of ideas during this time strongly influence and help shape the subsequent decision to initiate a given program, the period can be justifiably thought of in this light. As these choices are made in the latter part of this phase, some fairly definite objectives emerge in the form of tentative operational requirements and research and development objectives.

Once the decision has been made to examine the desirability of developing a new weapon system, some fairly definable phases follow over the next 6 or so years. In the first phase, referred to by the DOD as the concept formulation phase, attention more and more starts to focus on specific program possibilities. Even at the outset of this phase, a number of choices are still open to the decision-maker, including a decision not to proceed.

[1] Secretary of Defense McNamara, testifying before the House Armed Services Committee in February 1965, stated: "Over the past 10 years, more than $10 billion was spent on the development of ballistic missiles, including $2.3 billion on Atlas, $2.6 billion on Titan, $2.5 billion on Polaris, and $2.1 billion on Minuteman I."

Should he decide to proceed, however, the features of the future program will be established with sufficient clarity to permit entering the contract definition phase, in which the program will be refined and planned in greater detail.

At the conclusion of contract definition—if the decision is to continue with the development of the system—the third phase, the full-scale design and development program, will be undertaken. If system acquisition is decided on, production will commence at a point overlapping the development and test of the system. Production itself will be overlapped later by the acquisition and operation phase. While future improvements may be made to the system and later models of the system may be designed and built, the original program is essentially complete at this point.

The Pattern of Activities

Regardless of the organizational structures employed by the large aerospace corporations, each apparently utilizes its scientists and engineers in similar functional activities. Shapero and Vollmer,[2] for example, in a survey of about 30 major aerospace firms (including an indepth examination of the manpower utilization in one) were able to identify eight functional divisions which seemed to account adequately for the separation of activities in each company.[3] As might be expected, they were able to detect from the data gathered during the survey that in general the educational backgrounds and work functions of the scientific and engineering personnel in one division differed perceptibly from those in another. From their description of the scientific and engineering activities in the functional divisions of the organizational structure, it is possible, as shown in figure A-1, to relate the eight functional divisions to the six weapon system program phases mentioned above.

Generation and evaluation of ideas. Broadly stated, the opening phase of a large-scale weapon system program is characterized by indeterminacy. The problems to be addressed are loosely defined, if indeed they are defined at all. The future military needs are uncertain, for the environment itself 5, 10, or 15 years hence is itself uncertain. And, while many ideas may have a great deal of appeal at this stage and may appear to offer new and vastly improved military capabilities, the capabilities would have utility only if the need for them should develop. Therefore, this initial phase is largely concerned with generating new ideas and evaluating them against present estimates of future needs.

But from where do the ideas originate? The answer depends to a large extent on the nature of the ideas. Study groups in the military departments, for example, continually examine the expected future environment, attempting to estimate the military threat and, from its characteristics, determine the military needs which may have to be met at a later time. The scientific community, including colleges and universities, industry, and government laboratories, are the source of new technological advancements which may make possible the development of needed military capabilities previously unattainable. Long-range planners in government, industry, and the not-for-profit organizations[4] are instrumental in evaluating and bringing many of these ideas to the attention of appropriate decisionmakers.

Thus, the pattern of activities during this phase encompasses a wide variety of unrelated, mostly undirected research efforts, experimental developments, studies, and analyses—undirected in the sense of not being pointed toward a single, specific program, but all contributing in some degree to the fundamental purpose of the activities, i.e., to establish appropriate military operational goals and supporting research and development objectives. At this stage, only a small (but an exceedingly active) fraction of the scientific and engineering personnel in the aerospace companies is involved. The activities are primarily (1) planning and staff advisory functions at the corporate management level; (2) research and development, often as a part of the company's independent research and development (IRAD) program; and (3) operations and systems analysis, often in support of the company's marketing activities.

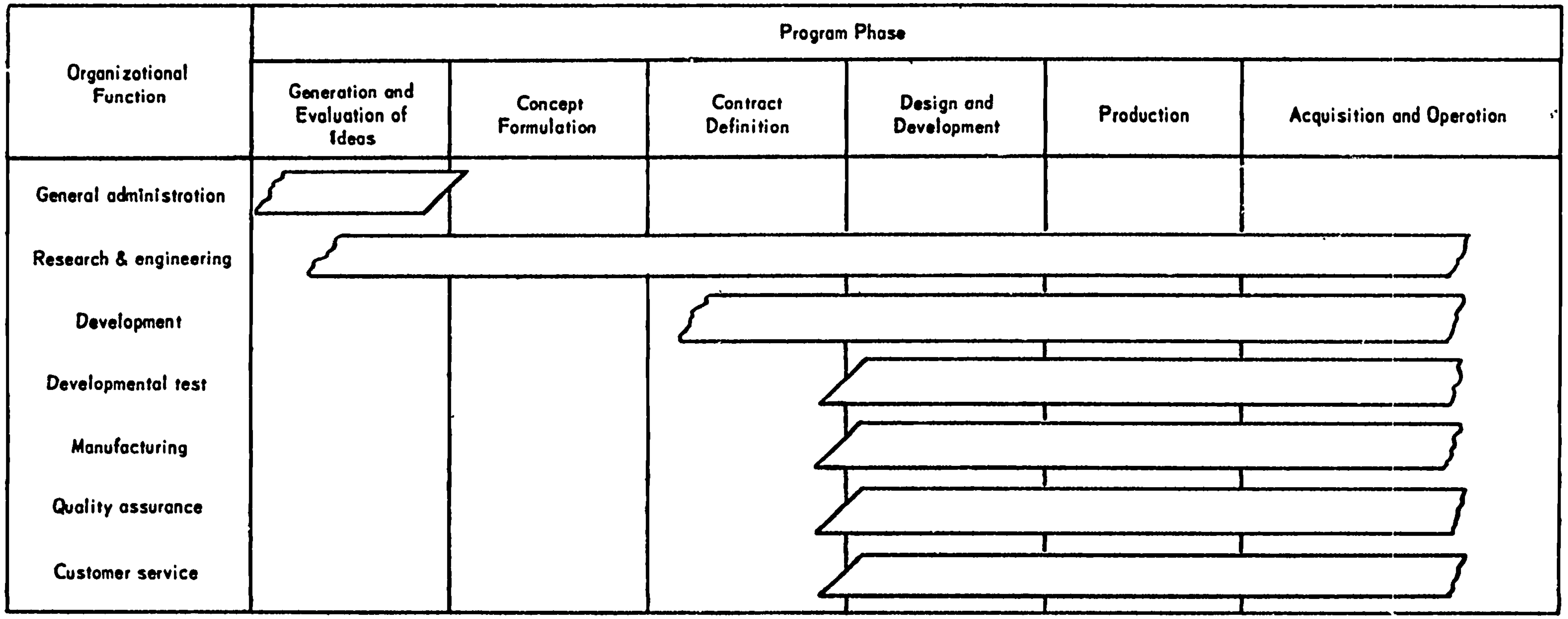
Concept formulation. In many respects, the activities of the aerospace companies are somewhat peripheral during the period preceding concept formulation—peripheral in the sense that their activities have not been meshed with those of the military departments to the degree that they start to be when the concept formulation phase begins. For at this point, when a weapon system concept can be perceived with some degree of clarity and a preliminary specific operational requirement has been established (i.e., after the military need has been clarified and the operational objectives formulated), the interest of industry is heightened by the possibility of obtaining a contract award for the follow-on contract definition phase that could, in turn, put the company in an advantageous po-

[2] Albert Shapero and Howard M. Vollmer. "Technical Profile of the Industry," *The Industry-Government Aerospace Relationship*, vol. II (Menlo Park: Stanford Research Institute, 1963), p. 256.

[3] The eight functional divisions were (1) general administration, (2) research and engineering, (3) development, (4) developmental test, (5) manufacturing, (6) procurement (only a negligible number of the total scientists and engineers were found in this division), (7) quality assurance, and (8) customer services.

[4] For an excellent discussion of the role played by planners in helping formulate an idea and in gaining acceptance of it at the highest echelons of government, see Bruce Smith's doctoral thesis on The RAND Corp. (to be published by the Harvard University Press, Cambridge).

FIGURE A–1. ***Relationships Between Organizational Functions and Phases of Weapon System Program (Based on Scientific and Engineering Activities in Each Organizational Function)***



sition for obtaining the later weapon system development contract.

The primary purpose of concept formulation, as stated by the Department of Defense,[5] is to determine whether contract definition should be initiated and to establish a sound basis for that phase, should it be undertaken. As a result, the activities of the concept formulation phase are mostly given over to a determination and demonstration that six prerequisites have been met. In brief, it must be shown that:

1. Engineering rather than experimental effort would be primarily required should a weapon system development be initiated and that there is a high degree of confidence that the weapon system could be developed within the scheduled time and estimated costs;
2. Thorough trade-off analyses have been made of alternate missions and system performance capabilities, including analyses of the feasibility, cost, risk, and schedule of each associated technical approach;
3. The best technical approach has been selected;
4. The mission and performance envelopes have been defined and optimized in the sense that the best balance has been achieved among all factors, including technical feasibility and cost factors;
5. The cost and effectiveness of the proposed system have been determined to be favorable when compared to the costs and effectiveness of other competing Department of Defense systems;
6. The cost and schedule estimates are credible and acceptable.

While the military department concerned (Army, Navy, or Air Force) has the responsibility for showing that the six prerequisites have been met, many of the supporting studies and analyses are performed by aerospace contractors—sometimes on a funded basis but more often not. Moreover, in addition to the technical feasibility studies, systems and operational analyses, and cost studies performed by industry, results from their research, exploratory development, and advanced development contracts with the military are often used in the concept formulation phase. The general pattern of activity within an aerospace company during concept formulation involves only a small percentage of the scientists and engineers in the organization. To a large extent, the task at this point in the life cycle of a weapon system program is to devise and analyze possible systems that promise to provide a needed military capability. Hall calls this twofold process "functional synthesis" and "functional analysis."[6] In essence, functional synthesis takes as its starting point the desired system inputs and outputs and proceeds within the known design and performance constraints to the point where the required functions have been delineated and interrelated in an overall system concept. Doing this for each system possibility and analyzing and comparing each concept with all others provides a basis for selecting an optimum system. Rarely, however, will two companies agree on the same optimum system concept and this, of course, is the underlying basis for the competitive nature of the follow-on contract definition phase.

Contract definition. The activities of the firms participating in contract definition are devoted basically to the preparation and performance data on their proposed sytems, estimation of firm costs and schedules, formulation of the management structure for the planned weapon system development program, and, in less detail, major characteristics of the project for several years beyond the design and development phase. Early in this period, the scientific and engineering manpower starts to build up slowly and, as shown in figure A-1, the development function becomes increasingly important, although primarily limited still to analytic, or *paper*, design. Then, too, other organizational functions become involved on a limited scale as the companies start to refine their preliminary development proposals, originally prepared during concept formulation.

To some extent, the pattern of activities in the contract definition phase is a continuation of the pattern followed in the preceding phase. But at this point, where explicit and detailed reports have to be prepared covering a wide range of specialized company operations, representatives from the various organizational functions are required. A typical list of the documents (often running as high as 15 to 20 bound volumes) supplied by a single contractor at the conclusion of contract definition illustrates the depth and breadth of the subjects covered:

1. A plan outlining the management approach and controls to be used in the weapon system development program;
2. An engineering development plan describing the engineering design and development tasks;
3. A plan detailing the approaches to be used in achieving the required reliability goals;
4. A plan detailing the procedures to be followed in meeting system maintainability requirements;

[5] "Initiation of Engineering and Operational Development" (Department of Defense Directive 3200.9, July 1, 1965).

[6] Arthur D. Hall, *A Methodology for Systems Engineering* (Princeton: D. Van Nostrand Co., Inc., 1962), pp. 111-113.

5. A quality control plan defining specific methods and procedures to be used in ensuring product integrity;
6. A manual establishing a PERT/COST Control system for the proposed program;
7. A manufacturing plan outlining the approach to the fabrication, assembly, and manufacturing test of the proposed system;
8. A logistics plan delineating requirements for spares, handbooks and manuals, customer personnel training, and field maintenance and service;
9. Detailed plans and schedules covering all elements of the proposed development program;
10. A detailed test plan covering planned testing activities in the contractor's plant and in the field;
11. A plan specifying the program that will be followed in establishing uniform and adequate specifications;
12. A plan to emphasize the application of design principles for maximum system operating safety;
13. A plan identifying the value engineering approaches to be used in ensuring that sound economic trade-offs are used from design inception through field operation;
14. A configuration control plan to ensure an integrated system design.

Using the proposals of all participating contractors, consisting of documents such as these—and often others of a more specialized nature—the military department concerned formulates a project plan. Negotiating around the contents of this plan, the military department awards one or more definitive contracts, and at this point the design and development of the weapon system is undertaken.

Design and development. Where, until now, attention has primarily focused on the determination of needs and how they might best be met, at this point in the life cycle of the program the emphasis shifts to the engineering, fabrication, and test of the weapon system. The engineering manpower loading starts rising sharply and, by now, the development functions begin to predominate. Concurrently, as shown in figure A–1, the developmental test, manufacturing, procurement, quality assurance, and customer service functions assume an increased importance. The research and engineering function, previously concerned with the planning and initiating of the program, now starts to look more and more like an evaluating, supporting, and coordinating function of the program director's office.

At the outset of the design and development phase, the program director and his staff spend a great deal of their time making arrangements to man the project, coordinating the preparation of detailed plans and schedules, and to serve both as a basis for customer and subcontractor negotiations and for work statements from which detailed task assignments can be prepared. The wide range of highly complex, and at times seemingly unrelated, activities which result very quickly involves a large part of the company's capability.

In the early weeks of the project, before the imposition of a "design freeze"—i.e., before the time when further design changes are executed only through an elaborate review and approval procedure and normally only on a manufacturing lot basis—the interactions among the large number of subsystem designs give rise to serious interface problems and numerous design iterations. But as the project progresses, tests of yet unproved parts of the system confirm theoretical designs; computer simulations verify early performance assumptions; and full-scale system mockups provide solutions for subsystem packaging, installation, and interconnection problems. And in a matter of months, a coordinated and integrated system design emerges in the form of several hundreds of engineering drawings that will be used to fabricate a number of developmental systems which will undergo a succession of tests, culminating in the flight test program.

Meanwhile, as the design evolves, production planners become increasingly involved, examining and analyzing each design release, to extract tooling, manufacturing and assembly, production testing, inspection and quality control, and other information important to the production phase of the program. Plant engineers commence work on preliminary floor layouts of available manufacturing areas. And as the design and development phase enters its flight test stage, if the decision has been made to proceed with system acquisition, the life cycle of the program reaches the point where the production phase and development and design phase start to overlap.

Production. While at this point the development function still predominates, its scientific and engineering components have once again begun to change as a greater percentage of the activity now becomes devoted to the flight test program, design improvement changes, and technical support of other functional divisions such as manufacturing, quality assurance, and customer service. The research and engineering function, although continuing to encompass the day-to-day staff duties in support of the program director, begins to shift an increasing amount of its attention to the period beyond the current program. Looking to the possibility that new technological developments could, if incorporated, provide new or greatly improved operational capabilities, the program office undertakes and completes advanced system studies during this period. New missions for the system being developed are explored. And, in many respects, a small part of the research and engineering function starts to have the characteristics it formerly possessed during the concept formulation and contract definition phases.

In its simplest form in the aerospace industry, serial production—i.e., manufacturing a series of nearly identical systems using production tooling and processes—generally breaks down into the fabrication of detail parts, assembly of the parts into subassemblies and assemblies, fabrication of the airframe, final assembly operations, and inspection and test. By far the largest engineering component in the manufacturing process is concerned with inspection and test (including quality assurance), and while the largest percentage of the activity is devoted to the preparation of manufacturing inspection and test procedures, very often engineers from the research and engineering and development functions will initially inspect and test the first production systems and subsystems. At the same time they are often occupied with the organizing and training of manufacturing inspection and test personnel.

As the production phase proceeds, manufacturing, quality assurance, and customer service functions more and more tend to displace the scientific and engineering components of the program. The engineering manpower which started to increase sharply at the inception of the development phase now starts to fall, although at a slower rate than it previously increased. By the time that the first operational system is delivered, many of the development engineers, designers, draftsmen, and engineering support personnel have been transferred to new assignments, some possibly to production engineering activities. The production phase and the acquisition and operation phase of the program start to overlap, the flight test program enters the operational test and evaluation period, and, in a matter of months, the cognizant military command has gained an initial operational capability.

Acquisition and operation. In the life cycle of a large-scale weapon system program, in which the elements of change are almost always present, great difficulty is usually experienced in trying to establish just where the program is concluded. The Titan I program, for example, merges into the Titan II program. The Titan II becomes the Titan III program, and so on. Then, too, where a weapon system program is originally established under a project organizational arrangement that draws support from appropriate divisions within the company, it often eventually becomes—because of its size and lifetime—an operating division of the company itself. Consequently the tendency to maintain the organization, to find new assignments within it to occupy the time of its scientists and engineers, grows. Thus, even during the acquisition and operation phase, some small scientific and engineering components persist in the program. Still, by this time, the utilization of scientists and engineers in the program as it was originally conceived has reached nearly negligible proportions. From this point of view, the life cycle of the program is essentially complete.

APPENDIX B

Background Data of Aerospace Industry Personnel Participating in the California Studies

Background data on study personnel were obtained by two methods. The first method, used with three of the four companies, was to interview the study personnel. Because the fourth company preferred it, the second method was to submit questionnaires to its employees and ask them to complete and return them by mail. All were asked questions in the following areas:

1. Their educational and work backgrounds.
2. Possible reasons for their having been placed on the study team.
3. What problems they encountered in their study.
4. The fields in which additional education or training appeared desirable to them should they continue work in the study areas.
5. What they felt the possibilities were for the aerospace industry in the area of their study.

The background data obtained by these two methods are presented in tables B–1 through B–9. On most questions there were some who gave no answer, and for the questions on which tables B–5, B–6, and B–7 are based some gave more than one answer.

TABLE B–1. FORMAL EDUCATION OF STUDY PERSONNEL

Field of degrees or study	Last degree (or area studied if no degree)	Some college, but no degree	Bachelor's degree	Master's degree	Doctor's degree
Education	2	1	------	1	1
Business administration and engineering management	12	1	6	5	1
Law	1	------	------	[1] 1	------
Political science	------	------	3	------	------
Military science	1	------	1	------	------
Economics	1	------	1	2	1
Psychology	6	------	5	5	2
Biology	------	------	1	------	------
Biochemistry	------	------	1	------	------
Chemistry	1	------	3	1	------
Physics	3	------	3	------	1
Mathematics	5	1	3	2	1
Electrical engineering	5	------	4	2	------
Aeronautical engineering	1	------	1	------	------
Mechanical engineering	6	------	7	4	------
Civil engineering	3	------	3	1	------
Chemical engineering	2	------	2	1	------
Naval engineering	------	------	1	------	------

[1] LL. B.

TABLE B–2. DISTRIBUTION OF STUDY PERSONNEL BY ORGANIZATIONAL FUNCTION

Organizational function	Latest function engaged in [1]	Total past and present function experience
General administration	6	12
Research and engineering	30	31
Development	14	23
Developmental test		3
Manufacturing	------	3
Procurement	------	------
Quality assurance	------	1
Customer service	3	6

[1] Before the present study.

TABLE B–3. DISTRIBUTION OF STUDY PERSONNEL ACCORDING TO LENGTH OF TIME THEY HAVE WORKED FOR THEIR PRESENT COMPANY

Years at present company	*Number of personnel members*
1	2
2	3
3	7
4	1
5	3
6	3
7	3
8	4
9	2
10	1
11	2
12	0
13	0
14	0
15	1
16	1
17	0
18	1
19	0
20	1
21	0
22	1

TABLE B–4. DISTRIBUTION OF STUDY PERSONNEL ACCORDING TO AGE

Age	*Number of personnel members*
28	1
29	2
30	0
31	2
32	3
33	1
34	1
35	2
36	2
37	3
38	2
39	2
40	1
41	2
42	3
43	3
44	2
45	3
46	0
47	1
48	1
49	0
50	0

TABLE B-4. DISTRIBUTION OF STUDY PERSONNEL ACCORDING TO AGE—Continued

Age	Number of personnel members
51	1
52	0
53	0
54	0
55	0
56	0
57	0
58	0
59	0
60	0
61	0
62	0
63	1

TABLE B-5. REASONS STUDY PERSONNEL THOUGHT THEY WERE PICKED TO WORK ON STUDY

Reasons given	Number of personnel members
Experienced in the area	8
Experienced in an area needed for study	20
Interviewee requested to be on project	8
Between projects	6
Knew project leader	4
Other [1]	5

[1] 1. Acquaintanceship with another member of the team.
2. Possession of graduate school training.
3. For communication between the study group and the administration personnel.
4. His outside interests.
5. Hard worker.

TABLE B-6. AREAS IN WHICH STUDY PERSONNEL ENCOUNTERED PROBLEMS ON CALIFORNIA STUDY

Problem areas	Number
Need of additional technical knowledge about field	7
Need of additional nontechnical knowledge about field	11
Requirement of new techniques [1]	6
Other [2]	7
No problems	7

[1] Typing, interviewing, etc.
[2] 1. The lack of central agencies makes the research difficult.
2. Some research data are difficult to locate.
3. Has not been on job long enough to know.
4. Time is short for the magnitude of the project.
5. More specific requirements and definition of problem are needed.
6. The State people do not know what they want.
7. A more specific statement of the overall study objective is needed.

TABLE B-7. FIELDS IN WHICH STUDY PERSONNEL WOULD DESIRE ADDITIONAL STUDY IF CONTINUING WORK IN AREA OF CALIFORNIA PROJECT

Field of additional study	Number
Technological	18
Nontechnological	11
Technique [1]	3
Other	0
None	7

[1] Typing, interviewing, etc.

TABLE B-8. DISTRIBUTION OF STUDY PERSONNEL ACCORDING TO PERCENT OF TOTAL TEAM MEMBERS THEY HAD PREVIOUSLY WORKED WITH OR KNOWN

Study personnel	Percent of total team members						
	0-10	10-20	20-30	30-40	40-50	50-60	60-70
Number who had known the corresponding percent	11	6	9	2	5	1	2
Number who had worked with the corresponding percent	14	6	9	2	4	0	1

TABLE B-9. DISTRIBUTION OF STUDY PERSONNEL ACCORDING TO OPINION ON FUTURE POSSIBILITIES FOR AEROSPACE INDUSTRY IN THEIR STUDY AREA

Opinion of future for aerospace industry	Number
Good	22
Poor	2
Other [1]	5
Do not know	2

[1] 1. Fair.
2. Only 10 percent of employees qualified—others too specialized.
3. Maybe.
4. Would need to hire some different people—more social scientists.
5. Maybe.

APPENDIX C

Proposed California Study Tasks[1]

The following study tasks were proposed by three areospace companies in response to the State of California's requests for proposals.

Waste Management—Aerojet-General Corp.[2]

Task 1—Characteristics of a Representative Waste-Management Region: Establish the basic waste-management characteristics of a representative region.

Task 2—Performance Requirements: Establish the specific waste characteristics that the waste-management system(s) under study must receive, handle, process, and discharge. This activity accounts for the effects of interfaces with other problem areas.

Task 3—Definition of Other Regions: Provide the information needed to predict future equipment and construction costs.

Task 4—Cost-Effectiveness Criteria: Establish a criterion for selection of systems, based upon cost-effectiveness or similar worth criteria.

Task 5—Current Processes and Techniques: Obtain, organize, and screen a body of data which describes the performance capabilities and cost of waste-system equipment.

Task 6—Design for Representative Region: Produce a long-term construction and equipment plan for the specified waste-management region.

Task 7—Typical System Plans for Remaining Regions: Prepare a gross construction and equipment plan for each remaining region within the State.

Task 8—Analytic and Data Handling Procedures: Specify the requirements for computer programs needed to implement the development program, and establish a conceptual design for a data acquisition, storage, and retrieval system.

Task 9—Functional Description of a Coordination Agency: Provide an organization and long-term personnel plan for a coordinating agency.

Task 10—Cost Projection: Estimate the dollar resources needed for waste management in future years, and consider appropriate dollar sources.

Task 11—Needed Legislation: Report implications of the optimal system upon relevant laws and regulatory procedures.

Task 12—Research, Development, and Construction Projects: Identify and establish the scope of proposed research, development, and construction projects needed to fill gaps in waste-management technology, and prepare specific prototype proposal requests.

Information System—Lockheed Missiles & Space Co.[3]

Task 1—Perform a system analysis of 18 functional areas, including all State agencies, special State units, local governments, and various private enterprises. The work will be

- —Survey agency and department objectives and relationships within and between organizations
- —Determine information requirements, sources, costs
- —Evaluate the present system in terms of effectiveness criteria to be developed
- —Forecast present and future information and capability needs.

Task 2—Develop the conceptual design of a statewide information handling system based upon information gathered in the system analysis phase:

- —Synthesize general objectives and requirements of a statewide system
- —Review statement of objectives and requirements with affected State organizations
- —Develop information flow and departmental interfaces
- —Evaluate equipment capabilities against requirements of the system and develop an equipment plan
- —Evaluate the system in terms of the effectiveness criteria such as cost, accuracy, time span, sufficiency, etc.

Task 3—Develop an implementation plan:

- —Determine the best timing sequence to effect system design, methods of financing, and development and operation
- —Develop building-block phasing of subsystem development

[1] The proposed task breakdowns for only three of the four studies were made available.

[2] "Waste Management System Study—A Proposal to Department of Finance, State of California" (Aerojet-General Corp., Von Karman Center, Dec. 1964), pp. 31–32.

[3] "Proposal for State of California Information System Study" (Lockheed Missiles & Space Co., Dec. 18, 1964), p. VII.

—Propose financing of development through participation by Federal, local governments, and industry.

Transportation System—North American Aviation[4]

Task 1—The transportation system of the State and its major elements were to be defined. The major factors which influence the operation of the system were to be described, and the interrelationships between the influencing factors and the elements of the transportation system were to be established.

Task 2—A survey was to be made to appraise the present state-of-the-technical-arts in fields which either directly or indirectly influence the performance or location of (or requirements for) transportation and to extrapolate from this base to possible general state of these technical arts 30 to 50 years in the future.

Task 3—An inventory was to be made to determine what information or data were available, what additional data would be needed for the actual systems analysis study (it should be remembered that this was a study of how a study should be performed), and how these data could be obtained.

Task 4—An appraisal was to be made of the applicability of existing methodologies to a data-based systems analysis study of California transportation.

Task 5—A "blueprint" was to be drawn which defines or describes the methodologies, analytical flow, inputs, outputs, crossover, computations, etc., as well as the nonquantitative judgments that need to be applied to a data-based systems analysis study of state transportation.

Task 6—A very simple, elementary scenario was to be formulated for the purpose of testing the analytical "blueprint" or design.

Task 7—The complete design of the study program was to be finished by fixing its sequence and time phasing of the elements, costing the effort of the actual study, recommending a concept for the management of the study, and describing any other needed administrative considerations.

[4] Letter (William H. Bender, Program Manager, California Transportation Study, to Ronald P. Black, Analytic Services Inc., July 27, 1965).

TECHNOLOGICAL CHANGE AS IT RELATES TO AIR POLLUTION

Prepared for the Commission
by the
Division of Air Pollution
Public Health Service
U.S. Department of Health, Education, and Welfare

CONTENTS

Technological Change as It Relates to Air Pollution

I. Technological Change as a Cause of Air Pollution

While it is probable that the new technologies—when fully applied—are capable of satisfying our unmet need for cleaner air, there is no doubt at all that technological change is primarily responsible for the gravity and present nature of the problem of air pollution.

To be sure, there was air pollution when the eyes of our cavemen ancestors reddened and wept from the smoke of the big bonfires which they used not only for heating and cooking but also to ward off the terrors of the night. And the stench from a prehistoric kitchen midden must have been noisome beyond our own imagining or enduring. But it was not until the Industrial Revolution and the start of our ever-increasing combustion of fossil fuels that air pollution in the modern sense began to blacken the air of our cities and the lungs of our citizens.

The next big magnifier was the invention—and phenomenal proliferation in this country—of the internal combustion engine. Now the fumes from some 80 million motor vehicles are added to those from the stacks of our factories and powerplants.

Then came the technological "explosion" of the past two decades. During and following World War II, new processes created new kinds of chemical pollutants—often invisible and odorless—far faster than their power for harm could be accurately assessed. Tomorrow, there will be many more.

Already the pollutants which soil and spoil our vital air resource have increased faster than any other hazard of our modern environment. And unless the same technological skills which have given us the many new amenities of modern living are promptly and effectively directed toward curbing this ugly byproduct of our technological progress, it threatens to exact an ever more exorbitant toll on public health and welfare.

II. Nature and Sources of Air Pollution

Air pollutants may be solids such as dust or soot particles, liquid droplets such as sulfuric acid mist, or gases such as sulfur dioxide, carbon monoxide, hydrogen sulfide, and the oxides of nitrogen. They include metallic fumes and dusts from lead, vanadium, arsenic, beryllium, and their compounds, and fluorine and phosphorus compounds. In addition, new pollutants are created in the air by the interaction of these and other substances under the influence of sunlight. This is the origin of so-called photochemical smog, which is suffused with ozone, a highly irritant gas.

Although they overlap, air pollution sources may conveniently be classified as: (1) Industrial and commercial, (2) municipal, (3) transportational, (4) agricultural and natural, and (5) individual.

The first group is not limited to the effluents from the stacks of "big industry," exemplified by oil refineries, powerplants, steel mills, and other large factories; it also includes pollutants from such commercial sources as drycleaning and restaurant kitchens, which make up by their greater numbers for their smaller size. An increasingly important industrial source is the chemical industry. If manufacturing processes which use chemicals are included as well as those which manufacture chemicals, they produce a large fraction of all the goods in modern commerce, and it is in this area that the new technology has had its greatest impact.

Municipal sources include the burning of auto bodies, waste from building demolition, and city dumps; cement mixing, and asphalt-paving operations; and municipally owned powerplants.

Transportational sources include not only the exhaust pipes, carburetors, crankcases, and gas tanks of automobiles, trucks, and buses, but also the jetstreams of modern aircraft and, in some localities, smoke and soot from river, lake, and ocean vessels.

Volcanoes, forest fires, and dust storms are largely of natural origin, although the last are aggravated by man's road building and agricultural activities. Such airborne substances as pollens, spores, rusts, and smuts—known as aeroallergens because they cause allergic responses in sensitized individuals—come in part from natural vegetation and in part from cultivated crops. Other agricultural activities which may pollute the air are the seasonal burning of stubble, the handling and storage of grain, and the spraying of crops and forests with pesticides.

Individuals are involved, of course, in nearly all the sources so far mentioned, and particularly in the operation of their family cars. Other individual sources, important because they are so numerous, include home and apartment house heating plants and incinerators and the backyard burning of leaves and trash.

In a special separate category are radioactive materials in the air, which may become more important with the increasing use of atomic energy for industrial and power purposes.

III. Extent and Distribution of Air Pollution

How far do all these pollutants travel? Because the sources are now so widespread (with the motor vehicle practically ubiquitous), this question may not be of primary importance any more. But the forests in the Great Smokies are apparently being damaged by pollutants emitted by Tennessee Valley Authority installations in Knoxville and Chattanooga, and in at least one authenticated case, aerial contaminants originating in Texas and Oklahoma were identified in Cincinnati after traveling over 1,000 miles. Certain it is that they cross freely municipal and State and national boundaries, thereby greatly complicating legislative and administrative measures for controlling them.

Of even greater significance is the sensational spread—mostly within the last 25 years—of the air pollution problem to more and more cities, to smaller cities, and to rural areas, where its damages to crops and livestock are causing more concern than its possible harm to humans. First attacked as a smoke problem in our largest and most industrialized cities, then as a smog problem thought at first to be limited to southern California, air pollution now affects every American State, definitely including Alaska and Hawaii.

A 1961 study indicated "major" air pollution problems in 308 urban places, an increase of 84 in a single decade. About 7,300 American places, including all cities of 50,000 or more and accounting for 60 percent of the Nation's population, are faced with air pollution problems of greater or less severity.

The continuing movement of an ever larger percentage of the population into urban areas has concentrated the discharge of waste products into a very small proportion of the atmosphere, thereby intensifying the problem of air pollution. By 1960, 53 percent of the people were living on less than 1 percent of the country's land area. This trend results in the exposure of more and more people to more and more pollution without any corresponding increase in their available air supply.

In addition to growing population and urbanization, other factors which tend to increase the magnitude of air pollution include growing industrialization to provide for our ever-rising standard of living and growing per capita demand for power and transportation. This increase is more than proportional, because each of those growth factors reinforces the others. Already unclean air has become a major economic, esthetic, and public health problem that affects practically every American locality and citizen.

IV. Economic and Social Effects of Air Pollution

Most often overlooked in any catalog of the money losses chargeable to air pollution is the enormous wastage of fuel and sacrifice of efficiency associated with it. Yet in cold dollars and cents, this is probably the costliest of all the economic effects of air pollution. Whenever we see a dense black plume rising from a chimney or jetting from the exhaust pipe of a motor vehicle, it is prima facie evidence of incomplete combustion. The fuel, whether coal or gasoline, is not providing the full measure of heat or power of which it is capable. Considering that not only every factory and powerplant chimney and every motor vehicle of every kind but also the space heating requirements of every home and store and public building in the land contribute to the total, the annual dollar cost to the Nation in wasted fuel alone, while incalculable, undoubtedly runs into the billions.

One of the visible results of incomplete combustion, soot, is also responsible for much of air pollution's soiling effect. As President Johnson emphasized in his message to Congress of February 8, 1965, on the natural beauty of our country, air pollution destroys beauty. Our esthetic senses are affronted first of all simply by the dirt in the air. It not only soils the clothing we wear and the laundry on the line, our rugs and draperies, the paint on our houses, and the finish on our cars; it also mars the beauty of our buildings, our monuments, and even rare books and priceless works of art in our libraries and museums. As the President mentioned in his message, not even the White House is immune. Some air pollutants further affront our senses by their acrid or nauseous odors.

Air pollution also decays and corrodes. Certain air pollutants have caused nylon stockings to disintegrate, turned white housepaint black almost overnight, crumbled the marble in New York's City Hall, and decayed the solid stonework in London's Houses of Parliament.

Man-Made Darkness and Gloom

Reduction of visibility and sunlight is another of the adverse effects of air pollution. As long ago as 1927, a Public Health Service study in New York City showed that loss of light due to smoke was sometimes greater than 50 percent, and throughout the entire year almost a quarter of the sunlight was lost. It has been reported that Chicago's sunlight is reduced by 40 percent because of air pollution. Besides increasing lighting bills and making transportation hazardous, darkness in daylight generates gloom.

Materials discharged to the air also significantly alter the climatic conditions of urban areas. It has been estimated by the Weather Bureau that in winter there is 100 percent more fog in a city than in a geographically similar rural environment. Dust particles are many times greater, as are the levels of sulfur dioxide and carbon monoxide. Ultraviolet radiation in winter is 30 percent less in the city than in the country; it is cloudy 5 to 10 percent more often.

At the very least, the palls hanging over our metropolitan areas have a depressing psychological effect. But they also have important sociological effects: They cause a general loss of community pride, depreciate property values, lead to widespread deterioration of neighborhoods, and damage a city's reputation.

Obviously, air pollution limits the suitability of our urban environments as places of recreation. But its damages to flowers, ornamental shrubs, and trees are not confined by city limits. When ozone blights a pine forest, it may not only destroy industrial resources but also ruin the forest for vacationers and sportsmen. The contraction of the horizon by curtains of smog that can slow up or cancel air flights can also spoil the tourist's view of a natural wonder.

Damages to Vegetation

Agricultural losses alone in this country because of air pollution, including damages to livestock as well as to growing crops and other plants and trees, are estimated at approximately $500 million a year. While this may be no more than 4 or 5 percent of the total economic damage attributed to contaminated air, it deserves emphasis for at least two reasons: (1) Until recently, air pollution has been thought of, and dealt with—or ignored—by many lawmaking bodies as if it were exclusively an urban problem; and (2) evidence of its harmful effects on more and more kinds of vegetation and in more and more localities is accumulating with exceptional rapidity.

Earliest pollutants to be recognized as harmful to vegetation were sulfur dioxide, ethylene, and fluorides. Much more recently, increasing importance has been attached to photochemical air pollution; its typical toxic components are oxidants resulting from the photolytic reaction of nitrogen oxides and hydrocarbons in the presence of sunlight, especially ozone and peroxyacetyl nitrate, or PAN.

New and important types of crop damage are resulting from emissions from motor vehicles, from air pollution associated with our expanding urban development, and from stack gases from new industrial processes and from older ones which use fossil fuels at rates far beyond those of 15 years ago. Particulates as well as gases can be harmful to vegetation, too.

Of a wide variety of plants damaged by sulfur dioxide, the most sensitive are alfalfa, barley, endive, sweet peas, cotton, and coniferous trees, although many other vegetables and flowers are also adversely affected. Species highly sensitive to fluoride pollution include corn and many fruits and flowers; damage to citrus fruits and to gladiolus has been especially notable. The most spectacular damage by ethylene from industrial sources has been to cotton, and by ethylene from motor vehicle exhausts to orchids. Grape leaves and tobacco are especially sensitive to ozone, although damage to cereal crops, ornamentals, vegetables, and indigenous vegetation is also indicated. PAN affects especially citrus and salad crops and ornamentals. Oxidant damage is also considered partly responsible for destroying ponderosa pine in the mountains of the West and damaging eastern white pine. Many fruit and shade trees, especially in and near cities, are damaged by air pollutants.

Photochemical air pollution, first noted in southern California, is increasing rapidly in frequency, severity, and geographical spread. Typical smog and ozone injury to plants has been found in most of the major metropolitan areas of the United States. Its manifestations have now been reported in urban and adjacent rural areas in 27 States, the District of Columbia, Canada, and Mexico. The entire coastal area from Washington, D.C., to Boston has come to rival southern California for extent, severity, and economic loss to agriculture because of photochemical smog.

"Hidden" Costs Contribute to the Huge Total

As indicated earlier, air pollution also accelerates the deterioration of materials, structures, and machines of all kinds. This, in turn, greatly increases maintenance and replacement costs. Metals corrode, fabrics weaken and fade, leather weakens and becomes brittle, rubber cracks and loses its elasticity, paint discolors, concrete and building stone discolor and erode, glass is etched, and paper becomes brittle. Even when only soiling of materials is involved, the removal of the deposited grime is often costly and shortens the life of the materials.

Estimates of economic losses due to air pollution are often overly conservative. Rarely are the costs identified for using expensive materials that are resistant to pollutants in place of cheaper materials that would be satisfactory in clean air. For example, gold and other precious metals are widely used for electrical contacts because of their low chemical reactivity. The present cost of gold used annually in the United States for electrical contacts is approximately $15 million. If silver could replace gold, the saving would be $14.8 million, based on equivalent volumes of metal. The value of signal transmission hardware (printed circuit boards, telephone relays, etc.) which contains environment-exposed electric contacts manufactured in the United States runs into hundreds of millions of dollars a year. In addition to gaseous pollutants, dust can degrade metals chemically as well as mechanically.

The cost, because of air pollution, of replacing or protecting precision instruments and other equipment affected by pollutants is great and growing. The complex and expensive control systems which are becoming so commonplace in modern technology can be ruined or seriously damaged by the corrosive action of gaseous pollutants or by deposited dust. To prevent such damage, many industries—for example, those engaged in the manufacture of high-precision components for telecommunication or space vehicles—must clean, at considerable expense, air admitted to plants. So too must many makers of foods, confections, beverages, and other goods for which the utmost cleanliness is a requisite.

While exact data are not available on the full extent and total cost of air pollution's damage to property, various cost estimates have been made. The one most frequently used is $65 per capita per year, representing an annual cost to the Nation of over $12 billion. It is clearly evident that the dollars-and-cents cost alone is far greater than the amounts devoted to the abatement of pollution by industry and all levels of government combined.

Adverse Health Effects Have Economic Implications Too

The adverse effects of air pollution are usually considered as of three general kinds: Economic effects, social effects (esthetic, psychological, and recreational), and health effects. But there is a great deal of overlap among these. For example, the civic edifice or memorial soiled or corroded by sulfurous pollutants in the air must be expensively renovated . . . or remain an eyesore until it reduces nearby property values and hastens the deterioration of a neighborhood. And illness and absenteeism because of pollution-induced respiratory disease involve the patient's money as well as his health.

There is ample evidence today that contaminated air can aggravate our illnesses, deplete our strength, and shorten our lifespan. Most publicized have been the acute episodes in which exceptionally high concentrations of pollutants brought sudden death. Three which have been intensively studied were in Belgium's Meuse Valley in 1930; Donora, Pa., in 1948; and London in 1952. A similar episode in New York City in 1953 was not recognized until a study of vital statistics 9 years later revealed that there had been some 200 deaths in excess of normal during a brief period of weather stagnation with unusually high levels of sulfur dioxide and smoke. The most recent such episode on a large scale was the London smog of December 1962. Largely because of the intervening passage in Britain of a Clean Air Act, deaths officially attributed to this cause numbered only about 750, as against 4,000 in the 1952 London smog. In all these acute episodes, it was the aged and infirm, and especially the respiratory cripples, who were likeliest to be struck down.

Sensational and tragic as such disasters are, we are even more concerned with the slow, insidious effects of long-continued exposure to much lower concentrations of air pollutants, concentrations such as those which prevail constantly or recur frequently in most of our cities. These prolonged exposures to airborne toxic substances may produce many health effects, but our primary interest centers on the respiratory system through which these poisons can enter the body most easily. The report of the Health Panel at the 1962 National Conference on Air Pollution was positive and unequivocal on this point. "The evidence," it concluded, "that air pollution contributes to the pathogenesis of chronic respiratory disease is overwhelming."

This evidence applies to at least six different respiratory ailments. They are (1) nonspecific infectious upper respiratory disease, including the common cold, (2) chronic bronchitis, (3) chronic constrictive ventilatory disease, (4) pulmonary emphysema, (5) bronchial asthma, and (6) lung cancer.

Actually, the cost of pollution-induced illness, including absence from work, may constitute the most significant economic loss of all, even though it may never be possible to estimate this loss in dollars and cents.

The Cost of Effective Controls

Frequently included in estimates of air pollution's economic costs are expenditures by government and industry for air pollution control. This is a good deal like including the cost of firefighting equipment in estimates of damages by fire, and seems highly illogical. For every dollar invested in control measures should be expected to reduce the money losses due to air pollution by much more than a dollar.

Certain it is that current expenditures by both government and industry are grossly inadequate in relation to the needs.

On the State government level, for example, only 24 States have legislation authorizing any kind of State program for air pollution control. In 1961, local agencies which operated control programs were spending on them an estimated 10 to 12 cents per capita annually. Thanks largely to the stimulus provided by Federal financial assistance, these figures have now climbed to about 22 cents per capita. Experience suggests, however, that communities of 50,000 or more population should be spending from 40 to 50 cents per person per year in order to maintain air pollution control programs capable of doing the job. At the Federal level, appropriations for fiscal year 1966 for all purposes, including research, total a little over $26 million; to meet foreseeable needs and provide for specific Department of Health, Education, and Welfare plans, this figure would need to rise for fiscal year 1970 to $67.5 million.

Estimates by the National Association of Manufacturers indicate that industry is currently spending at the rate of $500 million a year for air pollution control. This is being spent, however, by comparatively few polluting industries and in comparatively few localities. In the view of experts this amount could well be tripled without inflicting any serious hardship on industry or exacting too high a toll from the public, which in the long run would have to foot the bill.

The maximum suggested expenditures for government and industry combined would not exceed $10 per capita per year for our present population. That compares with the estimated $65 per capita per year which air pollution imperfectly controlled is now costing us . . . and for which the public is already footing the bill. This figure certainly could be substantially reduced if only our present technical know-how were applied effectively at the manifold sources of pollution.

V. Current Status of Air Pollution Control

Ten years ago, when the Federal program was initiated, a prime prerequisite for air pollution control was more exact knowledge of the kinds, quantities, and movements of pollutants in the air. During the past decade we have learned a great deal about all three.

The National Air Sampling Network, operated by the Public Health Service and using improved sampling and analytical equipment which the Public Health Service developed, has accumulated extensive data on the amounts and chemical composition of particulates in the air of some 250 localities, rural as well as urban. At some 50 of the stations, several common gaseous pollutants are measured, including nitrogen dioxide, sulfur dioxide, and oxidants. These, plus nitric oxide, carbon monoxide, ozone, and total hydrocarbons, are sampled more extensively with continuous recording equipment at stations located in eight of our largest cities.

Advances in meteorology have provided better understanding of the forces which promote or restrict the dispersal of contaminants and the limitations of the atmosphere's ability to dilute pollutants. Its total mixing or absorptive capacity over broad geographic regions is of great importance in helping to determine the adequacy of pollution control.

Technological Control Measures Available

While further research will increase their efficiency and reduce their cost, effective technological control measures are now available for many types of air pollutants. Particulate pollutants can be removed by devices which employ principles of filtration, electrostatic precipitation, or centrifugal force. Principles used for reducing gaseous pollutants include liquid scrubbing, vapor recovery, combustion, and solid adsorption. Both kinds can often be reduced by better plant design, better operating procedures, and better maintenance of equipment.

Solutions also exist for many important nonindustrial sources of air pollution. Open burning of city dumps, leaves, scrapped automobiles, insulated wires, battery cases, and tires—as well as inadequate municipal incinerators—can be controlled. And while limitations on permissible fuel quality, improved stoking and combustion equipment, and education as to proper firing practices may be required, smoke pollution from domestic, commercial, and industrial incinerators, boilers, and heating systems can also be largely eliminated.

In fact, although two important exceptions are reported below (major unsolved technical problems), the technical know-how exists today to deal with the great majority of pollution sources.

Current Efforts by States and Communities

There were in 1964 28 States with air pollution programs which involved expenditures of $5,000 per year or more. This compares with 17 States in 1961. Funds expended for air pollution control also increased from $2,037,700 in 1961 to $3,572,550 in 1964, a rise of 75 percent. But even now, many State programs have funds which are grossly inadequate for the programs needed.[1]

California has set up a comprehensive program for regulation of emissions from motor vehicles. California, Oregon, and Colorado have adopted certain limited standards for ambient air quality, and New York plans to do so. In 17 States—with major assistance in most cases from the U.S. Pub-

[1] Both State and local expenditures have been substantially increased as a result of the new Federal program grants made under the Clean Air Act.

lic Health Service—statewide surveys have been conducted. In most States, primary responsibility for enforcement of control regulations is vested in cities or counties. In 16 cases, the State agency is also authorized to enforce regulations, but enforcement activities in most of these have been minimal. In these same States, local programs are also authorized.

According to a 1961 report, there were then 86 local air pollution control programs which spent $5,000 per year or more. Only 34 of these spent as much as $25,000 per year. Total 1961 expenditures were $8,200,000, of which California accounted for more than half. Between 1952 and 1961, except for California, personnel in all local agencies increased by about one-third, approximately equivalent to urban population growth for that period.

More recent data are incomplete but, in general, agencies which were operating in 1961 were continuing to operate in 1964 at about the same level. Chicago, however, had increased its budget by about 40 percent, and Louisville, New York City, and Cleveland had increases of 10 to 30 percent. Substantially funded new agencies were opened since 1961 in Portland, Oreg.; Cook County, Ill.; St. Louis County, Mo.; and Nassau County, N.Y.

It is obvious that with a few notable exceptions these programs have been grossly inadequate. In fact, at no governmental level—local, State, or Federal—has remedial action in the form of more effective controls kept pace with the growth of the problem.

Industry and Other Private Efforts

There are encouraging signs that important segments of industry are voluntarily undertaking to abate their own harmful effluents. As reported above, estimates by the National Association of Manufacturers indicate that industry is currently spending at the rate of $500 million a year for air pollution control.

The same NAM estimates put expenditures for this purpose since World War II by the electric light and power industry at $350 million. A single company, Consolidated Edison of New York, has testified that it has spent since 1937 over $100 million for control equipment and its installation. The Manufacturing Chemists' Association has stated that 125 of its member companies have invested altogether about $250 million in air pollution control facilities and are spending $34 million a year to operate them.

Members of the Western Oil and Gas Association are asserted to have spent since 1948, in Los Angeles County alone, $144,456,000 on the operation and maintenance of controls and on research. Also in Los Angeles County, all industry is said to have spent about one-fourth of its total equipment cost for air pollution control devices. In these instances, of course, the expenditures were probably dictated largely by the stringent control regulations in that area rather than undertaken voluntarily.

The steel industry in many areas has cooperated with control authorities by agreeing to invest substantial sums in equipment to curb its own emissions, notably those caused by the comparatively new and exceptionally "dirty" oxygen-lance process. In Chicago, for example, four companies, responsible for some 90 percent of Chicago's steel production, have undertaken virtually to eliminate from their operations, within an 8-year period, all particulate emissions, which had totaled some 60,000 tons a year. The cost to these companies is said to be in excess of $50 million. In a single Kaiser steel plant at Fontana, Calif., control measures which cost $17 million are reported to be 99-percent effective in reducing objectionable effluents.

In order to accomplish the historic cleanup of Pittsburgh's emissions of visible smoke and soot, industry in that area was required to expend more than $250 million for antipollution equipment. On a smaller scale, but no less impressive, is the experience of Union County, N.J., where 27 industries spent for air pollution control, in the 10 years prior to 1963, $9,149,000.

Industrial associations, including those representing the chemical, steel, oil, and automotive industries, have made substantial contributions to air pollution research. A member of universities and private research organizations have also conducted a number of research projects in addition to those supported by the Public Health Service.

Even if the good examples reported above were typical of all polluting industries—and they are not—and even if all polluted localities benefited by them—and they do not—and even if the estimated annual total expenditure by industry were devoted exclusively to measures which reduce objectionable effluents—and this is questionable—$500 million a year seems an almost trivial sum in comparison either with the capital investment and annual earnings of American industry or with the economic damages attributed to air pollution of $12 billion a year.

Impact of the Clean Air Act of 1963

Since the inception of the Federal program in 1955, modest but steadily increasing funds have been made available to the Public Health Service for four principal activities in the air pollution field: research, technical assistance to States and communities, training of personnel (for industry as well as for control agencies), and the development and dissemination of information.

These activities resulted in remarkable advances in our knowledge of the sources of air pollution, of its effects, and of practical methods for abating it. They helped to assess the most urgent needs in many different States and communities and to point out the steps required for dealing with them. They also helped to alleviate the acute shortage of trained men. The informational activities further helped by creating a climate of public concern and of public awareness of the need for more effective legislation at all governmental levels.

The passage of the Clean Air Act of 1963, which President Johnson signed into law in December of that year, has served not only to step up the Federal effort but also to stimulate more extensive control measures at State and local levels, too. Under this Act, the Federal activities previously authorized were retained and expanded, important new ones were added, and the entire program was strengthened by the authorization of substantially increased appropriations.

The expanded program of research and development called specifically for the development of practical control methods, techniques, and prototype devices, as well as for the development of low-cost methods for removing sulfur from fuel in order to reduce the volume of sulfur dioxide released into the atmosphere.

Another important area emphasized was research leading to the development of air quality criteria for the guidance of State and local control agencies in setting up enforceable standards for ambient air quality, and limitations of emissions at the source.

The importance of emissions from motor vehicles was again stressed, and the Department of Health, Education, and Welfare was instructed to cooperate with the automotive and motor fuel manufacturing industries in assessing progress and in initiating new research and development efforts toward control of motor vehicle exhaust pollution.

Better control of pollutants emitted from Federal agencies was provided by authorizing closer supervision of Federal installations by the Departmen of Health, Education, and Welfare.

Two wholly new areas of Federal action were authorized: Financial assistance to States and communities, and, in certain circumstances, Federal initiative in abatement actions. The Act provided for grants by the Department of Health, Education, and Welfare to pay up to two-thirds of the cost of setting up or improving State and local control programs, and up to three-fourths of the cost in the case of interstate or other regional programs. As of June 30, 1965, 93 grants had been awarded, totaling $4,180,000, to 21 States, 36 municipalities, and 36 intermunicipal jurisdictions.

On interstate air pollution problems, the Department was authorized to hold conferences leading to abatement action. If corrective steps are not taken after such conferences, public hearings can be called and, if necessary, the U.S. Attorney General may be asked to file suit in Federal court. Similar measures were authorized on intrastate problems, but only at the request of the Governor of the State concerned.

The Clean Air Act authorized appropriations on a rising scale—$25 million for fiscal 1965 (which began July 1, 1964), $30 million for fiscal 1966, and $35 million for 1967. Congress actually appropriated for fiscal 1965 $20,995,000.

Public Law 89–272 and Motor Vehicle Emissions

Research and investigations over the years have demonstrated that motor vehicles are a major and growing source of air pollution in practically all sections of the Nation, and conclusive studies have revealed the extent and adverse effects of motor vehicle pollution. Nationally, partial control of motor vehicle emissions has been effected on cars built since 1963 through the use of "blowby devices," which recirculate crankcase ventilation gases (formerly discharged to the atmosphere) to the engine intake.

Public Law 89–272, amending the Clean Air Act of 1963, was enacted in October 1965. Among other things, this provides a separate title on control of air pollution from motor vehicles. Under this title, the Secretary of Health, Education, and Welfare:

(1) Shall by regulation, giving appropriate consideration to technological feasibility and economic costs, prescribe as soon as possible standards applicable to motor vehicle emissions which do, or are likely to, cause or contribute to air pollution which endangers the health or welfare of any persons;

(2) Upon application by a manufacturer, shall test vehicles or engines for conformity with regulations, and issue certificates of conformity;

(3) May, by joint regulation with the Secretary of the Treasury, determine admissibility of vehicles imported into this country; and

(4) May prescribe and require that manufacturers establish and maintain records, make reports, and provide information to determine their compliance with regulations.

While Public Law 89–272 specifies no effective date for initial motor vehicle emission regulations, spokesmen for the major automobile manufacturers testified that they could, if required by Federal law to do so and given sufficient "lead" time, supply nationwide, 1968-model cars that comply with California standards.

VI. Barriers to Effective Control

Today, air pollution is more a social, political, and economic problem than it is a technological problem. There still are, however, some technical problems for which no solutions have yet been found that are both effective and economically practicable. The most important of these are the discharge of sulfur dioxide in the combustion of fossil fuels, and emissions from motor vehicles.

Major Unsolved Technical Problems

Two approaches to the sulfur problem are being explored: Removal of the sulfur dioxide from the stack gases, and removal of the sulfur from the fuel before it is burned. Both are technically possible, but have so far been considered too costly for general use. (In the advance desulfurization of coal, but not of fuel oil, there are still some strictly technological obstacles to be overcome.) Accelerated research in this area, stimulated by Federal legislation, is seeking to develop removal techniques which will be economically feasible.

In the case of motor vehicles, although devices are now available for substantially reducing emissions from the crankcase and the tailpipe (which together account for 90 percent or more of total automotive emissions), there remain problems not only of cost but also of maintenance and inspection to insure that the devices remain effective. It seems certain that present technical capability for reducing motor vehicle emissions will not provide a permanent solution to the problem. The expected increase in the number of motor vehicles will far outweigh the partial reductions which can be expected from presently available crankcase and exhaust control systems. Consequently, unless substantial further reductions are made in internal combustion engine emissions, the motor vehicle problem will become even more significant nationally. It is not anticipated that either new add-on devices or minor modifications in prevailing engine design, however helpful they may be, will solve this problem satisfactorily, even apart from cost considerations; increasing attention, therefore, may have to be given to more radical changes in gasoline engines and even to alternative power sources for motor vehicles.

Social, Legislative, and Economic Constraints

Before any real progress can be made in air pollution control at the State and community levels—where nearly all control measures must be initiated and enforced—the proper climate must be created. The gravity of the problem must be recognized, laws must be passed and executed, and control agency facilities and personnel services must be paid for. State and community authorities, lawmakers, and voters—all must be convinced of the need for remedial action and satisfied that its costs will be more than counterbalanced by its benefits. Since most of the adverse effects of air pollution are hidden and gradual rather than obvious and immediate, persistent education efforts are prerequisites for effective control.

As reported earlier, Federal informational efforts over the past decade have been productive. A remarkable increase in public interest is indicated by the appearance in recent months of innumerable air pollution features in national and local communications media: Magazines, newspapers, and radio-television.

The growing public concern is reflected, too, in our national legislative body; the Congress, after passing the Clean Air Act by substantial bipartisan majorities, continued committee hearings on the subject, and many new bills were introduced. As mentioned, one of them has now been enacted into law as Public Law 89–272.

There is new activity, too, at the State level; legislatures in more than half the States are currently considering measures designed to strengthen air pollution control. Although past action, especially in States which have rural-dominated legislatures, has often been slow and timid, many of these have shown interest in sharing in the new Federal program grants and, hopefully, control activities once initiated will be continued as long as the need remains. A continuing handicap, however, is the interjurisdictional nature of the problem; in many metropolitan areas, not only two or more States but also scores of smaller jurisdictions may be involved.

By far the most important barrier today to effective control is economic. The enforcement of air pollution control laws costs money. And the installation of remedial measures and devices at the manifold sources costs even more. At all lower governmental levels, air pollution must compete with a host of other problems, from slum clearance to roadbuilding, for a share of the available funds, which increasingly seem genuinely meager in view of the mushrooming needs of today's complex society. And major segments of industry, keenly aware of their competitors and of their obligations to stockholders, are understandably reluctant to invest large sums for equipment from which, in most cases, no competitive advantages or production gains can be expected.

VII. Four Basic Needs for the Future

The Department of Health, Education, and Welfare is aware of innumerable specific steps which ought to be taken—and at the earliest practicable moment—if the Nation is to hold its own in its fight for cleaner air. Many of these are implicit in the foregoing statement of the problem.

for example, nation-wide control of automotive emissions. Even more basic, however, for the long run, may be the need for changes in *attitude* on the part of those who have the power and the capability to deal with the manifold technological and economic problems involved.

More General Recognition of the Gravity of the Problem

Today, nearly all thinking Americans, if asked whether or not air pollution is a serious environmental problem, would probably acknowledge that it is. But much less generally recognized are the enormity of its present exactions on our welfare and our treasure, and the geometrical progression by which those exactions are increasing.

A beginning has been made, but educational efforts must be expanded and persistently continued . . . by the leaders of those groups which can help to create an informed public consensus and those which must respond to it if effective control is to be achieved: Communications media, scientists, the medical profession, civic and voluntary health organizations, lawmakers, enforcement authorities, industry, and not least, the general public, who in the long run must pay the bill.

Stricter Laws and Better Enforcement—State and Local

As reported earlier, the Clean Air Act has given new impetus to legislative and enforcement action at State and community levels. In many areas, action is still impeded, however, mainly by two factors: The feeling in many States that air pollution is a serious problem only in a few big cities; and the threat of industries in some localities to move their payrolls elsewhere if strict air pollution control is imposed.

As a matter of fact, the isolated cattle feeding lot in Nebraska or the single pulp and papermill in a New Hampshire village may be as objectionable to the nearby residents as is the complex mixture of pollutants from many sources to the people who live in a big industrial city. Besides, control regulations can be, and should be, tailored to fit the actual needs of each area, as disclosed by preliminary surveys. As for the threat of lost payrolls, when equitable controls to meet demonstrated needs become more prevalent, there will be, of course, fewer asylums for uncooperative industries to move to. (In practice, the threat to move is rarely, if ever, carried out.)

Acceptance by Industry of Control as a Social Obligation

Industry too is made up of people, and its paid managers—who in most of our larger firms have replaced the rugged individualists who founded these firms—share with the rest of us civic pride and dislike of ugly and unhealthful surroundings. Progressive industry today is also increasingly concerned about good community relations and a good national "image."

There are, in fact, many encouraging signs that important segments of industry are voluntarily undertaking to abate their own harmful effluents.

Undoubtedly, as the pressures of aroused public opinion and of actual or threatened new legislation at all governmental levels are added to the growing desire on the part of industrial firms to be "good neighbors," more and more of them, in enlightened self-interest, will accept air pollution control as a social obligation and cooperate wholeheartedly in the search for better means of applying it to their own operations. In addition, methods should be sought by all levels of government to provide further motivation for such cooperation by offering to industry tangible incentives, not necessarily limited to the tax concessions which the Congress is currently considering.

New Federal Legislation—As Need Arises and Knowledge Grows

The experience gained by the Department of Health, Education, and Welfare in exercising its current authority for abatement action in interstate air pollution, and its new authority to regulate emissions from motor vehicles, undoubtedly will provide further guidelines as to what may be needed to supplement present Federal powers in air pollution control. The determination of the need for new Federal legislation will also be influenced by the amount of progress made by State and local control agencies under the expanded programs, aided by Federal grant funds, which are now getting underway.

VIII. How Better Controls Might Help to Meet Community and Human Needs

If the cost of air pollution damage in this country is indeed $12 billion a year, its reduction to a fraction of this amount would obviously release a lot of money for satisfying more basic human wants. But part of the impact of air pollution on the Nation's economy is by no means so obvious.

Consider, for example, its effect on crops and forests. This is a good example, because much of its damage to vegetation has been recognized only recently, and this seems to be spreading very rapidly to new areas. Some of the pollutants which are now of only local concern may tomorrow become widespread.

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Larger Crops From Same Amount of Land

Looking to the future, it seems certain that in 50 years or less agriculture will have to feed twice as many people as it feeds now. While some new land can be brought into production, the amount is small, and more land will be diverted to non-agricultural use—for cities, factories, roads, and parking lots. There will be greater demands on our forests, both for fiber and for recreation. There will be greater demands for water, and our forests as well as our grazing land play a vital role in water conservation. There will be a demand for more parks, more greenbelts, more ornamentals, and more flowers.

We can ill afford the losses in agricultural crops, in forests, and in ornamentals we are now sustaining due to air pollution and we shall be less able to afford these losses in the future.

The ability to feed more people from the same amount of land has come in the past, and will come in the future, from better practices, better varieties, and better handling, based upon sound fundamental knowledge of the response of organisms to their environment. Air pollution is an important adverse factor of the environment and the extent to which we succeed in controlling it will help to determine our success in meeting our expanding needs for food and fiber from diminishing acreage.

Mass Transportation and Urban Renewal

As indications increase that motor vehicles may constitute the largest and fastest growing single source of air pollutants, our search for cleaner substitutes for the internal combustion engine might well lead us to a happy revolution in our commuting patterns. We might end up driving family cars which are quieter and safer than those of today as well as "cleaner"; or riding to work in genuine comfort via mass transportation which would get us there more quickly, eliminate our parking problems, and unclog our city streets.

Our cities themselves might even be revolutionized as we learn to design their industrial and commercial plants—and the cities themselves—with air pollution considerations in mind. The greenbelts planned as isolators of industrial areas could also harbor playgrounds and picnic areas. The location of office, home, shopping, and recreation areas all in close proximity would not only reduce pollutants from transportation sources but also free for happier uses many hours a week that are now wasted in commuting. With cleaner air, public monuments and buildings would be cleaner, trees and flowers would thrive better, neighborhood pride would increase and residence patterns become less changeable, city skies would seem bluer and could be seen more often . . . and to the many employment, educational, cultural, entertainment, and shopping advantages of city living, new cheerfulness and comparative healthfulness could be added.

Even if the high cost of such basic changes in transportation and in urban design could not be wholly recovered through savings in the high cost of cleaning, maintenance, and replacement of materials and structures, the potential gains in health and esthetic values should certainly make even such radical approaches worthy of most careful exploration.

New Careers and New Markets

Although it began somewhat earlier in California, the awakening of widespread interest in air pollution on the part of scientists, educators, and government administrators largely coincided with the passage, in 1955, of the first Federal air pollution legislation. From then on, and increasing steadily each year, the needs of air pollution research and development, administration, and control began to compete for the services of professionals—already in limited supply—with the needs of many other areas in our fast-growing technological society.

Because of its extreme complexity, air pollution called for skills in an exceptionally large number of professional disciplines. These disciplines include, but are not limited to, physicians, engineers of many specialties, chemists, physicists, veterinarians, plant pathologists, toxicologists, meteorologists, biologists, economists, lawyers, statisticians, public health nurses, health educators, information and public administration specialists, and city planners. Many of these must know more than a little about the specialties of their colleagues in other disciplines, and all of them must have, or acquire, a good working knowledge of technical factors peculiar to air pollution.

Openings for these experts—in almost every instance, greater in number than the number of qualified applicants—exist at every governmental level and in nearly all of the largest industries. (For example, the steel industry is concerned as air polluters and the telephone companies are concerned as receptors of pollutants.) For the foreseeable future, these openings are expected to increase in number steadily and rapidly.

New markets are also opening rapidly. A clue to industry's present expenditures for air pollution control equipment is provided by a report dated June 14, 1965, on the industrial gas cleaning equipment industry: The total value of 1963 shipments by 65 manufacturers of electrostatic precipitators, fabric filters, mechanical collectors, and scrubbers amounted to $50 million. The annual value of such devices will increase greatly as control regulations are expanded and strengthened; and these are by no means the only kinds of control devices that will be required.

The automobile industry, for example, offers another important new market. As soon as California legislation called for compulsory reduction in automotive emissions, a number of large firms began research and development on both blowby and exhaust control devices. And the new Federal emission standards to be enforced on 1968-model cars will call for the installation, at the factories, of new devices or parts with a possible value of, say, $50 each for some 8 million vehicles, or a total for the year of $400 million.

New Manpower Needs . . . and Possible Shifts

Some of the needs and shifts in manpower that will be required because of better air pollution controls were indicated above. Not only will more scientists, technicians, and administrators have to be trained or diverted from other fields; it will take a lot of man-hours in our factories to manufacture and install the new control devices and in our machine shops and garages to service and maintain them.

According to the authoritative Gross report,[2] there were in 1961 approximately 1,600 specially trained individuals in the field of air pollution associated with control agencies, industry, research, and teaching. The same report stated that, "assuming satisfactory progress," the estimated needs for air pollution personnel by 1970 would total 18,100, of whom 5,600 would be specially trained. The latter figure was raised in a later study[3] to 7,120 for 1975. Especially in view of the fact that many of the needs apply to highly skilled professionals, these figures are not inconsiderable, and the projected growth rate is impressive.

Another kind of shift in manpower will be greater or less, depending on the degree of success that is attained in actually restoring salubrious air to our communities. Hopefully, there will be fewer laundry workers, drycleaners, car washers, painters, and redecorators than would otherwise be needed; and more orchid growers, landscape gardeners, and suburban farmers, as well as more control administrators and technicians.

And perhaps more senior citizens. For better air pollution control will also mean manpower *saved*—less absenteeism on account of respiratory troubles, and longer working lifespans.

Other Human Values—the Nation's Well-Being

While for the purposes of this report economic considerations have been given the primary emphasis, there are other human values which are depreciated by contaminated air and which would be enhanced by better controls.

One of these is the natural beauty of our country, which President Johnson stressed to Congress. "Air pollution," the President said, "is no longer confined to isolated places. This generation has altered the composition of the atmosphere on a global scale . . . . Pollution destroys beauty." Better controls will help to make our air safe for growing plants and trees, help to preserve our precious monuments and works of arts, help to restore the Nation's natural and man-created beauty.

Better controls will also help to make our cities better fitted for human habitation. What price urban renewal if manmade darkness can enshroud a neighborhood in gloom for hours or days at a time? If, within a single generation, bright new neighborhoods can be sullied and "run down" again because of airborne filth?

Better controls can also help to prevent or alleviate the pain and discomfort of such dread diseases as emphysema and lung cancer, and to lengthen the human lifespan. But if the only effects of air pollution were its grime-and-gloom effects, it would hardly be unreasonable—in an America noted for its love of cleanliness—to seek to restore clean air to our communities.

We now have the technological skills that are needed to clear the air, and the cost of cleaning it should certainly be less than we are paying now for the damages caused by airborne contaminants. Because the volume of these contaminants, unless we do control them, threatens to increase constantly—at the very least, paralleling the hoped-for advances in the Nation's technology and living standards—the sooner we make whatever investment is required to reverse this trend, the greater the returns will be, for ourselves and for coming generations.

[2] *Report of the Committee on Environmental Health Problems to the Surgeon General, 1962* (PHS Publication No. 908).

[3] Colm, G. and L. A. Lecht, "*Requirements for Scientific and Engineering Manpower in the 1970's*" (National Academy of Science, Publication No. 1191, 1964).

WATER POLLUTION CONTROL

Prepared for the Commission
by the
Federal Water Pollution Control Administration
U.S. Department of Health, Education, and Welfare

CONTENTS

Water Pollution Control

I. The Water Resources Problem

In the development of the Nation's vital water resources, the problems of water quality and water quantity are inextricably interwoven. Within the framework of this development, the control of water pollution has become, and for the foreseeable future will remain, the overriding consideration in providing adequate water supplies for continued national economic growth, health, and welfare.

It is not enough to have the right quantity of water—it must also be of the right quality to serve the many purposes for which it is needed. More water can be kept available for use by effective water pollution control than by any other means. In this way, water quality can be maintained for repeated reuse by each downstream community, industry, farm, and recreation area, thereby greatly increasing the capacity to serve of the available quantity of water.

The Nation is not running out of water as is frequently heard; there is just as much water falling on this country now as there ever was. The fact is, water needs have grown where we must recognize that the supply is exhaustible and must be properly managed, both as to quantity and quality, if it is to serve all the purposes for which it is needed.

Oversimplifying a very complex situation, the water resources problem confronting the United States from now on is one of making its relatively fixed water supply meet a rapidly increasing demand by providing the right quality at the time and places where it is needed.

A. *Changing Trends in Pollution*

In the past, pollution control authorities dealt largely with problems caused by sewage, industrial wastes of known toxicity and behavior, and natural organics. Pollution control was aimed principally towards protecting downstream public water supplies, abatement of nuisance conditions, and protection of fish and aquatic life. For the most part, dilution provided by streams was adequate to prevent serious pollution; waste treatment plants, where provided, were designed to take full advantage of the self-purifying capacity of the stream; and the water purification plant provided the safety barrier for the water-consuming public. Pollution problems were principally local in extent and their control a local matter. Pollution is no longer a local affair. Long stretches of both intrastate and interstate streams are subjected to pollution which adversely affects their use for many purposes. Conventional biological waste treatment processes are hard pressed to hold the pollution line, and for a growing number of our larger cities, these processes are not adequate. There is growing concern over the ability of our water purification plants to adequately protect the public health against the sheer mass of biological and chemical pollutants entering their intakes.

B. *Municipal Pollution*

National growth and change have altered this picture in recent years. Progress in abating pollution has been outdistanced by population growth, speed of industrial progress and technological developments, changing land practices, and the consequent development of new and difficult problems. Population and industrial growth have figuratively and literally moved waste outfalls closer together and increased their number. Urbanization, increased living standards, and encirclement of industry by the municipality have increased the volumes and strengths of municipal wastes. In some communities, treated effluents today have polluting effects approaching and sometimes greater than the raw sewage discharges of 30 years ago.

C. *Industrial Pollution*

Increased production of goods has greatly increased the amounts of "common" industrial wastes. New technologies are producing complex new wastes and products that defy our current ability to treat or control them, or even detect their presence in water. The increased application of commercial fertilizers and the development and widespread use of a vast array of new pesticides are resulting in a host of new pollution problems from land drainage. The growth of the nuclear energy field and use of radioactive materials foreshadow still another complicating and potentially serious water pollution situation.

D. *Groundwater Pollution*

Pollution is still a local affair with respect to the growing pollution of ground waters, although it is often an intermunicipal and sometimes an interstate matter. Our exploding population is concentrating in urban areas and constantly moving outward from the central cities into suburbia and exurbia. Sewerage construction has not matched either this growth rate or its movements. As a result, a large share of our population must rely on individual septic tanks for its waste disposal, and in an increasing number of places, this has resulted in serious pollution of ground waters which often must serve this same population with water supply. Few metropolitan areas are escaping this serious public health problem.

Sea water intrusion is a growing ground water pollution problem in coastal areas. It is caused by excessive pumping of the fresh ground water which lowers the water table, allowing salt water to flow into the ground water aquifers. Oilfield brine disposal practices also are causing salt pollution of ground waters, particularly seepage from so-called "evaporation" pits. This is a particular problem in the oilfields of the midwest and southwest.

Sewage and industrial waste oxidation ponds and waste storage lagoons are often responsible for ground water pollution, especially when improperly located in permeable soils.

E. *Coastal Pollution*

Twenty-three States border on the ocean, and their estuarine and coastal waters have been subject to serious and increasing pollution for many years. Many of our cities and industries are located along the coasts and discharge their wastes, treated and untreated, into adjacent estuaries, bays, harbors, and onshore coastal waters. These waters are also subject to significant pollution from inland areas, transported into them by the drainage basins of the country.

Pollution of our onshore salt water resources is adversely affecting their recreational and shellfishery values and creating health hazards, reducing the value of waterfront properties, and may be affecting the fishery resource, either directly or through a breakage in its food chain. With much of the future national growth predicted for coastal areas, the problems of pollution will get much worse unless positive control measures are provided. The certain prospect of increased numbers of nuclear-powered ships berthing in estuarine and harbor waters will create still another potentially hazardous public health situation.

F. *Categories of Pollution*

The substances polluting our waters may be classified into eight general categories, each of which is unique in pollutional characteristics and effects: (1) Oxygen-demanding wastes, (2) infectious agents, (3) plant nutrients, (4) synthetic organic chemical exotics, (5) inorganic chemical and mineral substances, (6) sediments, (7) radioactive substances, and (8) heat.

Most wastes are mixtures of the above general categories of pollutants, thereby complicating the problems of their treatment and control. Municipal wastes usually contain oxygen-consuming wastes, synthetic organic chemicals, inorganic chemicals, sediments, etc. The same is true of many industrial wastes, which may contain substantial amounts of heat from processes other than cooling. Land drainage usually contains substantial organic matter in addition to sediments; also radioactive substances and air pollutants washed from the sky, vegetation, buildings, and streets during rainfall.

The water pollution control problem in general detail has been outlined above. The problem is complex as are the pollutants which comprise the problem. The problem is also in need of urgent consideration.

II. Water Pollution Control Technologies

A. *Waste Treatment Devices*

The major weapon against water pollution is, and will continue to be, the waste treatment plant. There is a wide disparity in the type and degree of treatment, ranging from the settling tank and the Imhoff type plant, giving only primary treatment, to more complete plants featuring secondary or tertiary treatment, utilizing the most up-to-date technological advances. A discussion of all the presently available technologies would involve considerable detail concerning a wide range of engineering devices. Therefore, the following discussion emphasizes major technological advances that will increase the efficiency of treatment methods presently in use or new methods which may revolutionize water pollution control.

B. *Advanced Waste Treatment*

The Advanced Waste Treatment (AWT) Research Program of the Federal Water Pollution Control Administration is developing and demonstrating practicable means of treating municipal sewage and other waterborne wastes to remove the maximum possible amounts of physical, chemical, and biological pollutants to restore and maintain the maximum amount of the Nation's water at a quality suitable for reuse. At present, even with the most complete sewage treatment we can provide, a significant percentage of the organic waste is still discharged as residual waste load which is creating problems such as those already described. Technically, advanced waste treatment may be looked upon as a two-step process: (1) Separating concentrated contaminants from the purified water "product," and (2) disposing of these contaminants in a way that will render them forever innocuous. The need for developing this two-step treatment process results from the fact that many of the inorganic and organic contaminants now entering our waters resist every phase of present-day treatment—sewage treatment, natural purification in streams, and water treatment. The ultimate and achievable goal should be to completely reclaim waste waters for reuse. This would, in one step, substantially reduce the water pollution problem while greatly increasing the supply of clean water available for all uses.

Pilot models of AWT systems are now in operation. Some of the more promising processes being investigated are: (1) Adsorption—the use of activated carbon to separate organic impurities from liquids; (2) electrodialysis—the removal of remaining dissolved mineral matter from solution; (3) foaming—the deliberate generation of foam to remove surface active impurities; and (4) coagulation—the use of chemical precipitants to remove suspended and colloidal solids and algae nutrients. Other treatment techniques under study include evaporation, chemical oxidation, ion exchange, freezing, and reverse osmosis. Following successful development of this advanced waste treatment technology, full-scale application is expected to renovate many waste waters to permit their reuse for agriculture, recreation, industry, and municipalities, as well as to achieve high levels of pollution control.

C. *Analytical Methodology*

Other technological advances have been in the realm of analytical methods to determine small amounts of hard-to-detect pollutants. Advances in gas chromatography are typical of the better methods being developed which can be adapted and refined for use in the fight for water pollution control.

D. *Inplant Waste Reduction Through Process Modification*

In most modern maufacturing processes, equipment for using or disposing of leftover materials or wastes is built into production facilities. In some cases, but certainly not all, this "entire plant approach" becomes profitable, or at least less costly, as the leftovers from primary products are recovered and changed into useful materials. For example, the distilling industry recovers about 90 percent of its fermentation residues and converts these materials into dried feed for livestock. Such inplant recovery reduces the pollution potential of the water employed by 90 to 96 percent. The brewing industry has a similar successful program. The younger antibiotic industry is rapidly moving from the more conventional waste treatment to inplant recovery despite the fact that each antibiotic presents its own special recovery problems.

Another example of using a waste for production of a needed and useful material is the making of nutritional yeast and other byproducts from spent sulfite liquor. The Sulphite Pulp Manufacturers' Research League started growing yeasts on spent liquor in 1943. Today, yeast plants adjacent to sulfite mills are a modern application of byproduct recovery in water quality management.

In other types of manufacturing, the emphasis is placed on the recovery from process water of materials which would otherwise be wasted. A notable example of an industry closely tied to water and which regards the recovery of basic materials as an important part of operations is the pulp and paper industry. In one segment of this industry—the kraft industry—fiber losses per ton of production have been reduced 76 percent since 1941, while total production has more than doubled during this period. Equally important savings in water have resulted.

E. *Product Modification with Respect to Pollutional Characteristics*

Industries are recognizing that pollution may be decreased and adverse publicity avoided if the chemical composition of a product is altered to reduce components that may produce potential pollution. The detergent industry is a notable example. By midyear 1965, the conversion was effected from the "hard" alkyl benzene sulfonate (ABS) sudsing detergent to the "soft" linear alkylate sulfonate (LAS) bio-degradable detergent which breaks down in treatment plants as readily as organic sewage, thus reducing foam on waterways. The pesticide industry is also showing interest in developing products that will decompose more easily and will not present such pollution hazards.

F. *Reservoir Management—Streamflow Regulation*

In plans of river basin development and management, considerable attention is given to multiple-purpose reservoirs to provide for sufficient storage for streamflow regulation. This regulation would permit the release of stored water to increase streamflow if the dilution capacity of the stream is exceeded. In other words, if adequate treatment has been provided and water quality in the receiving stream is not satisfactory for present or anticipated uses, means will be provided to increase the streamflow and thereby increase the stream's capacity to accept wastes without being unduly degraded.

G. *Computer Models and Systems Analysis*

Another technology which has begun to come into its own during the past few years is the use of systems analysis for river-basin management. This approach involves the management of water quality on a regional or river-basin basis. It depends largely on the development of mathematical models for waterways and the formulation of a computer program which adequately reflects changing stream situations and characteristics. The system provides rapid computation using continuous data on many variables such as the saline content of the water, wind velocity, wind direction, oxygen level, etc., and enables accurate, instantaneous forecasting to be done on future conditions in the river basin. Steps can then be taken to maintain optimum water quality in line with economic and other influencing factors.

H. *Automatic Monitoring and Telemetering*

The systems analysis approach depends on having continuous stream data which will reflect any trends in the physical characteristics and chemical composition of the waterway. Therefore, one of the key features of the systems analysis water quality management will be the increased utilization of automonitoring and telemetering equipment. This apparatus will take continuous samples and transmit stream data directly into the computer for rapid computation and forecasting.

III. Barriers to Progress

A. *Costs*

The greatest barrier to progress in water-pollution control has been the amount of financial investment required. The total number of dollars needed to construct waste treatment facilities or separate combined sewers, for example, is very large. Even in communities with a high per capita income, however, waste treatment plants generally have not been recognized as high priority community needs equal to other facilities such as schools and roads or such social services as fire and police protection. This priority has been reflected in expenditures allocated; the benefits produced by pollution-control activities have not been valued at the same level as those stemming from other expenditures. In many instances, abatement action is begun only when the pollution problem becomes so serious that an outraged public demands that something be done or enforcement proceedings are initiated. All indications are that public awareness of the need for pollution control is very rapidly increasing. New York State's citizens, for example, were sufficiently concerned that they voted five to one for a waste-treatment bond issue of $1 billion, the only money proposition on the ballot that passed.

The cost of water pollution is very difficult to determine because of problems of definition, inadequate information, and rapidly changing conditions. Pollution adversely affects the use of waterways and imposes an economic cost in the form of investment in abatement facilities or of impaired or lost uses of the streams or adjacent land activities. It is estimated, for example, that $26 million of additional water-softening facilities are needed in the Colorado River Basin to soften water that has been polluted by increased amounts of mineral salts.

A far larger amount of information is available concerning the investments required to construct facilities for pollution control. The following provides a general impression of the magnitude of costs involved.

1. *Municipal*

In its 9-year history, Federal assistance to municipalities has helped build over 6,000 local waste-treatment works costing $2.5 billion. These projects serve a population of 53 million and will improve the quality of water in 55,000 miles of streams. Despite these gains, however, pollution from municipal wastes has not been brought under control. Construction has dropped off sharply since 1963 when it reached an all-time high through the combined financial incentives of water pollution control and public works acceleration programs. Construction decreased from $8[illegible] million in 1963 to about $600 million in 1964. The present rate of construction is too low to do much more than maintain the status quo. The 1965 survey by the Conference of State Sanitary Engineers disclosed an existing backlog of 5,277 needed municipal treatment works costing $1.8 billion for a population of 33 million. The average annual cost for the elimination of this backlog by 1970 is $299 million. Sewage treatment facilities have a limited lifespan because of aging, technical advancement, or population relocation. These plants and related works must be replaced at an estimated average annual cost of $246 million.

To eliminate the backlog, replace obsolete treatment works, and provide for the continuing population growth in our urban areas will require an average annual expenditure of over $800 million for municipal waste-treatment works for the rest of this decade. This, however, is in 1964 dollars and does not account for constantly rising construction costs. When we allow for this factor the average annual cost for the rest of the decade increases to $865 million.

The projections for 1970 do not include an allowance for enlargement of construction work needed to separate storm and sanitary sewers, which has been estimated to be between $20 and $30 billion. These figures are construction costs only and do not include program management.

2. *Industrial*

A survey by the National Association of Manufacturers and the U.S. Chamber of Commerce reported that American manufacturing industry spent more than $100 million in 1959 to operate facilities it has installed to treat waste waters. More than $1 billion would be required to replace these facilities at 1959 prices. The extent to which these figures reflect expenditures made solely for waste treatment is not known, since expenditures include inplant changes which also result in waste reduction. However, in view of the extent of existing industrial pollution problems, this level is obviously inadequate even in terms of current conditions without considering future industrial expansion. One of the greatest needs in adequately appraising the extent of industrial pollution and consequently the costs of treatment required, is much more information on industrial wastes. To date, no adequate inventory is available to provide the information needed on a nationwide basis.

3. *Streamflow Regulation*

In conjunction with waste treatment, streamflow regulation is required for assimilation of treated waste effluents. On the basis of studies that reviewed the entire water situation in the United States, the Senate Select Committee on National Water Resources, Report No. 32, indicated that 229 million additional acre-feet of reservoir storage costing $374 million annually would be needed by 1980.

4. *Costs by River*

Costs of controlling pollution have been prepared for several rivers. The following illustrate some of the costs involved:

Hudson River

Studies have indicated that the costs of bringing municipal and industrial waste treatment facilities to a level of secondary treatment in the Hudson River below Troy, N.Y., would require an expenditure of $400 million.

Delaware River

Mathematical model studies of water quality conditions of the Delaware River have provided information on the costs of achieving water quality at various levels of waste treatment. One measurement of water quality is the amount of dissolved oxygen present. To achieve a minimum level of dissolved oxygen, or 4 milligrams per liter, from Trenton, N.J., to Liston, Pa., in the Delaware River Estuary, a capital expenditure for waste treatment facilities calculated at $281,700,000 would be required. This is the high cost of several alternative dissolved oxygen levels.

Potomac River

To clean up the Potomac River to a level suitable for swimming by 1975, the estimated total capital cost for the necessary works, including land, is $2 to $2.5 billion.

Lake Erie

Estimated costs of abating pollution and reversing the aging process of Lake Erie are based on providing a quality of water suitable for all legitimate uses, including swimming. Costs are estimated to be on the order of $20 billion.

B. *Reluctance to Accept Change*

Another problem in introducing new technological advances is the seemingly natural reluctance to change. Engineers and communities are hesitant about trying the new idea, the new equipment, without first having the reassurance of many years of proven field reliability. A factor in this problem is the lack of sufficient training for treatment plant operators to utilize new plants efficiently and to appreciate the benefits that a more modern treatment system would yield. In some instances, new methods are more costly than those in use and a community is unwilling to allocate the extra funds needed to install and operate the plant. This is the case in applying advanced waste-treatment systems.

C. *Inadequate Technology*

A unique industrial problem is the complexity of wastes requiring particular forms of treatment. Known methods could be applied to many industrial wastes, but their adequacy for all substances is unknown. While research is required to determine the adequacy of known methods for industrial application, since waste treatment does not increase sales or revenue and detracts from profits, industries are reluctant to bear the expense. Research is needed to develop new methods as well.

D. *Institutional Barriers*

The adaptation of systems analysis to the control of river basins depends on a suitable supporting institutional structure. At present, there is a lack of effective institutions that can cut across the political lines of individual States, counties, or municipalities. Institutional arrangements are necessary that will represent all interests and yet agree with one voice on needed actions before technology can be adequately applied.

E. *Lack of Adequately Trained Personnel*

The lack of adequately trained personnel in all aspects of the water pollution control field, from research personnel to waste treatment plant operators, has serious potential consequences. Highly trained scientists and engineers such as chemists, sanitary engineers, microbiologists, and others with experience in dealing with waterborne wastes, are presently in very short supply. It has been estimated that by 1968, 23,000 engineers and scientists will be required in the entire water pollution field to fulfill the national need for specialists. At present, roughly 2,000 engineers and scientists are employed by Federal, State and interstate agencies. Present levels of the training programs of educational institutions are not adequate to fulfill the estimate of personnel needed. Specialized training by a greater number and variety of schools and departments and increases in the level of financial assistance available to institutions are necessary.

The new treatment methods and modern plants have a great deal of operational flexibility which gives the plant operator wide latitude in adjusting the treatment for various waste loads. Well-trained operators are clearly among the priority needs. Recent surveys have shown that some of the newest sewage plants are operating at less than maximum efficiency due to the inadequate training of the plant operators.

F. *Summary*

In summary, resistance to technological improvements and innovations in water pollution control systems is mainly a resistance to monetary expenditure. These expenditures may be for needed research, the modification of existing apparatus, or the introduction of completely new techniques. Other barriers are inadequate political organizations, a reluctance to embrace new methods, and a lack of education both to operate new apparatus and to appreciate the need for the best possible water pollution abatement.

IV. Recommendations

A. *Develop Institutional Arrangement for Pollution Control*

1. Encouragement and support from Federal, State, and local governmental bodies should be given to adoption of institutional means necessary for implementing effective water pollution control measures on a regional or river basin level. Some more specific recommendations would involve:

a. Establishment of institutional arrangements, such as river basin commissions, regional planning authorities, or binding agreements and commitments among State and local governments, by which recommendations arising from comprehensive river basin planning studies can be put into operation effectively.

b. Development of basinwide operating procedures necessary to regulate streamflow for water quality control.

B. *Establish and Improve Manpower Training Programs*

1. Personnel trained in both the practical and theoretical aspects of water pollution control will be needed in larger numbers as control efforts and knowledge expand. Such programs as the following can contribute significantly to this need:

a. *Sewage Plant Operator Training*

Establish training programs for sewage treatment plant operators, such as the Neosha School in Missouri and operator training programs in Michigan and Texas.

b. *Operator Certification*

Establish certification standards by States and otherwise improve professional status of waste treatment plant operators.

c. *Seminars and Short-Term Training*

Increase opportunities for seminars, short-term courses, and other training procedures for the benefit of professional water pollution control workers.

d. *Support Professional Training*

Increase opportunities for training professional workers through increasing the number of training grants to universities for support of training programs, including expansion and improvement of facilities and payment of stipends to participating graduate students.

C. *Research Needs*

Research is needed to develop new waste treatment methods and to adapt known methods to the treatment of specialized types of wastes. Examples of the areas in which expanded research of this type is needed are (1) advanced waste treatment research; (2) improvement of existing waste treatment processes; and (3) industrial research.

1. *Advanced Waste Treatment Research*

More effective processes are necessary to remove larger amounts of impurities from water to permit direct and repeated reuse. After satisfactory development of the pilot models of such advanced treatment techniques as adsorption, electrolysis, foaming, and coagulation, full-scale application of the most efficient and least costly method for wastewater renovation is needed. Research costs for advanced treatment at the Federal level on the order of $200 million over a 10-year period would certainly appear warranted in view of the need and probable benefits from a successful program.

2. *Improvement of Waste Treatment Processes*

Research to improve conventional treatment methods to gain efficiency or reduce costs would be on the order of $25 million over a 10-year period by the Federal Government and approximately the same amount by industry.

3. *Industrial Research*

Increased attention needs to be given in industrial research and development to determine effects of new products and new technologies on the environment. Means to reduce anticipated damages must be sought in the research and development process.

An example of specific studies which have been conducted in this area are those made by the detergent industry. A new, more readily biodegradable "soft" detergent was developed that has diminished the foam on waterways caused by "hard" detergents which were not broken down by conventional treatment processes. Similar efforts are needed in the pesticide field to develop pesticides that can achieve the intended purpose but have no harmful side effects on other components of the environment.

4. *Economic Studies*

Studies should be conducted to gain a better understanding of the costs and consequences of water pollution control, both monetary and intangible, in order to facilitate decisionmaking. Studies would permit better comparison of investments and returns in pollution control among an array of investments and returns for other resource development activities.

An example of specific studies needed include: (a) Determination of incremental costs and benefits for changes in water quality; i.e., what costs are incurred and what benefits are provided as a result of changing dissolved oxygen levels in a stretch of a river from 4 to 5 p.p.m.; and (b) what costs are required to achieve and maintain a quality of water that optimizes user benefits.

REPORT ON THE SOLID WASTE PROBLEM

Prepared for the Commission
by the
Office of Solid Wastes
Public Health Service
U.S. Department of Health, Education, and Welfare

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Report on the Solid Waste Problem

I. Description of the Problem and Issues

Probably the most serious shortcoming in the field of public works since World War II has been a chronic inability to evaluate the status of the art of solid waste disposal and to develop logical and economical systems to meet the changing times. Although some $3 billion are spent annually in the United States to collect and dispose of refuse and other solid wastes, the collection and disposal practices in common usage are but little improved over those of a quarter century ago. Much of the blame must be attributed to the very nature and origin of the problem: Waste disposal has historically been relegated to the lowest levels of responsibility.

It is only too common a practice in all but the largest metropolitan areas in the United States to find solid waste management conducted through a "dirt-under-the-rug" approach. As long as refuse does not pile up in the streets or on the curbs or in the alleys, and as long as the rat-infested dump annoys only the nearby residents, matters of efficiency, economy, public health, and safety are overlooked, and the more "pressing" (and better understood) aspects of community life are studied and financed and programs implemented.

Solid wastes have not been accorded appropriate recognition as a national problem, unlike the liquid waste systems which require thoughtful design and construction, careful operation, and strong public support for generous funding. In the deceptive simplicity of solid waste collection and disposal operations lies the delusion.

Surveys of solid waste collection and disposal practices throughout the Nation reveal very few consistencies. Often the going practices turn out to be the result of cut-and-try techniques handed down from one generation to another. In the Los Angeles metropolitan area, for example, separate collection of food wastes for use as hog food continued for many years after the economic advantage to the communities was grossly outweighed by the far greater costs of making two separate collections. In other cities where outmoded collection service is provided by shoveling refuse from vaults, leaves are pitchforked from loose piles, separate trucks are driven over identical routes to different classes of refuse, and all deposited at the same disposal site, where an expensive incinerator was built on wastelands that could be reclaimed by sanitary landfilling.

II. Technologies That Could Be Applied To Solving the Problem

A. History of Solid Wastes Research

Introduction

Public disinterest in rejected materials has been reflected in a neglect of research in solid wastes management, with the result that problems have multiplied faster than solutions. After World War II the problems of solid wastes management could no longer be ignored, and concern has now reached national proportions. In 1949 the State of California began research which has continued at varying levels of intensity under a variety of sponsors. Similar investigative work was carried on throughout the United States by public agencies.

The early researcher was confronted with a dearth of reliable information on technology and economics of wastes management. When studies of composting of municipal refuse were initiated at the University of California in 1949, literature search turned up some 10,000 references, essentially none of which revealed any scientific understanding of the process or of its utilization in an engineered system. Investigations of incineration showed it to depend upon a technology empirically derived and poorly defined. Sanitary landfilling was found to involve practices of obscure origin and undocumented relevance.

Scope of Research

Research in solid wastes management has been directed to the discovery of basic information, to the development of processes and technology, to the impact of wastes management schemes on the air, water, and land resources, to the economics of collection and disposal, and to jurisdictional and planning problems. While the scope of past research may not be inappropriate, it has been limited by the inadequate scale of research and lack of effort to translate knowledge into effective systems.

Studies have yielded some basic data on the types, amounts, physical characteristics, and origin of refuse. Studies now being conducted by the California State Department of Public Health for the San Francisco Association of Bay Area Governments are producing similar data for the total wastes of metropolitan areas. From such investigations the nature of solid wastes may be established for specific areas, but the climatological and geographical variations from one area to another are so great that such data have only limited general usefulness.

From research on process fundamentals has come knowledge of the principles of composting, the fuel value of refuse, optimum incineration temperatures, the general nature of combustion products, and similar basic data.

Development of Processes and Technology

Investigation and demonstrations of technical feasibility have been conducted for incineration, composting, landfilling, grinding organic wastes with water and discharging the slurry to the sewerage system, and salvage and reclamation, but to different extents and with varied results.

Incineration

University research groups and public agencies have obtained significant information on the design, operation, and instrumentation of an incinerator, including the effectiveness of its various components and the control of its stack effluents. Studies of home incinerators have also been made. While such research has done much to improve the process, such factors as air pollution control, the growing volume of wastes, and the increasing urbanization of the Nation have spurred interest in research and development along the following lines:

1. Improved methods of refuse handling and furnace charging.
2. Determination of stoker and grate performance.
3. Establishing more precise design criteria.
4. Methods of sampling and monitoring incineration process and stack discharges.
5. Mechanical methods of removing fly ash and residue.
6. Control of particulate and gaseous stack discharges.

Composting

Studies of composting at the University of California, Michigan State University, and elsewhere in the early 1950's established the fundamentals of composting. Field scale demonstrations of open-windrow composting were conducted at Oakland and Berkeley, Calif., and mechanized composting was demonstrated at Altoona, Pa.; Norman Okla.; Sacramento and San Fernando, Calif.; and Phoenix, Ariz. Pilot composting plants have been operated at Burbank, Calif., and in Los Angeles. Several other successful and unsuccessful experiments have been conducted in the United States.

Composting combined with sanitary landfilling was demonstrated at Chandler, Ariz., by the U.S. Public Health Service, and application of the process to animal manures, farm wastes, sewage sludge, and cannery wastes have been investigated on a small scale. The National Canners Association, with PHS research grant support, is now operating a pilot plant for composting wastes from fruit and vegetable canning in California.

Investigative work needed to establish composting as an effective process in solid wastes disposal includes:

1. Determination of the market (or lack of market) for compost. Inability to develop markets has been a main cause of failure of composting schemes in the United States.
2. Demonstration projects to refine technical details and establish the economics of composting.
3. Development of equipment and methods for large-scale use of compost in agriculture.

Sanitary Landfill

Research on the sanitary landfill process and related problems has been directed to a variety of objectives. The University of California reported on the methods and techniques utilized by 13 cities and on the economics of landfilling. The American Public Works Association and the American Society of Civil Engineers each prepared manuals of sanitary landfill practice. Management of fills and cover material to prevent the emergence of flies was investigated by the California State Department of Public Health, and the California Water Quality Control Board sponsored studies of the ground water pollution potential of landfills.

Although sanitary landfilling is capable of handling the total solid wastes of a community, its broader application would be intensified by the following investigations:

1. Development of methods for precompacting refuse before placing in the fill.
2. Investigation of construction methods and building design to permit use of completed sanitary landfills for residential and industrial sites.
3. Improvement of methods to incorporate demolition debris in landfills.
4. Investigation of the deposition of compacted refuse in submarine canyons.
5. Development of means for using sanitary landfill at sites having high ground water levels.

Grinding to Sewer

Field-scale studies of shredding organic refuse and discharging it to the sewer have been conducted in southern California. Practical application of the method to a combination of community wastes such as animal manures, paper, garbage, tree trimmings, cannery wastes, plastics, glass, and similar grindable or shreddable materials would require a number of investigative studies, including:

1. Determination of the range of materials which can be water transported in an existing sewer system.
2. Determination of the ability of existing waste water treatment processes to handle shredded refuse materials.
3. Studies of process modifications and extensions, and the economics of adapting existing sewage treatment systems to dispose of water-transported refuse.
4. Studies of feasibility and the materials-handling techniques needed to utilize sanitary sewers as a transport system.
5. Determination of the possibility of converting refuse to particles which might be piped to the ocean and discharged without having floating particles or other pollution.

Salvage and Reclamation

Numerous experiments have been conducted on separation of salvageable materials from mixed refuse. These have been relatively crude, practical attempts to reduce costs to a profitable level, or to develop sophisticated devices, such as magnetic or ballistic separators, to salvage some particular element of refuse.

Experiments on reclamation of selected and limited amounts of certain organic fractions of industrial wastes have developed such products as bone meal, industrial alcohol, vegetable oils, animal feed filler, and wallboard from various components of solid wastes. Economic factors have limited the practical application of these methods. Needed studies in the field of salvage and reclamation are:

1. Methods of isolating salvageable materials before they become mixed into the total refuse.
2. Mechanical methods for rapidly and accurately selecting specific items from refuse; for example, various alloys of brass and aluminum, clear glass, and clean paper.
3. Basic research on the reclamation of reusable raw materials from solid wastes. Determine what compounds can be reclaimed and how reclamation can be accomplished technically and economically.

Reduction in Solid Waste Quantity

Little research has been directed to reducing the volume of solid wastes at the point of origin or disposal. Studies directed to such objectives include:

1. Development of soluble or degradable containers.
2. Improvement of methods of field processing of agricultural products.
3. Development of varieties of foodstuff with minimal waste fraction.
4. Feasibility of legal restrictions on nonreturnable containers, junk mail, etc.

Collection and Hauling

Research on the economic and logistical aspects of refuse handling, including studies made by the University of California which developed procedures by which an economic collection and haul system can be designed. Consulting engineering firms have also made studies for public agencies on both collection systems and equipment, but there is need for an entirely new approach through such avenues as:

1. Application of modern computer techniques and systems analysis to optimize collection systems.
2. Use of existing transport systems, such as public sewers, rapid-transit facilities, etc., for transport of solid wastes.
3. Studies of feasibility of long-distance transport of refuse by highway, railway, and pipeline to remote disposal facilities.

Environmental Resources Management

Air Resources.—The effect of solid wastes disposal on air resources has imposed restraints which require research beyond the relatively simple problem of controlling odors, dust, and fly ash in the immediate locale.

Incineration of solid waste materials results in a significant burden to the atmosphere. Principal attention has been given to the abatement of particulate emissions by internal settling basins or chambers in the incinerator and by particulate collection devices such as cyclones, electrostatic precipitators, and water scrubbers. Much less research has been performed to determine and control the types and quantities of organic gaseous products from the combustion of solid wastes, even though this group of emissions may pose the more serious threat to public health. Organic compounds in gaseous effluent include aldehydes, oxides of nitrogen, organic acids and esters, phenols, and polynuclear hydrocarbons. All cause abnormal physiological responses and some are known to be carcinogenic. Lack of research on the gaseous products, particularly the organics, has been due to inadequate analytical tools and time-consuming analytical processes, but extremely sensitive and relatively rapid methods have recently become available to separate and identify these and other complex compounds.

Specific research needed on the effect of refuse incineration and open burning on the air resource includes:

1. Quantitation of organic emissions in flue gases in relation to type of refuse processed; pertinent operating parameters are yet to be determined.
2. Determination of public health aspects of incinerator emissions.
3. Determination of the fate of organic residues, such as pesticides and herbicides, when agricultural solid wastes are burned.

Water Resources.—Ground water pollution by solid waste disposal has been of concern, especially in areas where water is scarce and ground water forms an important supply. Most research has been directed to effects of landfills on surface and ground waters.

Serious concern has arisen on the question of ground water pollution from landfilled rubbish by two mechanisms: (1) Carriage of water through the refuse and subsequent combination of the "leachate" with ground water, and (2) solution by the ground water of gaseous products of decomposition.

The relationship between refuse disposal and water pollution has been extensively studied in southern California. A 1961 collation study for the State presented the known data on the effects of refuse dumps on ground water quality and delineated additional specific study areas. Subsequent research investigated leaching from sanitary landfills and ash dumps (1953), determined the quantity and quality of gases produced during refuse decomposition (1964), and, currently, factors controlling utilization of sanitary landfill sites. These results showed that little or no impairment of ground water will occur from leaching if the fill is properly located away from intercepting ground water, but gross pollution may occur if ground water intercepts refuse.

Gas movements from a sanitary landfill, methods for controlling and minimizing the passage of gases, primarily CO_2, into the underlying ground are under study. (The solution of CO_2 in water renders the water more acidic, resulting in increased mineralization of ground waters.) It was found that sizable concentrations of CO_2 could be expected to be held in contact with the soil for many years. Field and laboratory research is now directed toward management procedures, such as controlled gas venting and impervious membranes, and development of procedures for minimizing potential CO_2 pollution.

Land Resources.—Solid wastes management, as it relates to land resources, has generated research largely concerned with landfilling processes. Competition for land resources increasingly affects solid wastes management. The State of California is evaluating disposal of solid wastes on the shoreline as a land feature having varied resource values.

Much research is needed in this field:

1. *Resource Planning*. Determine the institutional and legal means of bringing solid wastes and land resource management together at a policy level.

2. *Land Use Planning*. General and specific considerations are:

a. Local land use studies combined with solid wastes management.

b. Develop a "land pollution" policy similar to air and water pollution policies.

c. Need for development of a "problem-shed" system of solid waste management.

Jurisdictional Problems.—Any study of local problems in solid wastes management reveals the difficulty of providing adequate management within a framework of uncoordinated and overlapping jurisdictions, each with limited authority and responsibility. A current study in California seeks to apply operations research methodology to develop optimum jurisdictional arrangements for wastes management on a communitywide or regional basis.

Needed research falls into two broad categories:

1. *Legal and Institutional Factors*. A study of public policy, legislation, and institutional arrangements necessary to improve jurisdictional approaches to wastes management.

2. *Systems Analysis*. The application of modern operations research techniques to optimize solid waste disposal systems.

B. Proposals for the Solution of the Problem

Proposals for solving the solid wastes problem originate from three sources: Governmental groups, including local, State, or Federal public health departments, consulting sanitary engineering firms, and solid waste disposal process, equipment, or systems entrepreneurs. Two other groups provide valuable assistance in the study of solid wastes, but they are passive participants in the development of solutions: (1) Universities and technical institutions may study elements of the solid wastes problem, but do not serve as decision-makers in seeking solutions, (2) professional organizations such as the American Society of Civil Engineers, the American Society of Mechanical Engineers, the American Public Works Association, and the Air Pollution Control Association may compile information and circulate technical discussions which assist in the formulation of concepts regarding solid wastes problems. In California, a $100,000 study was made during the summer of 1965 by a private firm, on the concept of "totally integrated waste management," to propose ways and means whereby liquid, gaseous, and solid wastes from the Greater Sacramento area can best be handled. Systems analysis techniques for solution of solid wastes problems have also been studied by the Technological Institute at Northwestern University for several years.

Governmental Agencies

The larger governmental agencies engaged in a "utility-type" enterprise often devote a portion of their funds to research and development but smaller agencies may not be able to engage the necessary engineering specialists and keep them profitably applied to the solution of future problems. From these larger groups have come solutions to solid wastes problems for specific localities, with some applicability elsewhere. Larger metropolitan areas may continue to produce carefully engineered proposals to solve solid wastes problems for their own areas, but nothing short of State or Federal effort will produce proposals for statewide or national application. Tax funds which support a local agency cannot be used to make studies or develop proposals for areas other than those from which the funds were derived.

Some proposals developed and adopted by governmental agencies are relatively successful, but they are not sufficiently comprehensive. In the late 1940's, New York City embarked on a program for disposal of combustible solid wastes which requires 11 large incinerators. These may cost over $90 million before the program is completed in 1968. The program was decided upon when a search for landfill sites failed to reveal enough capacity for a long-range landfilling program. The Los Angeles County Sanitation Districts, on the other hand, found that landfill sites sufficient for 30 or more years existed in the metropolitan area. Much thought was later given to transporting refuse to more remote sites by transferring refuse from collection trucks to large-volume truck trailers. By this technique, since incorporated in the system, solid wastes can be transported up to 50 miles from the metropolitan center to landfills before costs exceed those for incineration. Neither these or similar studies have dealt with the problem of solid wastes collection; about $8 out of $10 spent on solid wastes disposal go for collection; the other $2 are spent on disposal.

Most "comprehensive" solid wastes studies are "disposal" studies, and few studies of the basic problems in solid wastes collection are being undertaken. The California study mentioned earlier deals with refuse collection problems to a limited extent, and the Los Angeles County Sanitation Districts are studying the use of large-diameter sewers for conveying large quantities of ground solid wastes from centrally located grinding stations to sewage treatment plants for removal and treatment by digestion, composting, or wet-combustion. The latter studies to date are encouraging and the economics appear favorable. The Los Angeles County Sanitation Districts are also conducting studies of solid wastes compressibility to develop a suitable system for disposal at sea. The agency is not empowered under the State law to collect solid wastes, consequently it is not conducting collection studies.

The U.S. Public Health Service, through the Division of Environmental Engineering and Food Protection and, more recently, the Office of Solid Wastes, has been instrumental in conducting and encouraging basic research in solid wastes. The Office of Solid Wastes is presently cooperating with the Tennessee Valley Authority in a demonstration of composting municipal refuse and determining its application in an agricultural region.

Commercial Agencies

Proposals for the solution of specific solid wastes problems come from three types of commercial enterprises:

1. Agencies engaged in the manufacture and sale of equipment used in solid wastes collection and disposal.

These agencies include manufacturers of refuse collection trucks, specialized materials-handling vehicles, earthmoving equipment, waste-storage containers, and incinerators. Some manufacturers spend considerable time and money in sales promotion for equipment, systems, and processes. Some use excellent motion pictures and other aids to demonstrate the suitability of their products. Many small communities receive little other information or guidance for their solid wastes problems.

2. Agencies engaged in the marketing of solid-waste disposal processes, usually patented.

The feasibility of these processes may depend upon expected profit or economies such as sale of salvage and end products or reduction in disposal costs. These proposals have two things in common: (1) They depend on careful segregation of solid wastes before or subsequent to collection, and (2) they propose solutions for limited portions of solid wastes and solve nothing with respect to the remainder. Early failure has been all too common. Composting and destructive distillation (carbonization) have been attempted in areas where the market for compost and charcoal has been far below design estimates. Such processes may find their place in the total solid wastes disposal picture, but they are not panaceas.

3. Agencies operating private solid-waste disposal systems.

Contract collection of municipal refuse or solid wastes from markets and industries and the contract disposal of solid wastes are all very much a part of solid-waste practices. Although sewage collection and disposal is almost exclusively a governmental function, solid-waste collection and disposal operations in the United States are divided between private and public agencies. Most major cities in the United States conduct their own municipal solid-waste programs, but there is no pattern for the small communities. By contrast, European practice is almost exclusively governmental. Several cities (Omaha, Phoenix, and Houston) have solicited bids for privately operated solid-waste disposal facilities. The private composting plant at Phoenix has been discontinued and Omaha is reported to have rejected all bids. Houston has let bids for an incinerator and a composting plant and two more compost plant bids are pending. A private firm is building a compost plant at St. Petersburg, Fla., on contract. The public health and safety aspects of solid wastes disposal should receive careful consideration when a determination is being made as to whether a system should be based on profit incentive or upon governmental motivation. Where salvage is involved, private enterprise may be better able to adjust to market fluctuations.

Consulting Sanitary Engineers

Proposals to solve solid wastes problems originate as a statement of the problem by a client; only then is a solution afforded by the consultant. Consulting sanitary engineers will continue to provide solutions to solid wastes problems on specific, local bases. Consulting sanitary engineers are not usually funded to pursue research beyond the needs of their clients, although a limited amount may be necessary for them to remain competitive. Studies by consulting sanitary engineers are usually limited to a single city, but recently several countywide studies have been proposed and at least two have been undertaken. Relatively few sanitary engineering firms make a realistic effort to understand the solid wastes problem, although they have an impressive array of specialized engineering talent. Consulting engineering services have not yet been applied to generalized solutions of the solid-waste problem, perhaps because of the lack of a suitable vehicle to coordinate use of such talent. Many consulting engineers have long shown little interest in the solid wastes field, since for years sewerage and water-supply projects have been the sanitary engineer's "stock-in-trade." Now that solid wastes problems are receiving greater attention, many firms are recognizing the business potential and (rather hopefully) list "solid wastes" as an added specialty. There is a current need for a several-fold increase in consulting service for solid-waste disposal and a rapidly increasing future need. The problem of judging which firms have capability in the solid wastes field is difficult for local officials.

C. Extent That Technology Is Presently Available

The technology of solid wastes management has developed, as have most other technologies, by gradual improvement of equipment and techniques to alleviate problems.

In order to present the current state of the art in solid-waste management rationally, it is necessary to examine solutions in terms of problems.

Solid Waste Production and Initial Handling

Solid waste is produced throughout the world. The problem begins with the gathering of solid wastes for collection and may include separation, bundling, or other types of preparation. This function is usually performed by the producer—the householder or business operator.

A change in this procedure is the use of garbage grinders. This change was due to householder demand for added convenience and sales ingenuity on the part of manufacturers. This has demonstrated that the householder may be willing to make the required capital investment for refuse disposal. Similar changes may support converting even greater fractions of solid wastes into the liquid-waste management systems.

Collection Systems

In urbanized society, collection vehicles are periodically sent through the neighborhood, gathering accumulated wastes. Motorized heavy equipment now allows greater loads to be carried by each vehicle, and emptying refuse is much more convenient. Increased vehicle capacity, specialization, and range permits selection of remote disposal sites.

Time and motion studies have been made to determine whether refuse should be stored and picked up at the rear of the house or whether the householder should place refuse at the curb for collection. Studies have also been conducted on the separation of salvageable items at the point of origin so that salvage would help defray the cost of refuse disposal. New systems of magnetic and ballistic separation, subsequent to collection, are presently being investigated and operated on a limited scale.

Transportation

Vehicles designed for collecting refuse are not suitable for transporting refuse any great distance. The specialized nature of the loading and packing devices on collection vehicles increases their cost, and it is not good economy to have them out of collection service during long hauls to the disposal site. For this reason, refuse transfer stations, where the collection vehicles are unloaded into large-capacity trucks for bulk delivery of refuse to the disposal site, have become economically feasible. Systems-optimization analyses of collection and transportation schemes are helpful in designing such systems to meet the wide variety of local conditions which influence the total cost of transportation and disposal.

Disposal Systems

Disposal systems may be of two types: (1) Disposal without provision for salvage or energy recovery; and (2) disposal with partial, or nearly complete, recovery of salvageable material and/or energy.

Disposal Without Material or Energy Recovery

The following disposal methods are in common use in the United States:

1. Open dumps.
2. Sanitary landfills.
3. Central incineration.[1]
4. On-site incineration.

Open Dumps. Open dumps, although common in the United States, cause a variety of difficulties, including the production of rodents, mosquitos, fires, and odors, and are unsightly and offensive to nearby residents. Sanitary landfills can replace dumps at relatively small additional expense. As the welfare of the country's smaller towns improves, open dumps may be eliminated with only slight prodding on the part of public health and public works agencies.

Sanitary Landfills. A sanitary landfill is an engineered burial of solid wastes. The problems common to open dumping do not develop. The technology of sanitary landfills has been improved by research to determine such factors as the depth

[1] Technically speaking, there are a few instances where energy is recovered heat. This represents a very small fraction of the total energy available.

of compacted earth cover required to prevent insect, rodent, and other vector infestations; the dangers of leachate reaching and contaminating ground water; the amounts and types of gas production and movement within the soil; the rate of settlement, and many other features. A sanitary landfill can be a very desirable asset in a community since, when completed, the site can be used for such purposes as recreation and parking or light construction.[2] An excellent sanitary landfill may be conducted for a total cost of approximately $1 per ton of refuse disposed (including amortization of land costs). Problems such as underground fires and dust nuisances created during construction result from careless operation and are easily minimized by careful management.

Municipal Incineration. Many U.S. communities, particularly the larger ones, use municipal incinerators to reduce the volume of solid wastes. Noncombustibles are either collected separately or passed through the furnace along with the other refuse. Magnetic devices may be used to separate ferrous metal from the ashes for salvage. Incineration reduces the rate at which land is used by one-half to a third of that required for sanitary landfilling. The operating cost of large-scale incinerators generally runs from $4 to $5 per ton, including ash-disposal costs.

Since transfer stations can be built and the waste transported to landfills up to 50 miles distant at a total cost of less than $5 per ton, a community should seriously consider such systems as competitive with incineration, if suitable landfill sites are available within this distance.

No current municipal incinerators are considered acceptable where climatological conditions create severe smog concentrations. Conventional designs can be used only at low (half normal) charging rates if Los Angeles' incinerator standards are to be met. Although the incinerators may be equipped with electrostatic precipitators to control particulate emissions, either of these alternatives increases incineration costs by an additional $6 to $8 per ton.

Incinerator equipment manufacturers are developing improved furnace equipment. Publications on this subject represent perhaps one-half the literature available in solid-waste disposal.

Onsite Incineration. Incinerators for effective disposal of combustible solid waste in the home and for apartment buildings and small business or commercial establishments, offer great promise for reducing the volume of solid wastes at the source. Present designs are generally inadequate and such incinerators contribute significantly to air pollution. Additional research, development, and demonstration are needed before this form of onsite incineration can be effectively applied to the solution of solid-waste disposal problems. Some communities still permit backyard burning of refuse as an onsite disposal method. This inefficient process invariably produces smoke problems. It remains in use in isolated communities and rural areas, but poses serious problems.

Other Methods. Municipal refuse has been disposed of at sea, but remnants drift back to shore and this method of disposal is not being used on any substantial scale in the United States. It may have potentials if solid wastes can be processed so as to cause them to sink to and remain on the ocean floor.

Disposal With Material or Energy Reclamation

The following methods are in use, or have been used, to dispose of waste and to salvage material and energy:

1. Grinding garbage to the sewers.
2. Feeding wastes to swine.
3. Fertilizer production.

Ground Garbage to the Sewers. When garbage is ground and discharged to the sewer, most of it is treated in the treatment plant's digesters. Additional methane which is produced by the digesters can be used as a supplemental or primary source of fuel. Digested sludge may be dried and used as a low-grade fertilizer or soil conditioner.

Research has been conducted on the effects of varying amounts of cellulose in sewage sludge and its effects on anaerobic digestion. This research indicates that much of the paper (cellulose) fraction of refuse might also be amenable to digestion and hence, if it could be shredded and deposited in the system, it would present little problem and considerable potential to the production of methane gas (increased digester capacity would of course be required).

Feeding Wastes to Swine. In the past, many cities disposed of garbage by feeding it to swine. To prevent the spread of vesicular exanthema in hogs, and trichinosis in humans, laws were enacted to require that garbage be sterilized by cooking before it could be fed to animals. Where widespread use of household garbage grinders has reduced the amount of garbage and where the costs and inconvenience of separate garbage collection are excessive, feeding of garbage to swine has declined.

Organic commercial wastes and restaurant and institutional garbage are sometimes still fed to swine, since such wastes are amenable to cooking.

[2] In a few cases where land values have increased phenomenally it has become possible to construct the necessary foundations to make building on fills a practicality.

Fertilizer Production. Composted refuse has some fertilizer and soil conditioner potentials. Composting is widely practiced in Europe, since European agricultural practices have long used manures and composts and there is an established market for compost. The U.S. market for compost does not appear as favorable.

Composting ventures have failed in this country, except for a few relatively small plants.

To help evaluate the overall market for commercial organic mulch, it may be noted that dairy manure in Los Angeles has a value of a negative $2 a ton f.o.b. the dairy and in Arizona the value of steer manure is zero and is dropping.

An integral part of composting is the separation of metals, rags, and glass from the refuse; presently the salvage value of these materials is barely sufficient to pay for the cost of separation.

III. Obstacles to Solution

A major obstacle to the solution of solid wastes problems is the lack of an awareness on the part of governmental decisionmakers that the problem even exists. This lack of awareness exists at all levels, including the mayors and councilmen of cities, county supervisors, State administrations, and, until recently, at the Federal level. The Solid Waste Disposal Act, Public Law 89-272, enacted late in 1965, marks a new awareness at the Federal level. The Office of Solid Wastes has been established within the Public Health Service to carry out the comprehensive program authorized by this legislation. At a study conference held at Cincinnati in 1964, some 30 solid wastes specialists stated unequivocally that the most pressing need in the solid wastes field is for a concerted effort by the Federal Government to make top-level officials at the State, county, and local government levels aware that a serious national problem exists in disposing of solid wastes. The study group also recommended a number of 1-day or 2-day informational courses to be held regionally by the Public Health Service, to be followed by a national conference on solid wastes to dramatize the problem and provide news and information media with information on the scope of problems and the fundamentals of solid wastes management.

Technological Obstacles

Presently accepted practices for solid wastes collection and disposal have been little changed: Collection vehicles usually turn out to be slightly improved copies of last year's models—except for a modest "breakthrough" occasionally such as the one-man right-hand drive vehicles being tested on the West Coast. Incinerators are not greatly changed, but refractories and internal equipment are gradually being improved. Sanitary landfilling is refined to the degree that it is an acceptable practice in Los Angeles County, even when conducted close to $125,000 homes.

Composting has been researched so that there now are a number of documented processes that produce acceptable compost from solid wastes. The technological obstacles do not lie in failure to understand the currently used processes; they lie in a failure to develop new or improved alternatives. Even systems analysis becomes useless when existing systems have been refined by trial and error methods until very little refinements can be made, even by rigorous mathematical treatment. Technological obstacles to the solution of the solid wastes problem are found at the most basic level of the system; i.e., the entire "hardware" structure is based upon refinements of simple techniques that have been little changed for many years.

As an example, a cursory consideration of the megalopolitan developments occurring in major cities indicates that present-day "onsite" storage of refuse is not appropriate for multiple dwellings. Special incinerators, collection, and storage systems have become essential. A piped pneumatic collection system for sewage and solid wastes might be feasible. In the Garchey system, solid or semisolid wastes, including cans, bottles, paper, garbage, sewage, rags, etc., are all conveyed to a central holding tank for collection by special trucks and subsequent treatment by burial or composting. Technology in the field of solid wastes systems for intensely developed communities in the United States is generally inadequate.

Obstacles Created by the Vested Interests of Existing Institutions

The interests most likely to present obstacles to changes in the field of solid wastes may include equipment manufacturers, salvage process owners and patent holders, operating agencies, and some consulting and public works engineers.

Equipment manufacturers have the most to lose in any major technological breakthrough. Developmental costs on specialized refuse collection and solid industrial waste collection vehicles are substantial, and the annual purchase of collection vehicles is estimated to be between $75 and $100 million. New developments are unlikely to affect the economy of this industry for a decade or more, but reductions in vehicle collection of solid wastes probably would be resisted.

Salvage process owners and patent holders are directly affected by changes in public policy on solid wastes management. A large salvage firm in Los Angeles almost ceased operations after the city discontinued separate collection of metal. Patent holders in composting, destructive distillation, or other such salvage operations will surely resist solid wastes systems that exclude application of their processes.

Private companies in the solid wastes collection field will most likely object to any changes that would transfer the operation to the use of municipal sewers and sewage treatment plants before their existing disposal sites were filled to capacity.

Engineers, both public and private, have vested interests in the techniques that they know best. Incinerator specialists, composting experts, transportation consultants, and others may find that changes in technology would require retraining and perhaps temporary economic dislocation as new ideas are developed and adopted.

Obstacles Created by Market Considerations

If the experience developed through the sale and use of kitchen food-waste grinders is an indication of the market acceptance of new and improved solid wastes systems in general, the public can be expected to pay a reasonable cost for convenience; the cost to the householder for owning, using, and replacing garbage grinders averages about $0.75 to $1 a month. Since many municipalities provide weekly pickup of *all* refuse at the curbs, there is little profit to the homeowner in operating his own garbage grinder. How successfully other forms of solid waste can be disposed of without home storage and truck collection remains to be seen. Costs to the homeowner for such service may well be greater than present-day costs. More important, present-day collection and disposal techniques may not meet the standards we are setting for future urban and metropolitan development. History suggests that people will demand the best service their technologists can provide them, if the cost is within reason.

Political Obstacles

Without a plan having as a basic element State and interstate planning and cooperation among local jurisdictions, the fragmented activities and uneconomic duplication of disposal facilities will continue. Although the county is frequently the most logical unit of local government to provide solid-waste disposal services, only 10 States have laws which provide their counties with the enabling legal authority and the administrative tools needed to carry out the work. Where metropolitan areas cover parts of several counties, other operating disposal agencies will have to be devised and organized to provide the advantages of areawide planning, disposal service, and economy of scale. An example of fragmented jurisdiction within the total urban-surburban-agricultural complex that constitutes a modern community is the San Francisco Bay area. Here there are 88 agencies responsible for solid-waste disposal, each seeking to dispose of its refuse in the other's backyard at 77 separate sites.

IV. Recommendations

1. Alert decisionmaking public administrators throughout the Nation to the serious nature of the solid wastes disposal dilemma. This could be accomplished in a number of ways, e.g., by a series of regional 1-day conferences to reach the local levels of solid wastes management responsibility. These conferences may reasonably continue for additional days to meet the training needs of public works officials and supervisory employees.

2. Enhance efforts toward national recognition of the solid wastes problem through support of a national conference on solid wastes management. This would encourage news media to alert the general public to support long-range planning, research, and development efforts.

3. Support full implementation of Public Law 89–272, the Solid Waste Disposal Act, which provides funds for needed research, demonstrations, training, surveys, and planning in all aspects of solid-waste handling, particularly to develop new and improved methods of solid-waste disposal for urban, suburban, and related industrial operations. Review effects of this legislation to determine if any changes are desirable after the first year of operation.

4. Encourage a comprehensive study of the market for salvaged solid wastes (or energy therefrom) as an economic guide to the feasibility of composting, destructive distillation (carbonization), incinerator waste-heat recovery, metal recovery (as from car bodies), glass recovery, and fiber recovery. No valid estimate of the true economic role of an individual salvage process can be made until such broad market surveys are completed.

5. Encourage research directed to the development of completely new systems of solid wastes collection and disposal.

6. Conduct research and development aimed at reducing air and water pollution and solid wastes into basic residues, taking into consideration such reductions as may be possible through reuse potentials. Conduct demonstrations in experimental regional environmental designs which incorporate residue management systems.

7. Review the effect of recent Federal solid-waste legislation to determine if any changes are desirable after the first year of the program.

THE ROLE OF TECHNOLOGICAL CHANGE IN TRANSPORTATION POLICY

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CONTENTS

The Role of Technological Change in Transportation Policy

1. The Issues

Changes in technology in numerous areas have created issues of importance to national transportation policy. These issues range from such easily understood matters as the replacement of manual labor in cargo handling by machinery to the basic economic and fiscal policy decisions which the Federal Government is called upon to make in the allocation of investments in such competing forms of transportation as highways and inland waterways.

The resolution of issues is complicated because in most instances the choice, far from being simple, is between the best of several alternatives. This multiplicity of choices is especially prevalent and important in the transportation area, where not only material resources but the effect upon human resources must also be given major consideration.

Another factor which complicates the resolution of transportation policy issues and makes even more difficult the most rational use of the tools of technological research is the lack of adequate data for planning at both the Federal and the private level. As the Secretary of Commerce has stated: ". . . there are major gaps in the available information about how people and goods move . . . ."[1] Planning is difficult even with the best data and there are large gaps in transportation where no data exist at all. However, adequate planning programs cost money and it has only been in recent years that industry and government have been willing to spend significant sums of money for programs that often do not give any assurance of large-scale and quick returns for the investment. Happily, this attitude appears to be changing, but research and development outlays still are a minor fraction of the total costs of transportation.

The changes which technology creates in the transportation policy area fall into several discrete but nonetheless interdependent areas. These changes involve the attitude of workers and labor unions towards shifts in labor requirements and the rate at which they will be made. The attitude of management toward decisions about investments in transportation equipment and facilities depends to a large extent upon estimates of the profitability of such investments and the possible obsolescence rate of capital equipment.

Adequate training for changing tasks and the allocation of costs of such training between the worker, management, and government is still another important issue. However, the drive toward automation has not in any sense lessened the emphasis upon higher skill requirements. Despite all that is said about the efficiencies possible through increased use of machinery, human talents are still a basic requirement to direct that machinery.

Technological changes not only involve new ways of performing the tasks of transportation, but they also relate to new techniques intended to improve the performance of present tasks. A case in point is the research program now underway to develop commercial aircraft to travel at supersonic speeds. But such a program creates many policy problems. How should such research and development work be financed? Should there be a major sharing of research costs between government and industry although the tangible results—profits from operations—will accrue mainly to industry? That persuasive arguments can be made for either position is typical of many current issues in transportation policy.

Technological changes in transportation often have an areawide or regional impact. For example, in the past, the shift to diesel locomotives greatly reduced coal consumption, which had a significant effect upon employment in the coal mining industry. There is little doubt that similar instances are at work in our economy today. What should the attitude of government at all levels be toward such technological unemployment? Meaningful answers must be developed for such issues.

2. National Requirements for Transportation

It is deceptively easy to define the national requirement for transportation. Simply put, it is for a transport system capable of transporting

[1] Statement of John T. Connor, Secretary of Commerce, to the Subcommittee on Transportation and Aeronautics, Committee on Interstate and Foreign Commerce, House of Representatives, May 25, 1965.

whatever needs to be transported when it needs to be transported. When one begins to look into the nature of that requirement, the task becomes difficult.

Since it is impossible to stockpile ton-miles (for freight) and passenger-miles (although the facilities for their production can be stockpiled) the measure of the national transportation requirement depends directly upon the level of demand for goods and services production. Although, as it will be demonstrated later, the correlation between the production of goods and services and the production of ton-miles and passenger-miles is not always precise, it is never negative for any appreciable period of time. The reason for this is apparent. Transport services are not produced when there is no demand for them. (True, freight cars, trucks, aircraft, and ships often move empty, but such movements are usually part of the general service pattern of the operator.) Therefore, there must be a continuing and basic correlation between national economic conditions and requirements for transportation.

In recent years the national requirement for transportation has moved steadily upward. The increase in demand as reflected in the ton-mile and passenger-mile statistics is illustrated in table 1.

Transportation is such a major aspect of our economy that its problems are of vital significance. Without going into detail, the impact of transportation on our economy can be demonstrated by the fact that payments for transportation account for about 20 percent of our gross national product, that is, one-fifth of the total value of all goods and services produced by the national economy. Table 2 summarizes national outlays for transportation in recent years and the share of GNP they represent.

While table 2 illustrates the impact of transportation in terms of cost and economic contribution, it does not show the economic pervasiveness of the vast amounts spent for transportation. Table 3 shows national costs for various freight transport media, while table 4 presents similar data for passenger transportation. These tables demonstrate clearly that the transportation industry creates demands for goods and services that penetrate the economic fabric of the country, and lead to the creation of substantial peripheral and subsidiary industries. Widely publicized studies of the automobile industry, for example, show that every State in the Union contributes something to meet the demands for materials that go into automobile production.

We might logically ask what we get for such expenditures of our national income. While this may be answered in several ways, perhaps the best is in terms of the output of the transportation industry in relation to the cost of that output. A comparison of recent trends in transportation output measures (ton-miles and passenger-miles) with trends in the cost of producing them will show what is happening to the unit cost of transportation service and the same time permit a rough appraisal of the effect of technological changes on unit cost.

In 1958 intercity freight traffic for both regulated and unregulated carriers reached an estimated total of 1,216 billion ton-miles with the freight bill estimated at $40.85 billion. In 1964 the comparable figures were 1,550 billion ton-miles and $56.08 billion. Thus, ton-miles rose by 27.5 percent and the freight bill by about 37.3 percent.

In 1958 intercity passenger traffic, including private automobiles, totaled 705 billion passenger-miles at an estimated cost of $47.96 billion. In 1964 passenger-miles totaled 875 billion and the cost rose to $19.63 billion. Thus, passenger traffic rose by 24.1 percent, and total costs by about 46.7 percent.

From these extremely rough calculations it appears that despite advances in technology and automation, the *total* unit costs of transportation have not been reduced. This is not to say that

TABLE 1. U.S. TRANSPORTATION SYSTEM PERFORMANCE, 1955–64

Year	In billions	
	Ton-miles [1]	Passenger miles [2]
1955	1,274	665
1956	1,356	697
1957	1,336	695
1958	1,216	705
1950	1,296	736
1960	1,328	759
1961	1,327	769
1962	1,393	802
1963	1,462	834
1964	1,550	875

[1] Intercity traffic, includes regulated and unregulated traffic.
[2] Intercity traffic, including autos.

Source: From data in *Transportation—Facts and Trends*, Transportation Association of America, Washington, 1965, 2d ed., p. 7.

TABLE 2. THE NATION'S TRANSPORTATION BILL, 1958–64 (BILLIONS)

Transportation costs in GNP	1958	1959	1960	1961	1962	1963	1964
Passenger bill	$48.0	$54.9	$58.0	$56.0	$61.8	$66.0	$69.6
Freight bill	40.9	44.0	44.5	45.9	49.2	51.9	56.1
Total	88.9	98.9	102.5	101.9	111.0	117.9	125.7
Adjustments [1]	1.2	.9	—.1	.5	.5	.4	.5
Adjusted total	90.1	99.8	102.4	102.4	111.5	118.3	126.2
Gross national product	447.3	483.7	503.8	520.1	560.3	589.2	628.7
Transportation costs in GNP (percent)	20.1	20.6	20.3	19.7	19.9	20.1	20.1

[1] Government expenditures not included in passenger or freight transport outlays, less duplications.

SOURCE: Adapted from estimates in *Transportation—Facts and Trends*, Transportation Association of America, Washington, 1965, 2d ed., supplement, Jan. 1966, p. 2.

TABLE 3. THE NATION'S FREIGHT BILL 1958–64[1] (MILLIONS)

Transportation	1958	1959	1960	1961	1962	1963	1964
Highway:							
Truck:							
Intercity ICC regulated	$6,081	$7,087	$7,155	$7,402	$8,062	$8,472	$9,196
Non-ICC regulated	10,834	11,419	11,708	12,705	13,709	14,504	15,953
Local	9,335	10,180	10,568	11,215	12,175	13,440	14,983
Bus	31	37	42	46	52	57	64
Total	26,281	28,723	29,473	31,368	33,998	36,473	40,196
Rail: Railroads	8,715	8,982	8,706	8,406	8,671	8,848	9,181
Water:							
International	1,331	1,515	1,514	1,393	1,538	1,529	1,480
Coastal, intercoastal and noncontiguous	665	704	689	677	666	655	632
Inland waterways	436	455	432	405	415	424	418
Great Lakes	224	224	277	244	252	266	296
Total	2,656	2,898	2,912	2,719	2,871	2,874	2,826
Oil pipeline:							
ICC regulated	721	765	770	787	811	840	871
Non-ICC regulated	117	125	125	127	128	137	142
Total	838	890	895	914	939	977	1,013
Air:							
Domestic	137	157	173	189	218	234	271
International	99	109	123	141	162	177	195
All-cargo and supplemental	73	71	74	95	140	115	138
Total	309	337	370	425	520	526	604
Other carriers:							
Freight forwarder[2]	416	446	438	444	466	471	488
REA express[3]	352	367	345	345	357	355	387
Other shipper costs:							
Loading and unloading freight cars	1,062	1,123	1,098	1,051	1,082	1,093	1,108
Operation of traffic departments	222	235	241	249	258	267	276
Total	1,284	1,358	1,339	1,300	1,340	1,360	1,384
Grand total	40,851	44,001	44,478	45,921	49,162	51,884	56,079

[1] Includes mail and express payments.
[2] Domestic ICC-regulated carriers. Total revenues before payments for services of other carriers.
[3] Excludes air express, included in air data.

SOURCE: 1958–62, adapted from estimates in *Transportation—Facts and Trends*, Transportation Association of America, Washington, 1965, 2d ed., p. 3, 1963–64; *ibid.* supplement, Jan. 1966, p. 3.

technology has not had beneficial effects upon transportation costs, for important evidence shows that it has. However, economies derived from technological advances seem to have been more than outweighed by other increases.

What effect will technological advances have upon the cost of meeting national transportation requirements in the years ahead? If recent past experience is any measure, prospects do not appear to be very bright. Virtually all economic forecasts predict a continuation in the steady rise of both ton-mile and passenger-mile performance, and evidence of the past 10 years supports this. Table 5 shows that from 1955 through 1964 ton-mile performance rose steadily from 1,274 billion to 1,550 billion. (However, during some years in that period performance fell slightly below previous years.) The upward trend in passenger-mile performance during the same period showed much greater stability. Performance rose from 665 billion in 1955 to 875 billion in 1964, with only 1 year (1957) registering a decrease, and negligible at that.

There is a much better correlation between GNP and passenger-mile performance than between GNP and ton-mile performance, which may have some bearing upon the relationship between the economic benefits of transportation technology research and unit cost trends in the transportation industry. For instance, it may indicate either that new passenger transportation technology has paid better dividends in reducing costs, or that the benefits of the great technological advances in freight movements have been largely if not entirely negated by other cost increases.

While increased capital investment plays a major role in technological advances, other factors are also critical. For example, a time and motion type analysis of the San Francisco port area made by the National Academy of Sciences in 1958 concluded that the greatest savings could be made not by substituting capital for labor, but by rearranging more efficiently the existing labor force within the existing or slightly modified physical plant. In this manner it was estimated that costs could be reduced by 25 percent.

Thus, more rational application of technology might contribute substantially toward reducing the steadily rising public and private cost of transportation and make it possible to meet expanding needs without relatively expanding the costs for services. However, unless such an effort is made we may have to become resigned to allocating some 20 percent of GNP for transportation. GNP for

TABLE 4. THE NATION'S PASSENGER TRANSPORT BILL, 1958–64 (MILLIONS)

Type of transportation	1958	1959	1960	1961	1962	1963	1964
PRIVATE							
Auto (includes business use):							
New and used cars	$14,916	$19,303	$20,237	$18,120	$22,093	$24,311	$25,549
Tires, tubes, accessories	2,502	2,787	2,777	2,867	3,017	3,194	3,505
Repair, greasing, washing, parking, storage, and rental	5,177	5,670	6,134	5,868	6,136	6,538	6,662
Gasoline and oil	12,922	13,654	14,457	14,615	15,231	15,879	16,547
Tolls	295	345	363	372	386	408	432
Insurance	1,895	2,119	2,320	2,407	2,405	2,450	2,519
Interest on debt	2,528	2,672	2,982	2,942	3,128	3,572	3,971
Auto registration fees	783	822	863	892	931	983	1,069
Total	41,018	47,372	50,133	48,083	53,327	57,335	60,254
Air (includes business flying):							
Aircraft	136	173	202	166	182	205	265
Operating costs	672	682	693	763	834	904	965
Total	808	855	895	929	1,016	1,109	1,230
Total private	41,826	48,227	51,028	49,012	54,343	58,444	61,484
FOR HIRE							
Local:							
Bus and transit	1,283	1,309	1,337	1,322	1,333	1,317	1,338
Taxi	808	848	858	803	828	838	835
Railroad commutation	124	125	122	127	127	130	134
School bus	420	441	474	506	540	578	612
Total	2,635	2,723	2,791	2,758	2,828	2,863	2,919
Intercity:[1]							
Air	1,592	1,910	2,068	2,164	2,398	2,541	2,891
Bus	530	565	588	611	655	630	671
Rail	680	647	635	610	593	511	492
Water	15	15	14	14	16	12	12
Total	2,817	3,137	3,305	3,399	3,662	3,694	4,066
International:							
Air	508	512	598	625	723	795	829
Water	172	268	267	240	267	310	336
Total	680	780	865	865	990	1,105	1,165
Total for hire	6,132	6,640	6,961	7,022	7,480	7,662	8,150
Grand total, private and for hire	47,958	54,867	57,989	56,034	61,823	66,016	69,634

[1] Includes 10 percent Federal excise tax until 1962, when it dropped to 5 percent on air only.

SOURCE: Adapted from estimates in *Transportation—Facts and Trends*, Transportation Association of America, Washington, 965, 2d ed., supplement, Jan. 1966, p. 4.

TABLE 5. TRENDS IN GROSS NATIONAL PRODUCT AND TRANSPORTATION, 1955–64

Year	Gross national product[1]		Transportation			
	Dollars (*billions*)	Index[2]	Ton-miles[3] (*billions*)	Index[2]	Passenger-miles[4] (*billions*)	Index[2]
1955	473	140	1,274	125	665	165
1956	484	144	1,356	133	697	173
1957	493	146	1,336	131	695	172
1958	486	144	1,216	119	705	175
1959	518	154	1,296	127	736	183
1960	531	158	1,328	130	759	188
1961	542	161	1,327	130	769	191
1962	576	171	1,393	137	802	199
1963	595	177	1,462	143	834	207
1964	623	185	1,550	152	875	217

[1] Total output of goods and services in constant 1964 dollars.
[2] 1947 = 100.
[3] Includes both regulated and unregulated carriers.
[4] Includes both for-hire and private carriers, including auto.

SOURCE: Ton-mile and passenger-mile data adapted from data in *Transportation—Facts and Trends*, Transportation Association of America, Washington, 1965, 2d ed., p. 5; GNP data for 1955–57 from same source; GNP data for 1958–64, *ibid.*, supplement, Jan. 1966, p. 2.

1975 is predicted to reach about $1,000 billion, nearly 60 percent higher than the 1964 level; this would mean that the national bill for transportation services in 1975 would reach some $200 billion, assuming the same 20 percent share. Thus it appears essential that all possible efforts, including more emphasis on technological advances, be made to reduce that share.

3. Obstacles to Technological Advances in Transportation

There is little question that advances in transportation technology are often hampered by factors which have little or no relation to technical feasibility. That is to say, the operation, technique, or process is technically feasible and could be developed and applied if it were not for obstacles. While a catalog of reasons for such obstacles could be developed, they may be summarized as falling into three general areas: (1) Objections to development cost, usually raised by management, government, or the public; (2) objections to labor displacement, almost always raised by labor organizations but on occasion by communities and public and private agencies concerned with the economic impact of such displacements; (3) apathy to change, possibly the most important and often the most difficult to combat because it is a silent obstacle.

The first obstacle, cost, usually is based upon two factors. One is uncertainty as to the real cost of proposed research, which, in many instances neither industry nor government know. If the estimated cost is set too high then the decision to go ahead is blocked at the outset; if the cost estimate is unrealistically low the end results may often be unsatisfactory simply because it was impossible to do what was necessary to achieve the goal. The latter has probably caused much more dissatisfaction with technological research in transportation—and in other fields as well—than the objection to high cost.

Underestimating research costs has another undesirable side effect—failure dampens the prospects for research programs to follow, even though later programs may be more realistic respecting cost. There are numerous examples in both industry and government where such initial failures were overcome only by the most urgent demands for continuing research based upon critical competitive considerations in the case of industry, or critical public needs in the case of government. New product research—the development of the diesel engine in trucks and passenger cars, nuclear propulsion in merchant ships, and the jet aircraft are typical examples—costs a great deal of money, and sometimes the most dogged determination to stick with initial research is required for ultimate success.

Cost as an obstacle sometimes stems from failure to pursue the complementary research needed to develop supporting techniques and equipment. For example, it has been known for many years that the efficiency of internal combustion engines could be improved by using more heat resistant metals, but their widespread adoption had to wait until cost reductions made them commercially practical for automobiles. Likewise, during the last few years the use of such once almost exotic metals as stainless steel, aluminum, and magnesium has been greatly increased in the transportation equipment field, primarily because costs have been brought within the range of competition with other less suitable but cheaper metals.

Barriers to technological progress arising from objections to labor displacement have a long background. Early railroad development and expansion was opposed by stagecoach and freight wagon operators; trucking development was opposed by competing forms of transportation. However, in these instances opposition was often based upon resistance to capital displacement as well as to labor displacement, and labor and capital joined hands to resist the new technology. But most of the resistance to new technologies which threaten to displace labor or reduce labor requirements, even temporarily, probably stems primarily from workers. In our modern society, this opposition is predominantly expressed by organized labor.

There is little question that the opposition of labor to technological innovation has often had significant negative impact upon the rate of introducing new techniques designed to reduce the cost of transportation. Opposition to cargo-handling equipment, container traffic, and reduced shipboard manning are dramatic examples of this. Less publicized opposition to innovation includes such practices as placing allegedly uneconomic limits on work output, even though higher levels of performance are now entirely feasible through new technologies; for example, unreasonably short-run assignments in rail transportation and unduly low load limits on transport equipment which fail to utilize fully the designed capacity.

Basically, labor's opposition stems primarily from the understandable fear of reducing employment. However, in many instances labor organizations have recognized both the need for reduced labor costs and the inevitability of reduced labor requirements. Moreover, the basic problem has been recognized as often a matter of temporary displacement rather than permanent unemployment. In many instances innovations which were resisted at first have actually resulted in more net employment. As this becomes more widely recognized, some of the present opposition to technological changes may possibly decline significantly.

A review of employment in the industry and closely related occupations over past years supports the view that labor opposition to innovations may decline as long-range labor expansion benefits become more widely known. For example, despite all the labor-saving techniques introduced in recent years, labor requirements have increased substantially and, more important, maintained a virtually constant share of the total labor force. Employment figures from various official sources indicate that in 1947 employment in transportation, transport equipment, maintenance, and related industries totaled 7,725,000, or 13.4 percent of the civilian labor force. In 1964, the comparable figures were 9,145,000, or 13 percent of the civilian labor force.[2]

Of course, despite the stable percentage level, there have been sharp changes in individual sectors of the total labor force. These changes have caused many instances of unemployment, some temporary until retraining could be effected and

[2] From data prepared by Transportation Association of America, Washington, 1965.

some resulting in permanent separation from the industry. Although the effect of the latter has been conditioned to some extent by new opportunities in other fields, much remains to be done to ease the impact of technological unemployment. Moreover, the extent to which that impact is eased will have a direct bearing upon the attitude of labor toward technological innovations, an attitude which might, in time, significantly influence policy in promotion or regulation.

Transport policy planning is severely limited in its ability to effect changes which would soften the blow of labor displacement due to technological changes. National policy must, insofar as possible, be based upon equitable measures which do not favor one form of transport over another. Yet many of the steps required to ease the burden of labor dislocation would clearly favor one sector of the industry over another. Thus, the extent of such actions most often transcend the bounds of policy and become matters for general welfare discussion.

The effect of apathy toward technological change is more difficult to assess than overt opposition based on cost or labor displacement. Apathy is particularly troublesome to combat because it is vague, amorphous, and seldom based upon economic reasons, and the policy planner is unable to marshal cogent arguments against it. Apathy is also often disguised under other reasons. For example, technological change, new processes, new management programs are often opposed on the basis that they cost too much or will displace labor to an unacceptable degree when the opponents actually have no factual basis for such arguments; they simply do not want to change the old way of doing the job.

A major task of the transportation policy planner is to devise new approaches to this indifference if our Nation is to take the fullest advantage of the potential benefits of new technologies. But how is this to be done? The answers lie in clear and incontrovertible demonstrations of the economic and social benefits of proposed changes. This requires much more emphasis on soundly based research, and more thoughtful and imaginative programs, less fragmentation of direction and policy control, more direct appeals to the self-interests of management and workers, and, above all, support from the public which is the ultimate beneficiary of technological research.

4. Proposals for Solutions

No knowledgeable person would dare suggest that the above brief outline of problem areas is in any sense definitive. However, these areas contain not only the major to'`:s of controversy but also many which may be thought to be outside.

In discussing economic and social solutions for the problems imposed by technological change, it is essential to recognize at the outset that solutions very often involve disagreeable alternatives. This was ve:y well put recently:

> The benefits to society from technological change are not costless. For some individual workers, businesses, and communities, technological chan; brings new opportunity: Better jobs, higher profits, greater prosperity. For others it imposes burdens and even hardships. For technical change may reduce the value of—or even make obsolete—particular labor skills, plant and equipment, or natural resources.[3]

Transportation policy planners can assist technological development by helping to assure that adequate funds are made available for research. In recent years the importance of transportation technology research has been increasingly recognized by the Federal Government. Possibly of equal importance is the Government's recognition that assistance outside the Federal area is well justified as in the public interest for research with direct application to public problems, even though the main thrust may have been initially directed toward the private sector. The importance of such cooperation is reflected in the recommendations of the Corson report on transportation research and development which stated that the Department of Commerce should accelerate its development of analytical techniques designed to "demonstrate the likely consequence of alternative policy choices" and recommended that the Department:

> (a) Build up its R. & D. capability in the appropriate agencies as fast as staff can be found, primarily in systems analyses and other modern research methodology suitable for improving the basis for policy decisions, and
>
> (b) Develop a program of industry-government cooperative R. & D. to undertake and support jointly research on topics of mutual interest and urgency.[4]

Although there is considerable criticism of government support of private research, industry now spends far more than government for such research. A survey made in 1961 by the National Science Foundation reveals that private industry at that time was spending over $1 billion for transportation R. & D. activities; manufacturers and suppliers spent the bulk, while carriers and other transport service companies spent only a small portion of the total (see table 6).

In contrast to private R. & D. expenditures, Federal agencies in fiscal year 1963 spent some $345 million for R. & D. applicable to civilian transportation activities. The bulk was for air transport research and the major agencies were, as might be expected, the Department of Defense and the Federal Aviation Agency (see table 7).

[3] "The Promise and Problems of Technological Change," *Economic Report of the President*, January 1964, p. 98.

[4] *Report of the Panel of Transportation Research and Development of the Commerce Technical Advisory Board to the Secretary of Commerce*, Washington, May 1965, p. 11.

TABLE 6. ESTIMATED COST OF COMPANY-FINANCED R. & D. IN THE TRANSPORTATION INDUSTRIES

Industry source	Annual expenditures (in millions)
Suppliers:	
Motor vehicles and other transportation equipment [1]	$628
Aircraft and parts [2]	379
	1,007
Carriers [3]	20
Total	1,027

[1] National Science Foundation, *Research and Development in Industry, 1961*, table A–8, p. 69.
[2] NSF, *op. cit.* Estimated from NSF 1961 figures. Since 1960 the standard industrial classificatior ·· ·r NSF reporting has been changed to include missiles (SIC 19) witr and parts (SIC 372). Straight extrapolation of previous data giv he estimated portion of $392 million total to be assigned to aircraft ... s alone.
[3] NSF. Estimated survey gives the total R. & D. figure for 11 different nonmanufacturing (transportation and nontransportation) industries as $65 million in 1961; transportation carriers and services comprise 10 percent of that group. However, railroads and airlines 'one are reliably reported to have spent about $12 million on R. & D. in a recent year. Therefore, this estimate appears reasonable.

TABLE 7. TRANSPORTATION R. & D. EXPENDITURES APPLICABLE TO CIVILIAN SECTOR BY FEDERAL AGENCIES BY MODE, FISCAL YEAR 1963 (MILLIONS)

	Air	Hwy.	Water [1]	Pipeline	Rail	Mixed	Total
DOD	$171	$13	$10			$10	$204
FAA	59						59
NASA	43						43
HHFA		1			$7	12	20
BPR		8					8
AEC			3				3
HEW	(2)	2			(2)		2
Marad			2				2
Others	2					2	4
Total	275	24	15	(2)	7	24	345

[1] Both ocean and inland waterway.
[2] Less than $1 million.

SOURCE: *Report of the Panel on Transportation Research and Development of the Commerce Technical Advisory Board to the Secretary of Commerce*, Washington, May 1965, p. 77.

Table 6 demonstrates clearly that while the transportation industry as a whole spends a significant amount of money on R. & D., the carriers, who are the ultimate beneficiaries, expend a negligible amount for research. There may be good reasons for this failure; for example, in developing products, suppliers undoubtedly carry out research in operations, much of which would only be duplicated by carrier research. However, carriers would be likely to profit by expanding and extending their own research to cover their own operating problems. While costs may sharply limit the amount of research that individual carriers may perform, there appears to be no valid reason why the trade and technical organizations serving them (and there are active organizations in each form of transportation) cannot pool resources and do much more than any one carrier could afford.

Cost as a barrier to increased research could, of course, be reduced through more government participation. Transportation policy planning might well consider the public benefits from more research in the private sector, and especially by carriers, to overcome the existing imbalance.

Table 7 illustrates a major gap in government transportation research policy; that is, the lack of correlation between public money spent on each form of transport and the public demand for that transport. For example, air transport, which accounts for a small portion of the national freight ton-mile performance and a very small portion of the passenger-mile performance, in fiscal 1963 received nearly 60 percent of Federal R. & D. expenditures for transportation.

This is *not* to suggest that there must be absolute correlation between performance figures and public expenditures for each mode of transport. Such an approach is both economically impracticable and illogical as public policy. However, there should be some correlation between public financial support and public demand for various forms of transport. The precise nature of that correlation is a matter for policy decisions.

Obstacles to technological change raised by labor organizations and individual workers stem chiefly from the fear that innovation will reduce the number of jobs in a particular sector as opposed to overall demand for workers in the transportation industry as a whole. Labor contends that it is small consolation to displaced workers to be told that technological change will eventually increase the total demand for labor. While this is demonstrably true, it has two basic failings: (1) workers must be able to shift to the new jobs; and (2) there is often a timelag between losing the old job and getting the new job.

The answer to the question of what steps can be taken to overcome labor opposition to technological developments which threaten displacement transcends the scope of transportation policy and cuts across a wide range of national policies. Labor, education, retraining programs, and other factors also play important roles in Federal policy decisions concerning displaced workers in the transportation industry.

Transportation policy planners could contribute effectively to national policy decisions by carefully examining the effect of such labor displacements on the cost and efficiency of labor as a factor in national transportation costs. It will be recalled that the cost of transportation and related activities now account for about 20 percent of the gross national product. In view of this substantial economic outlay, it appears to be in our best interest to assure that the social costs of technological improvements do not ultimately outweigh their apparent economies. If, however, certain technological improvements can effect major savings in total national transport costs then it appears logical that a portion of such savings be spent to ease the impact on those affected by the change. How should such savings be spent? Retraining, relocation, early retirement obviously have some application to the best answer.

Fragmentation of authority for decisions leads inevitably to indifference, intentional or unintentional, at all levels. While this is understandable, it nonetheless blocks the effectiveness of the transport policy planner who must necessarily consider the total situation and not just some fragments. However, the transport policy planner can take some actions to overcome this obstacle. Lack of understanding of the problems and their potential for solutions can be met by educating decision-makers as to the issues, the alternatives, and the real social costs of action and especially inaction.

Although solutions to all the problems of fragmentation go beyond the logical scope of transportation policy planning, the benefits of overall planning are so apparent in some areas of transport technology that good management principles, if nothing else, demand that piecemeal approaches be reduced to the absolute minimum. By instilling a new sense of unity to transportation technology problems the policy planner would do much to reduce the inevitable sense of social indifference which fragmentation almost certainly engenders in the minds of those who must make the necessary decisions and those who must live with the results of those decisions.

THE LIFE SCIENCES, TECHNOLOGY, AND UNMET HUMAN AND COMMUNITY NEEDS

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CONTENTS

The Life Sciences, Technology, and Unmet Human and Community Needs

Introduction

It is apparent that in coming years the impact of technological change on the Nation's economy, social structure, and well-being will be considerable. Accordingly, it is important to seek out the most effective means for channeling modern technology into promising directions and to determine how it may be applied most effectively to unmet human and community needs. In this light it is purposeful to note that the application of advances in the physical sciences and engineering to the life sciences is having and will continue to have an important bearing on the well-being of people. The material that follows considers briefly some currently developing areas that illustrate this relationship, and in some instances makes suggestions as to their further implementation.

Regional Health Computer Systems

The report of the President's Commission on Heart Disease, Cancer, and Stroke, and the enabling legislation stemming from it, seem to reflect the President's determination to make available to all the people the full benefits of progress in the health sciences. A subcommittee of this Commission made plain its belief that the ambitious recommendations of the main report cannot be implemented adequately with existing manpower, and left open the question whether expanded training of manpower along present lines will suffice. As provision for appropriately trained manpower is a primary concern, and as optimization of manpower utilization could have a greater impact upon health than many conceivable research achievements, we are concerned here with a way to provide and multiply the effectiveness of such manpower.

It is increasingly clear that knowledge of how to prevent and cure disease has outstripped its application, and many health needs remain unmet in the country. Progress has been slow in devising new and more efficient methods of organization and in the application of the technologies called for by the changing pattern of medical care. Particularly, the capabilities of big computers to make generally available the benefits of accumulated knowledge and experience have scarcely been tapped.

Regional health computer centers could provide medical record storage for perhaps 12 to 20 million people, and hospitals and doctors in the area could be given access to the computer's diagnostic and other capabilities via telephone line connections. Such regional systems could help:

1. Provide better care to everyone regardless of geographic location than is possible at present.
2. Reduce unit costs, thereby relieving the economic load on the Nation.
3. Provide for a more efficient use of manpower and alleviate the unmet need for health workers presented by Medicare and the regional medical programs.

Technology now exists [1] to enable the establishment of regional health computer systems providing for (1) storage and rapid recall of individual health records; (2) collection and evaluation of important medical statistics; and (3) automation of certain aspects of medical diagnosis. Computers can perform any repetitious task requiring analysis of information and establishment of probability more consistently and accurately than any human. Diagnosis is a repetitious task based upon analysis of information gained from history, physical signs, and laboratory determinations. Machines can accept items of history and such as those embodied in the electrocardiogram, electroencephalogram, and phonocardiogram, and accept chemical information presented to it in analog or digital form. Moreover, the machine can learn from its experience, can reject inconsistent data, and is increasingly able to establish the probability of some diseases.

Each step toward the above goals could bring incalculable benefits to the health of the Nation, and realization of these goals would bring about such significant changes as: (1) Revisions in medical education to enable doctors to function effec-

[1] See appendix I (list of currently active areas in automation and the health sciences).

tively in a changed environment; and (2) reeducation of existing medical personnel to enable them to cope effectively with this same environment. The institution of regional health computer systems is probably the single most significant step that can be taken to make available to everyone the benefits of modern medicine.

Although considerable basic information has accumulated to date on various individual projects on hospital records, epidemiologic studies, the automation of certain aspects of medical diagnosis, etc., there has been little attempt to coordinate these into an integrated system. Accordingly, it is timely to undertake research, development, and computer sytems analysis leading to the establishment, testing, and operation of regional health computer systems that will provide (1) regional data processing for automated clinical pathological laboratories; (2) automation of certain aspects of medical diagnosis; (3) storage and rapid recall of individual health records; and (4) collection and evaluation of statistics relating to large medical populations. These centers should be developed for integration with individual hospital information systems, with the decentralizing efforts of the National Library of Medicine in national medical information retrieval and dispersal (MEDLARS), with Food and Drug Administration needs in the drug information field, and with the regional medical programs.

Following an initial 2-year period of analysis,[2] research, and development, it is reasonable that construction of two centers might be set up with approximately 12 scientific units appropriate to the chosen operational areas. There would be particular backup capability in the hardware, software, and information and communications aspects of computer systems. Each center would also have a strong research and training area.

After thorough testing and evaluation, up to 10 other systems could be established in the next decade, based upon experience with these first prototypes. Such a program would require extensive contract operations and research-grant support. To an extent, and in time, full-scale operation of the project as a public information utility could result in a sharing of costs, as the expense of many of the services available may be recoverable by charges to the consumer.

Initial feasibility analyses and program definition study to date indicate that, beyond initial research and development expenditures of $4 million in the first 2 years, the construction cost per center would be approximately $2 million, and the operating expenses per center, $3,600,000 per year. At the end of a decade the building program would total $20 million and the operating expenses would be approximately $40 million per year.

[2] See appendix II (evaluation of current state of art in automation and the health sciences).

Continued Scientific Development for Mature Life Scientists

While the perimeter of research activity in the life sciences continues to expand explosively, the deficiencies of some mature biomedical scientists in mathematics and the physical sciences are becoming more and more apparent as a major problem. It is strikingly evident in their lack of ability to oversee and adequately guide the interdisciplinary education and research of young men now in the developmental stages of their careers. Consequently, planning for the continued scientific education of these mature scientists is most necessary if they are to continue to work effectively at the frontiers of education; to be able to incorporate into their own areas of research the emergence of technologies as yet unsuspected; and to guide responsibly young men interested in applying technological advances to the solution of problems in the life sciences area. The core effort here should concern itself primarily with the remedial treatment of deficiencies in fundamentals rather than current technological breakthroughs or exciting contemporary foci of interest in the physical sciences.

In common with others, life scientists are confronted with an exponentially increasing body of knowledge supposedly to be mastered by lonely scholarship in moments stolen from expanding curriculums, clamoring students, meddlesome administrative hierarchies, and a host of distractions, a significant one of which is contributing to planning on a national scale. In contrast to others, life scientists are confronted now with the need to master the advanced aspects of exacting disciplines for which they may never have acquired the rudiments of mathematically based physical science. With all this, professional advancement requires that they maintain a respectable rate of production of published research conceived during quiet hours of reflective thought, culminating in meticulously designed and exhaustively executed experimental tests.

Although a scientist, almost by definition, may take nothing on faith, he falls short of this ideal in some respects. It is an act of faith that the scientist is educated for a lifetime of learning. It is an act of faith that the scholarly scientist, solidly schooled in basic disciplines, does not fall behind the pace of scientific advance while he avidly follows the literature of his own and related fields, probes a frontier of knowledge in his own research, and is stimulated by colleagues and students in a richly intellectual university environment. These attitudes, formed in an earlier and quieter age to conform to social conditions long since vanished, constitute a barrier to rational examination of the continuing educational needs of the scientist in the mid 20th century.

Harassed by the pressures of change as other scientists are, the others are still in a better position than life scientists. For the life scientist finds his field in revolution. If in or beyond his fifth decade, his indoctrination was probably more appropriate for descriptive biology, requiring meticulous observation and painstaking reporting of innumerable facts, than for an emerging theoretical science which places a premium on the sparkle of fancy. More than this, it is necessary that theory be expressed in mathematically precise terms in order to enable critical deductions from hypotheses and precise testing of consequences. Descriptive biology, including correlation of structure and function at all levels, will remain a major preoccupation for which educational requirements may not change rapidly, although there are exceptions, for example, in molecular biology. Theoretical biology, however, requires a sophisticated preparation in mathematics, physics, physical chemistry, and in such biologically esoteric fields as systems theory, with which a classically trained biologist cannot conceivably cope without a major updating of his intellectual tools.

It is clear that the mathematical rigor of life science research will increase as young men recognize and move into new fields opened by development of quantitative approaches in engineering and the physical sciences which they perceive to have relevance to the problems they face. But young men are less able in their graduate and early postdoctoral years to relate these exciting ne- approaches to the whole field than are mature investigators. Moreover, the education of the young men may be conducted more effectively if their seniors are conversant with these advances and are skilled in their uses. To become conversant in rigorous fields requires not merely extension of previous knowledge but repair of areas, particularly those based on mathematics, for which the initial preparation of most biologists has not been ideal.

These educational needs of the speculative thinker, aware of vast opportunities inaccessible to him because of functional illiteracy in mathematically rigorous science, are of particular concern here. It is not reasonable to expect him to acquire a foundation, in his spare time and without formal instruction, which is comparable to that on which scientists in other fields lavish years of study. Yet he is deterred from seeking the obvious remedy by his own conviction that he should be able to educate himself, as well as by a keen awareness that his colleagues share his conviction. For him to admit that he needs to devote full time to basic, formal education for possibly 2 years or more is tantamount to an admission of sloth and incompetence. For most, the barrier is formidable enough to insure that the middle and later years will be spent on elaboration and embellishment of earlier work rather than on bold adventures.

Sad as this is for the speculative thinker keenly aware of his own shortcomings, the sadder consequence is that he reproduces obsolescence in students. Many of these students now come equipped with mathematics and the physical sciences sufficient to enable them to attack problems to which their teachers are unable to direct their attention or to guide their efforts intelligently. Restoring a scientist to productivity on a new frontier restores him also to serve as an inspirational leader, to launch his students on careers of productive research in areas of theoretical biology that might otherwise lie untouched for another generation or so, and, of increasing importance, renders him a competent, responsible, interdisciplinary participant in matters relating to technological advance and unmet community and human needs.

The strongest evidence that the need exists is that correctives are already being applied here and there. Individual study in the tradition of the contemplative scholar, frequently supplemented by formal study of hopefully relevant mathematics and physical sciences, is being undertaken by younger and more restless faculty while they discharge their responsibilities to students and departments. Occasionally a department chairman, sensitive to the needs of his faculty, will organize an interdisciplinary program, drawing upon resources of other departments to create a curriculum which will facilitate achievement of competence in some adjoining field. In some cases, too, representatives of other disciplines may be added to a faculty in part to afford better insight into the relevance of mathematics, physics, or control theory to the research interests of the group. Such faculty additions serve to stimulate interest and enhance the value of interdepartmental programs.

Education away from the home university is also an academic tradition. Unfortunately, the sabbatical leave of absence is too brief and too infrequent to enable any thoroughgoing revision of a scientist's basic education. In any case it is likely to be a sojourn abroad engaged in collaborative research with an intellectual counterpart which for the reputation of both must culminate in publication of one or more papers. Special fellowships which might be used to enable more extended leave for the wholly different purpose of achieving new competence are commonly used to support part of the costs of the sabbatical.

One concludes that individual fellowships which serve to free a man to undertake education appropriate to his unique needs should be supplemented by carefully structured programs. These should be designed to enable groups with common interests to achieve functional competence in mathematics and the psysical sciences, and then to probe in depth into areas of science not readily accessible to the classically prepared biologist. Examples of such areas are quantum biology, the communication sciences, biological control systems, simulation of systems by analogue and digital computer, and the computer handling of multiple variables.

In summary of the characteristics of such structured programs: (1) They should essentially be programs in mathematics in which other material appears primarily as applications; (2) they should require the equivalent of 1 to 2 years of full-time effort; (3) optimally, they should be conducted in a very few centers for advanced study; and (4) they should serve not as another final education but as mechanisms to enable scholars to continue to advance by their own personal efforts.

In the main there are five ways that the objectives of continued scientific development might be accomplished: (1) Special fellowships, (2) summer institutes, (3) intrauniversity programs, (4) adapted existing graduate training programs, and (5) centers for advanced study.

The summer institutes are of interest and deserve comment. They would offer a mechanism which avoids some of the factors that make the more prolonged periods of study in centers of excellence unattractive to a large part of the academic community. First, there is no necessity for a major break in a man's career with the attendant uprooting of family and interruption of ongoing research. Second, the summer institutes would permit a man who aspires to undertake an extensive program to test his motivation and ability to handle rigorous mathematical approaches without a major commitment or the risk of suffering an obvious and humiliating defeat. Third, a sequence of summer institutes linked by part-time work during the regular academic year may suffice to meet the educational needs of a large proportion of the academic community.

Centers for advanced study may offer a particularly good answer to the problem. They would best be established in a very few major universities in order to insure a suitable and scholarly environment. Basic course material could be taught by junior faculty of that university, but some superstructure items would have to be handled either by faculty on leave from their home universities for a period of 1 to 3 years, or in summer sessions by invited faculty. Both faculty and scholars should be highly selected.

Participation in programs of continued scientific development should be confined to professorial faculty of proved performance and excellent potential who wish to pursue their research interests into areas for which they are not now equipped. The faculty of the parent institution might be supplemented by visiting professors on leave for a year or two to participate in this program, both as teachers and in the conduct of their own research programs. As in individual awards, continuity of employment and freedom from economic penalty should be insured.

One recognizes that these approaches to supplementing existing educational programs for faculty in the home universities would entail risks for the individual and for the schools. As the scientist-students concerned would be drawn from among the best qualified in the universities, some disruption of departmental activities seems inevitable. Provision may be needed to enable universities from which faculty are withdrawn for as long as 2 or 3 years to expand in order to avoid vitiating the benefits of reeducating some by overburdening others. Such facilities would then be in a position to rotate members out of the department for continuing education away, thereby reducing the risks for all.

A system of awards and special programs could be aimed principally at the needs of men of quality in their middle years, although some promising younger faculty members might be enrolled, and talented individuals in their sixties should surely not be excluded. It is one comforting aspect that these cohorts are relatively numerous as compared to the 25- to 35-year-old group born during the depression years of the thirties. This group now rising to responsibility is restricted in number and necessarily burdened with much of the routine teaching as well as direction of graduate study. The older faculty can better be spared for the time periods involved and upon their return will be able to assume a substantial portion of teaching in advanced areas for which they are not now qualified.

There can be no need to apologize for the beneficial consequences that would result from advancing the education of men who have demonstrated excellence as investigators and teachers. It is likely that many of them would enter a period of renewed productivity quite possibly comparing favorably with an earlier one. Such men returning to schools that do have interdepartmental programs for education of faculty would be priceless assets in encouraging and improving these university efforts. These talented scientists returning equipped with advanced capabilities would contribute to preparatio : young scientists and to their inspiration to u ake a lifetime of investigation punctuated by opportunities to renew themselves in their turn. Granting that there are many real interfaces of importance between the advance of the life sciences and technological change, it is of particular significance that these senior scientists and the men they train will be better equipped to participate actively with others in the major societal consideration of how technological change can be channeled most effectively to meet human and community needs.

Clinical Manpower for the Health Sciences

An important implication of the report of the President's Commission on Heart Disease, Cancer, and Stroke is that there will be an increased need for training clinical investigators in the area of surgery, radiology, and anesthesiology. The Commission's report and the bills enacted into law pursuant to it have accelerated the demand, and active attention must be paid to those areas where major shortages of trained scientific manpower exist.

Surgery

In the last 25 years surgery in its broadest physiological and biological sense has become more of a true science due to the extensive introduction of the physical sciences into it. Applied without skill or conscience, the techniques arising out of the advances in the basic biological and physical sciences bring only hardship and expense in their wake. Applied with wisdom and mercy, they have been responsible for the growth of what has now become the largest single agency for definitive treatment in all of medicine.

Because of the urgent need for more skilled clinical investigators in surgery, high priority should now be given to the establishment of an outstanding program in this area. This program should be designed to provide carefully selected candidates with training in depth in the basic biological and physical sciences and in surgical research. This will lead to the development of surgical scientists and scholars who are interested in the area of academic surgery and in careers as clinical investigators in surgery. It is expected that such men will be capable of applying fundamental scientific concepts directly to clinical problems in the area of surgical practice, will be productive in research and research training, and may ultimately chair research-oriented surgical departments. This will create an environment within departments of surgery where opportunities to bring new data and concepts to patients immediately will be available, where cross-fertilization will become exceedingly fruitful, and where young people will be stimulated and motivated to introduce more physical science and advanced technology into the practice of surgery.

For surgery to continue to exhibit its proper relationship with science, universities, national societies, and the Federal Government, these institutions must take note of the fact that the young surgeon must devote additional years to his education. If properly supported, this will not in the slightest constitute an inordinate demand, particularly as these young persons move into a period that will see education gradually become more of a life process.

As to the application of fundamental scientific concepts and advancing technology to clinical problems in surgical practice, in specific instances these research surgeons might well be trained to work with biomaterials scientists and biomedical engineers, and with immunologists and geneticists on the transplantation of organs.

Physical materials can be used, in many instances, within the human body to substitute for a diseased or a destroyed part. The materials currently used are extremely diverse, and the requirements for their long-term existence in the body are not well known. In consort with biomaterials scientists, surgeons are becoming concerned with the design of these implants and their characterization at the molecular level in order to define the needs of part replacement within the body.

During the next 5 years, biomedical engineering is expected to undergo a further extension of its rapid growth, as newly trained doctoral level engineering scientists become engaged with surgical scientists and investigators in the conduct and direction of research pertinent to biomedical engineering and surgery. Current developments in transistors and miniaturized circuitry suggest that rapid progress will be made in the creation of adequate control mechanisms for certain artificial internal organs. In this light, the study of biological control systems and their feedback circuits can be expected to contribute to the design of better prosthetic devices ranging from artificial limbs to the lung. Such purposeful developments in systems engineering can be made only by a coordinated integration of surgeons, engineers, technicians, and other basic scientists. This will be necessary if the theory involved is to be exploited and if the development and the production of actual materials for routine use in patients are to be achieved.

For the above undertakings, the exploitation of industrial capability in the final design and construction of these devices will be absolutely necessary, since fabrication can only be accomplished by enlisting the combined interaction of surgeons, biomedical engineers, and the highly competent developmental organizations that are not found in university environments.

As for the area of heart disease and stroke, in recent years there has been an increasing volume of surgery on newborn infants, and prompt surgical intervention in this hazardous age group is beginning to show striking results. Prior to the extension of surgery into the area of congenital heart defects in infants, 35 percent of the children not treated by surgery died within the first month of life, and 55 percent died within the first year. It is estimated that of the approximately 50,000 children with congenital heart defects born each year in the United States, 70–80 percent could be either cured or helped by surgery.

Stroke is caused by the blockage of blood vessels that supply the brain. In most instances the obstructions are caused by arteriosclerotic deposits or by blood clots. On occasion these obstructions to the flow of blood are located in the arteries of the neck and upper chest and are thereby accessible to surgical intervention and the relief of obstruction. The treatment in this situation is to remove the obstruction, or to bypass the obstruction with synthetic blood vessel grafts. It is significant that approximately 45 percent of such cases can be helped or cured by surgery because of the location of the obstruction outside of the brain itself.

Continued advances in the above areas are considerably dependent on extended sophistication in diagnosis and treatment, and the application of advances in technology. Increasingly improved results can be obtained by the intensive preparation of surgeons who will be able to bring advances in the physical and basic biological sciences directly to bear on research studies and patient care.

Diagnostic Radiology

In the past 70 years the clinical science of diagnostic radiology has grown to the point where it is employed in an extensive spectrum of human diseases. However, academic diagnostic radiology is now in a troubled and serious situation, as both the quality and quantity of medical care are particularly threatened unless more trained radiologists are available to meet the increased demands for their services. This shortage poses an alarming problem for the Nation's hospitals and medical centers and is grounds for grave concern. There is ample evidence that we are not drawing enough young people into radiology training programs to take care of the work necessary in the days ahead, particularly to perform the burgeoning sophisticated procedures that are becoming routine in modern radiologic practice. In this light, it has become apparent that radiology must be made more attractive as a profession.

A basic need is to enhance the status of the field. The support of both research and training in radiology has been relatively meager in the past, and its development has been limited by the lack of an overall attack upon the problems that face the area. A particular problem is that the development of the field, in recent years, has been considerably dependent upon the availability of large and expensive equipment; it is now becoming increasingly dependent upon the availability of adjacent computer resources. Also the extreme shortage of radiology departments with traditional academic orientation and relationships, and of appropriate environments for the development of radiologists as academicians presents a serious problem.

Needed in diagnostic radiology are programs with a strong radiological research environment and the availability of strong basic science and physical science departments that can give the underlying scientific background required for modern clinical radiological research. Such programs can have a great influence in elevating the standards and performance of academic radiology, and in enhancing the status of the field, and thereby the entire practice of radiology in the country. This is an excellent example of an area in which careful integration of resources, research, and training can have a profound effect.

To meet these needs, new programs for research training in diagnostic radiology are required. These programs should be designed to provide carefully selected candidates with training in the basic sciences and in radiological research. This should lead to the development of scientists who are interested in academic radiology and in research careers in diagnostic radiology. It is expected that such men will be capable of applying fundamental scientific concepts to the area of diagnostic radiology and will be productive in research and research training.

With respect to the findings of the President's Commission on Heart Disease, Cancer, and Stroke, it is timely to note that accurate diagnosis in these areas is being hindered by a lack of radiologists trained to bring a full armamentarium of the physical and clinical sciences to bear on them. The problem of diagnosing impending stroke, or identifying individuals who are susceptible to stroke, is a major challenge to the diagnostician and radiologist. Personnel are urgently needed for the further development and implementation of cine cerebral arteriography, which dynamically outlines the blood vessels of the head and indicates possible diseased areas, of techniques of arteriocatheterization, of instrumentation to measure bloodflow in the brain, and of new computer methods in radiology. Development of the clinical use of fiberoptics, high energy beams, or computer intensification of X-ray images requires that the skills of the mathematician and the physicist as well as those of the clinician should be extended to these areas.

To meet these needs, an increased interaction of biomedical engineers and diagnostic radiologists should be encouraged. In specific instances, research radiologists should be trained to work with biomedical engineers to develop better, safer, and more accurate methods for the use of X-rays, radioisotopes, heat, and ultrasound in the diagnosis of disease.

Conclusions

Continued appropriations are needed to implement the recommendations and the enacted legislation that have resulted from the President's Commission on Heart Disease, Cancer, and Stroke if a more effective and quicker application of the results of medical research to diagnosis and treatment is to be brought about. The training of specialists in surgery, radiology, and anesthesia must be an essential feature of the program if the benefits of modern research are to be made available to segments of the population that are now inadequately served.

Summary

1. *Regional Health Computer Systems*

It is timely to undertake research, development, and computer systems analysis that would lead to the establishment, testing, and operation of regional computer systems that can provide: (a) Regional data processing for automated clinical pathological laboratories, (b) automation of certain aspects of medical diagnosis, (c) storage and rapid recall of individual health records, and (d) collection and evaluation of statistics relating to large medical populations. These centers should be developed for integration with individual hospital information systems, with the decentralizing efforts of the National Library of Medicine in national medical information retrieval and dispersal (MEDLARS), with FDA needs in the drug information field, and with the regional medical programs. They would help in the optimization of manpower utilization, and could have a greater impact on health than many conceivable research achievements. They probably represent the single most significant step that can be taken to make available to everyone the benefits of modern medicine.

2. *Continued Scientific Development for Mature Life Scientists*

While the perimeter of research activity in the life sciences continues to expand explosively, the deficiencies of some mature biomedical scientists in mathematics and the physical sciences is becoming more and more apparent as a major problem. It is strikingly evident in their lack of ability to oversee and adequately guide the interdisciplinary education and research of young men now in the developmental stages of their careers. Consequently, planning for the continued scientific education of these mature scientists is necessary if they are to continue to work effectively at the frontiers of education, to be able to incorporate into their own areas of research the emergence of technologies as yet unsuspected, and to guide young men interested in applying technological advances to the solution of problems in the life sciences area. The core effort here should concern itself primarily with the remedial treatment of deficiencies in fundamentals rather than current technological breakthroughs or exciting contemporary foci of interest in the physical sciences.

3. *Clinical Manpower for the Health Sciences*

An important implication of the report of the President's Commission on Heart Disease, Cancer, and Stroke is that there will be an increased need for the training of clinical investigators in the area of surgery, radiology, and anesthesiology. The Commission's report and the bills enacted into law pursuant to it have accelerated the demand, and active attention must be paid to those areas where major shortages of trained scientific manpower exist. These needs accentuate a necessity for the establishment of research and training centers in biomedical engineering and biomaterials science where these developing investigators can participate in interdisciplinary, physical science oriented, and life science studies.

Appendixes

APPENDIX I

Active Areas in Automation and the Health Sciences (From 1,016 Listings for Computers in Biomedicine)

I. *Automated Clinical Pathological Laboratory Studies*
  (a) Automated analysis of:
    Blood chemistry levels
    Bacteral sensitivity and grouping
    Mitotic cell configuration
    Blood smears
    Ultracentrifuge photos
    Spectroscopic findings
    Electrophoretic patterns
    Electromicrographs
    Radiation and radioisotope studies
    Other clinical pathological laboratory tests
  (b) Computer analysis of the above studies
  (c) Total automation of clinicopathological laboratories
  (d) Population screening using above techniques

II. *Special Computer Oriented Diagnostic Testing*
  (a) Electrocardiograms
    Electroencephalograms
    Phonocardiography
    X-rays
    Radiological scanning
    Specific neurologic tests (eye movements, etc.)
    Graphic record analysis (for computer diagnosis)
    Pattern recognition for diagnosis
    Other computer-oriented diagnostic tests
  (b) Bioinstrumentation (related to the automation of diagnosis or therapy)
  (c) Mental health (psychological, psychophysiological, and psychiatric testing)
  (d) Simulation studies (for medical diagnosis)
  (e) Patient monitoring
  (f) Biotelemetry (as related to diagnosis)
  (g) Automated anesthesia
  (h) The development of automated equipment or computer hardware or software for medical diagnosis

III. *Machine Aided Clinical Diagnosis*
  General medical diagnosis
  Special areas—congenital heart disease, neurological diseases, respiratory diseases, blood diseases, . . .

IV. *Computer Storage of Health Records*
  Central repository for health records
  Hospital information systems
  Hospital records research

V. *Computer Studies of Medical Statistics*
  (a) Demographic studies
    Epidemiologic studies of a general or categorical nature
    Large population analysis of the effects of treatments
    Infectious disease analysis
    Psychological, nutritional studies
    Tumor registries
  (b) Computerized drug studies
  (c) The collection, storage, and retrieval of medical literature and information

VI. *Attempts at the Local or Regional Integration of the Above Areas (or others) into Central Health Computer Systems*

VII. *Training Related to Above Areas.*

APPENDIX II

Current State of the Art in Automation and the Health Sciences

An initial evaluation should be made of the technical state of the art in automation and the health sciences in the following five areas:

1. The automation of chemical laboratory procedures for information gathering; for example, use of laboratory apparatus which can produce standardized computer-readable outputs.
2. The use of computer systems in performing special diagnostic tests, such as the recognition and classification of ECG and EEG patterns and analyses of psychological tests.
3. The use of computers in systems or subsystems for machine-aided diagnosis. This comprises the processing of configurations of multiple data inputs to develop diagnostic hypotheses or conclusions, initially in such specialized areas as cardiovascular disease and eventually in general.
4. The gathering, storage, updating, and retrieval of those aspects of lifetime medical records for which centralized processing is relevant.
5. The collection and evaluation of significant medical statistics relating to diagnosis and treatment of large populations, and to research studies of these topics.

The initial evaluation should also encompass the current state of technical feasibility as regards the integration of the above components into regional health computer systems.

In each of the five areas listed determinations should be made relative to:

1. What is being done now on a routine basis and in pilot studies that will shortly become routine. This should provide a picture of what is possible now and should indicate the techniques, equipment, and manpower resources by which it can be accomplished.
2. What significant research work is being done that is likely to result in practical application in the next 5 years. This should identify the key research efforts that are the most likely to accelerate progress in these areas if adequately supported.
3. The most desirable parameters that might be measured. This should be considered with particular regard to research in instrumentation development that might be necessary.

Current and imminent technical capability in the five areas should be evaluated from the point of view of:

1. The reliability of the techniques and methods.
2. The limitations of what can likely be realized in the near future.
3. The costs involved in implementing a practical application of these techniques on a substantial scale.
4. The benefits possible to individual patients and to the progress of health research.

Particular attention should be given to:

1. How the best balance of human versus mechanized information-gathering can be achieved. That is, which tests and diagnostic procedures lend themselves best to automation and analytic computation methods. This should indicate developmental areas which might purposefully be supported.
2. The identification of promising developments in certain specific methodologic areas of pattern recognition and classification theory. This would not be concerned at this time, however, with highly abstract developments that are not likely to result in useful procedures in the next 5 to 7 years.

An evaluation of the various possibilities for integrating these five areas into regional health computer systems would be an important aspect of the study. It should be noted for clarity that, operationally, developments in the areas of (a) automated micromanipulative clinical laboratories; and (b) computer-based hospital information systems would serve as inputs to regional health computer centers. The automated clinical pathological laboratories being developed by Dr. George Z. Williams at the NIH, and the study now being conducted by Bolt, Beranek, and Newman in collaboration with the Massachusetts General Hospital are such examples.

As regards the extensive implementation of regional health computer systems:

1. The questions of technology, potential utilization, and cost should be investigated.
2. The existing personnel resources required for staffing a number of centers should be identified.
3. The features of training programs that would be supportive to additional centers should be characterized.

SURVEY OF THE STATE OF THE ART: SOCIAL, POLITICAL, AND ECONOMIC MODELS AND SIMULATIONS

Prepared for the Commission
by
ABT Associates Inc.
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ABSTRACT

This report presents the results of a 2-month survey of the state of the art of social, political, and economic models and simulations recently completed or well in progress in the United States as of December 1965. Seven social scientists and systems analysts of Abt Associates, Inc., conducted the survey during October and November 1965. This report includes a statement of survey objectives, scope, and content; descriptive typologies of over 50 representative current social, political, and economic models, computer simulations, and human player games; staffing, time, and money requirements of these model projects; an assessment of the strengths and weaknesses of the current art and its applicability to public policy planning; and recommendations for government policy regarding the new intellectual technology of modeling.

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CONTENTS

Survey of the State of the Art: Social, Political, and Economic Models and Simulations

1. Introduction

Logical thinkers, whatever their particular fields of interest, have always sought improved analytical frameworks for their ideas. Our understanding of complicated and changing factors and how they interact with each other is limited by our ability to devise conceptual schemes in which they can be accommodated. Any conceptual scheme presupposes simplification and selection from the original process under analysis. In general it is true that the greater the degree of simplification, the easier it is to manipulate the system—to try out the effects of various changes in its components. The usefulness of a system depends crucially on the ability to manipulate it. On the other hand, the more refined and abstracted is the conceptual scheme from the process it is designed to analyze, the fewer are the real factors it can take into account. If an analytical system is to be useful, it must be capable of including a large number of the factors which are salient in the real process.

The balance which is drawn between simplicity and complexity in the analytical scheme employed will depend on the nature of the process being examined and on the reasons for the inquiry. It will also depend, and often critically, on the prior availability of an appropriate scheme or framework within which to organize the analysis. If a process is to be analyzed by means of traditional "literary" exposition, there is immediately a severe limitation on the number and complexity of the variable factors which can be taken into account, a limitation stemming from the individual's inability to comprehend simultaneously all the interrelationships of a complex system.

The last 20 years have seen remarkable advances in the design of analytical systems susceptible to extensive manipulation and capable of handling highly complex interrelationships. The methodological approaches which best exemplify these advances are modeling and simulation. *A model is a representation of a process;* since constructing a model requires more time and energy than simply "thinking about the problem" the process represented is normally a complex one which cannot be understood through introspection alone. Simulation is used in a strict sense to mean the operation or exercise of the model, and implies that the variable factors are all given specific (though not necessarily known) values for the purpose. On the basis of this definition, a model can be designed without provision for simulation; but a simulation necessarily implies the existence of a model. Simulation may be accomplished either by human player games, by computer simulation, or by a combination of the two.

The means by which a model represents a process can vary. The whole process can be physically reproduced in a scaled down version. Or certain properties of the model can be taken to represent quite different properties of the process being analyzed—for example, flows of water through tubes can for certain purposes simulate income flows in the economy. Finally, the model may use logical or mathematical symbols to designate the factors represented and the relationships between them. It is this last type of model which offers the most flexible and manipulable tool to the analyst and the decisionmaker, and it is the one most commonly referred to when social science modeling or simulation is discussed.

The effective use of symbolic models relies on the operator's ability to manipulate the logical and mathematical relationships which make up the model. The development of high-speed electronic computers has both stimulated and been stimulated by advances in model building. The computer cannot, of course, perform more than a very small number of the operations performed by the human brain. Its enormous advantages are its ability to perform those limited functions at extremely high speed, and the ability to store large quantities of data and interim results for insertion into the computation process at predetermined periods.

A quite different, though ultimately related, development has come in the use of game techniques for simulation purposes. Game-type simulations can be structured so as to permit multiple simultaneous interactions among competing and cooperating players. As in the case of a computer, the system can be manipulated and the effects analyzed by an observer. The computer has at once the advantage and the disadvantage of being much simpler and more predictable than the human player.

New research efforts, advances in the methodology of model building, and improvements in the design of computing equipment and gaming techniques are continually expanding the areas of research where modeling and simulation can be applied. This is especially true for the social sciences, where the theoretician's task is to abstract general relationships from large masses of information, and where he is not often in a position to conduct controlled experiments on the process he is examining. By building a model which represents the real process, and by simulating the operation of the model in time using a computer or game, he overcomes at least some of these problems and gains a clearer understanding of the process.

The field of social science which has used models longest and has developed them furthest is economics. Recently, however, numerous attempts have been made to use the same approach in analyzing political, sociological, and psychological processes, and efforts in this direction will undoubtedly increase in the future.

By far the larger part of model building is carried on in universities and research organizations across the country, and descriptions of projects undertaken and results achieved all too often receive only limited circulation among Government planners and decisionmakers.

Because the substance of politics is also the object of the social scientist's inquiries, there is an inevitable interest by social scientists in what policymakers are doing and vice versa. The construction of models and simulations of social phenomena in the widest sense has not been well documented outside the professional literature—with the exception, perhaps, of certain large econometric models. And even within the learned journals, modeling activities tend to be reported with reference to the substantive content of the process being modeled, rather than with reference to the general applicability of the modeling technique to governmental planning and decisionmaking.

It was in response to this situation that the following report was commissioned. Our task has been to survey the state of the art of economic, political and social models, and simulations in the United States. The survey was conducted very rapidly, entirely within 6 weeks during October and November of 1965. It could not, therefore, be an exhaustive review of all social science models currently in operation or under development. We selected for examination those models which seemed to involve the most significant advances in the state of the art. We defined advances in terms of methodology rather than substance—that is to say, we were more concerned with a new technique for estimating consumer expenditures, say, than with the new insights into consumer behavior that might emerge from using the technique. At the same time, we did not ignore substantive matters, and we have tried to point out where old techniques might usefully be applied to new subject areas.

The survey was conducted by means of interviews, literature search, and correspondence. Obviously we owe a large debt to all of those who were willing to respond to our requests for information. We were invariably accorded a most generous reception in arranging personal interviews.

Clark C. Abt, John Blaxall, Morton Gorden, James C. Hodder, John J. McDonnell, Martha O. Rosen, and Marvin Zonis, staff members of Abt Associates, Inc., are primarily responsible for the contents of this report. The errors of oversight and judgment that occur are ours, not those of any respondents.

2. The Survey

Procedure

We have tried to select those models, currently in operation or in course of development, which are most capable of simulation, and which represent significant advances in the methodology of modeling. We have not been primarily concerned to investigate how modeling and simulation have advanced the state of the art of economics, for example, but rather to examine the state of the art of modeling itself.

In the time at our disposal, we could not follow up every possible lead, and we may have omitted some significant new work in the field. We believe, however, that our coverage has been reasonably complete, and certainly it is broad enough to support the general conclusions which form section 10 of the report.

Our procedure relied heavily on interviews with those actively engaged in model development, and for this purpose a set of questions was drawn up around which the discussion could be structured. Since any examination of a model must be related in some degree to its subject matter, the specific questions asked about the economic models were slightly different from those used for political and social models. Normally interviews were conducted by two persons, at least one of whom was thoroughly acquainted with the model's subject matter, although for some areas of the country only one interviewer was able to visit the respondents. The set of questions was used more as a prompting device than as a list of questions to be posed in a predetermined order, so that not every question was asked and answered in every interview.

In addition to conducting personal interviews, we expanded our coverage by mailing requests for information to a number of people with whom we were unable for one reason or another to arrange personal interviews. Response to the mailed questions was not high (10 to 15 percent). It was in anticipation of this difficulty that we had decided to devote our major effort to personal interviews. The list of respondents, including both interview and mail respondents, appears in appendix 1.

Our third source of information was, of course, the available literature, and in particular documentation supplied or suggested by our respondents. Appendixes 2 and 3 contain selected bibliographies for the survey.

Content

As we examined each model, we focused attention on six general areas: Subject matter and scope; the data input required and the information output produced; internal structure and characteristics; performance and validation; current and potential applications; and cost, skills, and administration. Within this overall framework, we were particularly interested in two topics: New advances in the state of the art and the potential usefulness of the art as a whole to Government policy decisionmaking.

In framing our questions, and in interpreting the answers, we tried to be as objective as possible, but we were repeatedly faced by the problem of terminology. Because models and simulations are developed by economists, political scientists, social psychologists, and others in separate disciplines, certain words acquire special and precise meanings in particular contexts. Occasionally the special meaning is not only different from normal usage, but is even quite opposite to the meaning applied by other specialists. The words "exogenous" and "endogenous," for example, have precise meanings to economists which are unclear to some mathematical political scientists. By using interviewers and analysts who were themselves knowledgeable in the respondents' areas of specialty, we believe we have overcome this difficulty.

Our inquiries about subject matter and scope were intended to prompt a general discussion of the model's objectives and assumptions—what it was intended to do. The section on data input and information output was designed to illuminate what kinds of information are needed to operate each model, and the extent to which model building is limited by the availability of data. We were also interested in new methods of estimation, and statistical techniques for avoiding "contamination" of reliable data when used together with less reliable data.

To be able to generalize on how models work, we asked about the internal structure of each model—how large it was, how complicated the interactions, and what was unique or advanced about the simulation. We also sought information on how far the model's structure was designed as a reasonable representation of the real process—how far it was isomorphic with reality—as opposed to being a "black box" which produced realistic answers, though with no attempt to reproduce reality. As far as simulations were concerned, we wanted to know what kinds of computer or game facilities were necessary to operate the simulation and the extent to which their availability affected the model's usefulness.

The section on performance and validation is self-explanatory. It may be worthwhile to build a model and simulate it merely for the sake of the educational benefits of the exercise, but our concern with potential applications for Government made us especially interested in the extent to which validation had been attempted or was anticipated. At the same time, we asked specific questions about application of the models, to find out how far, for example, the intended or actual usage varied among designers of apparently similar models. We asked about potential applications as well as current or planned applications, and we posed specific questions about possible governmental employment of the models.

Finally we inquired about the staff skill, financial, and administrative requirements of the model design efforts. This kind of information was not always easy to obtain, since most model designers are also teachers or carry on other research at the same time, while costs in terms of computer time and facilities employed are often difficult to assess.

The responses to the survey are set out in sections 5, 6, 7, and 8 of this report. By way of introduction, section 3 discusses the limitations of our sample, and section 4 presents a summary typology of the models included in the survey.

3. The Limitations of the Selected Survey Content

Ideally, this survey would have constituted a sample of the entire population of political, social, and economic models and simulations. The constraints imposed by a 2-month time limit on the efforts of the seven analysts have necessarily limited the number of models considered and model designers interviewed. Although this sample then is not exhaustive, it is large enough for us to believe that most of the models on the "frontiers of the state of the art" are represented. Over 50 models and simulations were included in the survey. While we do not claim to be aware of all U.S. model simulations, it seems unlikely that there are more than 100 in all.

The initial sample was selected on the basis of a review of the current literature of economics, sociology, and political science. This was followed by further selections suggested by the experts interviewed in the initial sample. Most of the respondents were university professors, with the remainder approximately equally divided between nonprofit institutions and industry.

The seven analysts sought out the designers of models wherever they were: On the east and west coasts, in the Midwest and the South. The location of the surveyors (interviewers) in Cambridge, Mass., their connections with Harvard and MIT, and the short 6 weeks available for interviews may have resulted in a slight geographic bias favoring the Northeast despite an overall coverage of the other main geographic areas of the country.

The limitations of industrial secrecy, combined with the academic tradition of open disclosure, may also have resulted in an institutional bias which stressed university research. This operated not so much as a result of private corporations denying information to the surveyors (which was relatively rare), but rather as the result of private corporations in modeling having had much less mutual exchange of information than had university scholars in this type of activity. Thus, many professors were able to suggest other models and researchers, while fewer model designers in industry were able to do so. Also, the absolute number of university scholars surveyed being larger than the number of industry researchers resulted in the greater amplification of the former type of respondent which tended to bias the coverage further in the direction of universities.

The surveying staff consisted of two economists, two political scientists, a sociologist, and two computer systems engineers. All seven had experience in the design of social, political, and economic models and simulations. The multi- and interdisciplinary nature of the staff skills has, we believe, minimized any bias with regard to subject or academic discipline. However, it must be admitted that the survey staff began with, and retains, a methodological bias in favor of models, game simulations, and computer simulations for the research of complex interdisciplinary problems.

4. Typology of Models Surveyed

The 57 models considered in detail in this report are listed in tables 1 and 2. Table 1 gives an overview of the range of characteristics of the models surveyed. In table 2 the models appear in alphabetic order of the principal investigators' last names.

For each model, table 2 gives information on substantive scope (social, political, economic) and the major process simulated. The table indicates whether the simulation is carried out by means of a game (human players only), a computer (a computer program independent of human players), or both together (a man-machine game). The size of the modeling effort in each case is suggested by the project costs, which are divided into ranges of $1,000 to $10,000, $10,000 to $100,000, and more than $100,000. These cost figures are often crude approximations, and in a few cases are not given at all. Finally, a starting date and the status of completion are given where this information is known. It should be noted that "completeness" is a relative concept, and most models are revised and rebuilt continually for as long as the author's interest is maintained. For purposes of the table, "complete" should be taken to mean "in operation" rather than "perfected."

The models whose substantive scope is exclusively economic are considered in detail in section 5, and the social and political models are discussed in section 6.

TABLE 1. SPECTRUMS OF THE MODELS SURVEYED (AN OVERVIEW OF MODEL CHARACTERISTICS)

SUBJECTS	Qualitative ⟷ Qualitative+Quantitative ⟷ Quantitative
	Psychology Politics Sociology Economics Engineering
SCOPE	International—National—Regional—Urban—Small group firm—Individuals Industry
DETAIL	(Large-scale, aggregated) Macrovariables (GNP, unemployment rates, votes) … Microvariables (subjective decision criteria, perceptions)
OBJECTIVES	Education—Planning—Forecasting—Research—Analysis Training Evaluation Coordination
PROCESSING MODE	Human-player games … Man-machine simulation and games … Computer simulation
"TRANSPARENCY"	"Black box" (only inputs and outputs represent process) … "White box" (decision structure represented)
COSTS: Skills	Humanities … Social sciences … Physical and engineering sciences … History Sociology … Political science … Economics … Computer programing … Mathematics
COSTS: Time	10 years 50 man-years … 3 months 3 man-months
COSTS: Money	$2000 $2000/year … $2, 000, 000 $400,000/year

TABLE 2. TYPOLOGY OF MODELS SURVEYED

Principal investigator and institution	Model name or acronym	Social	Political	Economic	Major process simulated	Game	Computer	Project costs ($000) 1–10	10–100	100+	Project started	Status: In process	Complete
1. Prof. Robert Abelson Yale University	Individual Belief System IDEOM.	X	X	----	Changes in belief systems	----	X	----	----	X	1962	X	
2. Dr. Clark C. Abt Mr. Martin Gordon Abt Associates, Inc.	COIN Game	----	X	----	Insurgency and counter-insurgency.	X	----	----	X	----	1965	----	X
3. Dr. Clark C. Abt Dr. Morton Gorden Mr. James Hodder Raytheon Company	TEMPER	----	X	X	Strategic decisionmaking	----	X	----	----	X	1961	----	X
4. Prof. Hayward Alker Yale University	United Nations Model	----	X	----	International decisionmaking.	----	X	----	X	----	1965	X	
5. Prof. Clopper Almon Harvard U. E.R.P.	Inter-Industry Forecast to 1975.	----	----	X	U.S. economy	----	X	----	X	----	1961	----	X
6. Dr. Jack Alterman Bureau Labor Statistics	Inter-Agency Growth Mode.	----	----	X	U.S. economy	----	X	----	----	X	1962	X	
7. Mr. John Blaxall Mr. Martin Gordon Abt Associates, Inc.	MANCHESTER	----	----	X	Industrial revolution	X	----	X	----	----	1965	----	X
8. Prof. Lincoln Bloomfield M.I.T.	Political-Military Gaming Exercise.	----	X	----	Political decision policy planning.	X	----	----	----	----	1960	----	X
9. Dr. Robert Boguslaw Dr. Robert Davis Dr. E. B. Glick S.D.C. Falls Church	National Policy Formation	--	X	--	Conflict among pressure groups.	X	--	--	X	--	1964	--	X
10. Dr. Richard Bolt, Bolt, Beranek and Newman	Doctoral Feedback in Higher Education.		--	--	Flow of Ph. D.'s into education.	--	X	X	--	--	1961	--	X
11. Prof. Stanley Buchin Harvard Business School	HARBETS	--	--	X	Executive decisionmaking	X	X	--	X	--	1963	--	X
12. Prof. C. West Churchman U. of California	Technological Innovation	--	--		Technological innovation in the firm.	X	X	--	--	X	1962	X	
13. Dr. John Cogswell Dr. John Bratten S.D.C. Santa Monica	Simulation of School System.	X	--	--	Resources and activities in education system.	X	X	--	X	--	1962	X	
14. Prof. Bernard Cohen Stanford University	Conformity Status Characteristics.	X	--	--	Persuasion process in small groups.	--	X	--	X	--	1959	X	
15. Prof. Bernard Cohen Stanford University	Expectation of Competence	X	--	--	Development of belief system.	--	X	--	--	X	1962	X	
16. Dr. Kenneth Colby Stanford University	Internal Psychological Conflict	X	----	----	Mental processes	----	X	----	----	X	1962	X	
17. Prof. James S. Coleman Johns Hopkins U.	Career Game	X	----	----	Choice of career	X	----	----	X	----	1963	----	X
18. Prof. James S. Coleman Johns Hopkins U.	Legislature Game	--	X	--	Voting in a legislature	X	--	--	X	--	1963	--	X
19. Dr. Martin David Dr. Charles Holt U. of Wisconsin	Microanalytical Model of Household Sector.	--	--	X	Microanalysis of household sector and labor force.	--	X	--	--	--	1964	X	
20. Prof. James Duesenberry Harvard University Dr. Gary Fromm Brookings Institution Prof. Lawrence Klein U. of Pennsylvania Prof. Edwin Kuh M.I.T. (Brookings—S.S.R.C.)	Brookings—S.S.R.C. Model of U.S. Economy.	--	--	X	U.S. national economy	--	X	--	--	X	1961	X	
21. Prof. Phoebus Dhrymes U. of Pennsylvania	Model of Investment	--	--	X	Firm's investment and dividend behavior.	--	X	--	X	--	1964	--	X
22. Prof. Richard Eckaus M.I.T. Prof. S. Chakravarty Delhi University	Planning Models for Indian Development.	--	--	X	Indian economy and planning.	--	X	--	--	--	1962	--	X
23. Prof. James Friedman Yale University	Firm Behavior Patterns	--	--	X	Firm behavior in duopoly, oligopoly.	X	--	--	--	--	1961	X	
24. Prof. W. Gamson U. of Michigan	SIMSOC	X	X	--	Group formation for resource allocation.	X	--	X	--	--	1964	X	
25. Mr. Martin Gordon Mr. David Merrill Abt Associates Inc.	POLITICA	--	X	--	Prerevolutionary political conflict.	X		--	X	--	1965	X	
26. Prof. Harold Guetzkow Northwestern U.	Inter-Nation Simulation	--	X	--	International conflict and cooperation.	X	--	--	--	--		--	X
27. Dr. John T. Gullahorn Dr. Jeanne E. Gullahorn S.D.C., Santa Monica	HOMUNCULUS	X	--	--	Interpersonal relations	--	X	--	--	--	1962	X	
28. Dr. Cyril C. Herrman Dr. Ira M. Robinson A. D. Little Inc.	San Francisco Community Renewal Project Model.	--	--	X	Land use and development	--	X	--	--	X	1962	--	X
29. Dr. Edward Holland Simulmatics Corp.	Simulation of the Venezuelan Economy.	--	--	X	Venezuelan national economy.	--	X	--	--	X	1963	--	X
30. Prof. Hendrik Houthakker Harvard University	Projection of Consumer Demand.	--	--	X	Consumer demand in U.S. economy.	--	X	--	X	--	1961	--	X
31. Prof. Morton Kaplan U. of Chicago	Balance of Power Model	--	X	--	International balance of power.	--	X	--	X	--	1962	X	
32. Prof. Manfred Kochen U. of Michigan	Image Formation in Automata.	X	--	--	Information structuring	--	X	X	--	--	1965	X	
33. Prof. Gerald Kramer U. of Rochester	Precinct Level Campaign Model.	--	X	--	Canvassing strategy	--	X	X	--	--	1963	X	
34. Prof. Wassily Leontief Harvard U., E.R.P.	Multiregional Interindustry Model.	--	--	X	Interregional study of U.S. economy.	--	X	--	X	--	1962	--	X

TABLE 2. TYPOLOGY OF MODELS SURVEYED—Continued

Principal investigator and institution	Model name or acronym	Social	Political	Economic	Major process simulated	Game	Computer	Project costs ($000) 1-10	Project costs ($000) 10-100	Project costs ($000) 100+	Project started	Status: In process	Status: Complete
35. Prof. J. C. Loehlin, University of Texas	ALDOUS	X	--	--	Mental processes including emotion.	--	X	--	--	--	1962	X	
36. Prof. Richard Meier, University of Michigan; Prof. Richard Duke, Michigan State U.	METROPOLIS	X	X	--	Urban planning	X	--	--	X	--	1964	X	
37. Prof. John Meyer, Dr. David Kresge, Dr. B. V. Martin, Dr. Charles Warden, Harvard University	Mod[illegible] for [illegible] Transp[illegible] [illegible]s.	--	--	X	Transportation sector in national economy.	--	X	--	--	X	1962	X	
38. Prof. Robert North, Stanford University	General Inquirer International Conflict.	--	X	--	Content analysis of decision documents.	--	X	--	--	X	1958	X	
39. Prof. Guy Orcutt, U. of Wisconsin	Micro-Analytic Model of a Socio-Economic System.	X	--	X	Microanalysis of economy	--	X	--	X	--		--	X
40. Dr. Lewis Paradiso, Dr. M. Liebenberg, Dept. of Commerce	Econometric Model of U.S.	--	--	X	U.S. economy	--	X	--	--	--	1963	--	X
41. Prof. Ithiel Pool, M.I.T.	CRISISCOM	X	X	--	Salience and affect in decision maker's perception.	X	X	--	X	--	1964	X	
42. Prof. Ithiel Pool, M.I.T.	COMCOM	--	X	--	Communication structure of Communist nations.	--	X	--	--	X	1962	X	
43. Mr. R[illegible]rt Rea, Mr. Thomas Synott, Mr. Ambrose Nutt, U.S. Air Force	Research and Development Effectiveness.	--	--	X	Laboratory resource allocation.	--	X	--	X	--	1962	--	X
44. Mr. Robert Rea, Abt Associates Inc.	Systems Development Planning Structure.	--	--	X	Weapons system development for U.S. Air Force.	X	X	--	X	--	1965	X	
45. Prof. William Riker, U. of Rochester	Three-Person Coalition Game.	X	--	--	Bargaining and coalition formation.	X	--	--	X	--	1964	X	
46. Dr. Sidney Rome, Dr. Beatrice Rome, S.D.C., Santa Monica	LEVIATHAN	X	--	--	Decision making in an organization.	X	X	--	--	--	1960	X	
47. Prof. Thomas Schelling, Harvard University	Two-Person Nonverbal Bargaining.	--	X	--	Bargaining with communication blocks.	X	--	--	--	--			X
48. Dr. David Seidman, Delaware Valley R.P.C.	Activities Allocation Model	--	--	X	Regional distribution of activities.	--	X	--	--	--		X	
49. Dr. Gerald Shure, S.D.C., Santa Monica	Territories Game	--	X	--	Bargaining tactics and communication.	X	X	--	--	X	1962	X	
50. Prof. Robert Solow, M.I.T.; Prof. James Tobin, Yale University	FUSEG	--	--	X	U.S. economy (full employment).	--	X	--	--	X	1963	X	
51. Dr. Wilbur Steger, CONSAD	Pittsburgh Urban Renewal Model.	X	--	X	Urban development	--	X	--	--	--	1964	--	X
52. Mr. Peter Stern, A. D. Little Inc.	Ohio River Basin model	--	--	X	Regional development	--	X	--	--	X	1962	--	X
53. Prof. Daniel Suits, University of Michigan	Econometric Model of U.S. Economy.	--	--	X	U.S. economy	--	X	--	--	--	1953	--	X
54. Prof. Robert Summers, U. of Pennsylvania	Lifetime Income Distribution Model.	--	--	X	Distribution of income over life.	--	--	--	--	--		X	
55. Mr. Marshall Wood, National Planning Association	PARM	--	--	X	U.S. [illegible]nomy after nuclear excha[illegible]e.	--	X	--	--	X	1959	--	X
56. Mr. Marshall Wood, National Planning Association	DEEP	--	--	X	U.S. regional economy after nuclear exchange.	--	X	--	--	X	1964	X	
57. Prof. Arnold Zellner, U. of Wisconsin	Microanalytical Model of Household Sector.	--	--	X	Microanalysis of household sector.	--	X	--	X	--	1962	X	

5. Economic and Managerial Models

Empirical research in economics has advanced at a rapid rate during the last few years. There are a number of significant advances in economic modeling, for example, which have widened the scope of analysis for economic forecasting and for scholarly research into the structural relationships of our economic system. We are explicitly concerned, in this report, with some of the more recent contributions to economic modeling, and, in particular, with the potential applicability of modeling techniques for Government policy-planning purposes. Included here will be a description of the substantive content of the several economic models included in our survey, a summary of the scope and research design set forth by the modelers, and an evaluation of the actual and potential applications of the various models. The report will focus on the outstanding features evolving from the survey as a whole, and especially on the problem-oriented character of some of the more recent models. Our conclusions will indicate, to a limited extent, where breakthroughs are or can be expected to appear in the near future which can significantly improve the quality and direction of Government planning efforts.

A number of the models and simulations examined for this survey are discussed in considerable detail. For others, some of which do contain advances in economic and statistical decision theory, we did not have sufficient information for lengthy description, and these will be mentioned only in passing. The principal economic models which have been examined are:

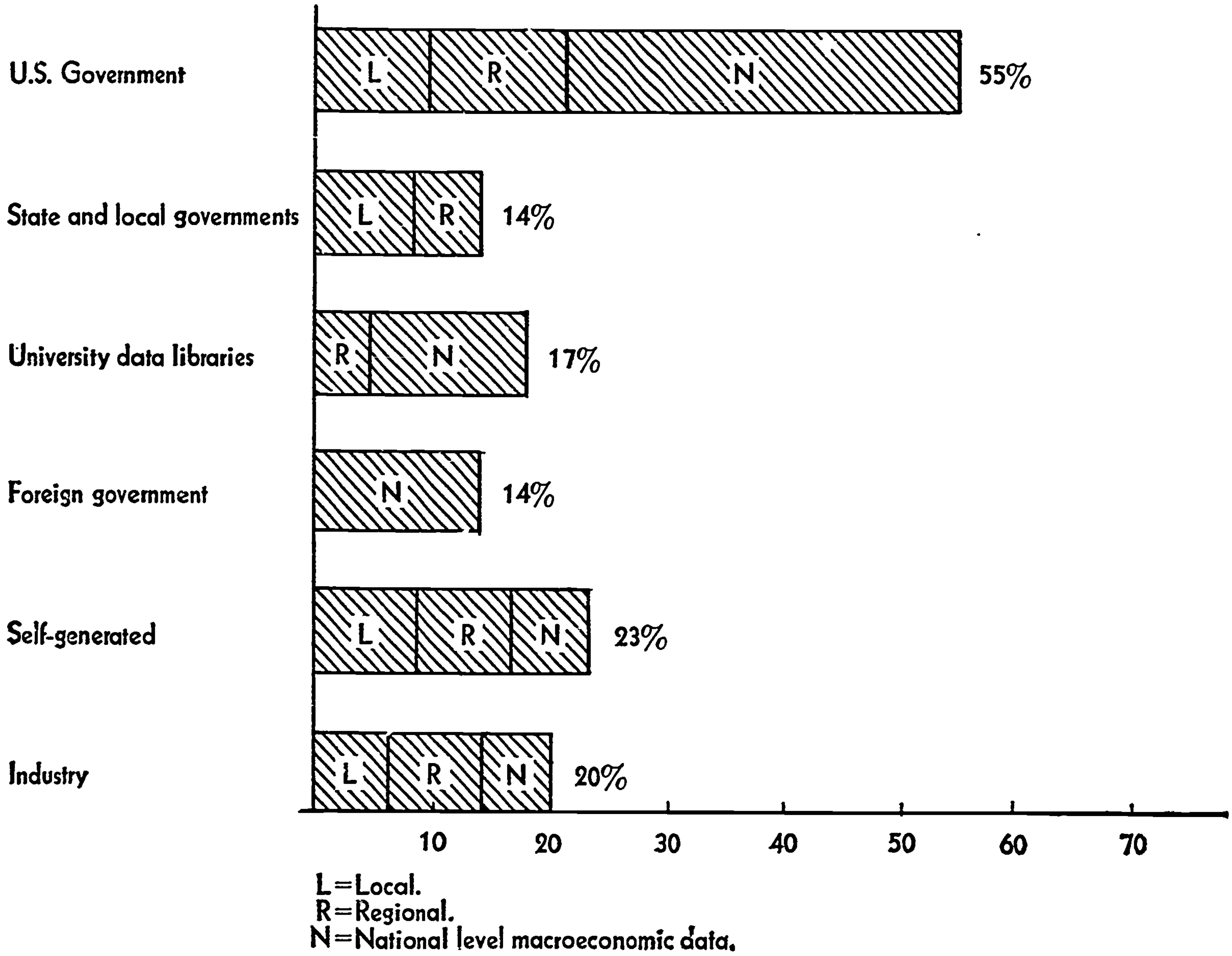
Name	*Principal investigators*	*Institution*
1. Brookings-SSRC Model	Prof. James Duesenberry Dr. Gary Fromm Prof. Lawrence Klein Prof. Edwin Kuh	Harvard. Brookings. University of Pennsylvania. M.I.T.
2. Future U.S. Economic Growth (FUSEG)	Prof. Robert Solow Prof. James Tobin	M.I.T. Yale.
3. Econometric Model of the U.S	Dr. Lewis Paradiso Dr. Maurice Liebenberg	Office of Business Economics, Department of Commerce.
4. Program Analysis for Resource Management (PARM).	Mr. Marshall K. Wood	National Planning Association.
5. Dynamic Economic Evaluation of Programs (DEEP).	Mr. Marshall K. Wood	National Planning Association.
6. Multi Regional Interindustry Model	Prof. Wassily Leontief	Harvard Economic Research Project.
7. An Interindustry Forecast of the American Economy to 1975.	Prof. Clopper Almon	Harvard Economic Research Project.
8. Interindustry Employment Table (Interagency Growth Study).	Dr. Jack Alterman	Bureau of Labor Statistics.
9. Projection of Consumer Demand	Prof. Hendrik Houthakker	Harvard University.
10. Planning Models for Indian Economic Development.	Prof. Richard Eckaus Prof. S. Chakravarty	M.I.T. Delhi University.
11. Econometric Model for Evaluating Transportation Systems.	Prof. John Meyer Dr. David Kresge Dr. Charles Warden Dr. B. V. Martin	Harvard Transport Technology Department.

Name	Principal investigators	Institution
12. Econometric Model of the U.S. Economy	Prof. Daniel Suits	University of Michigan.
13. A Model of Lifetime Income Distribution	Prof. Robert Summers	University of Pennyslvania.
14. A Model of Investment Dividend and External Finance Aspects of Firm Behavior.	Prof. Phoebus J. Dhrymes	University of Pennsylvania.
15. A Microanalytical Model of the Household Sector and a Simulation of Labor Force Participation Decisions.	Dr. Martin David Dr. Charles Holt	Social Science Research Institute, University of Wisconsin.
16. A Microanalytical Model of Household Economic Activity.	Prof. Arnold Zellner	Social Science Research Institute, University of Wisconsin.
17. A Microanalytical Model of a Socioeconomic System.	Prof. Guy Orcutt	Social Science Research Institute, University of Wisconsin.
18. San Francisco Community Renewal Project Model.	Dr. Cyril C. Herrman Dr. Ira M. Robinson	Arthur D. Little Inc.
19. Ohio River Basin Model	Mr. Peter Stern	Arthur D. Little Inc.
20. Model of Technological Innovation in the Firm	Prof. C. West Churchman	University of California.
21. Harbets Simulation Exercise in Management Control.	Prof. Stanley I. Buchin	Harvard Business School.
22. The Pittsburgh Urban Renewal Simulation Model.	Dr. Wilbur A. Steger	CONSAD Research Corp.
23. Model of Behavioral Patterns of Firms in Duopolistic and Oligopolistic Markets.	Prof. James Friedman	Yale University.
24. MANCHESTER (a Game of the Industrial Revolution).	Mr. John Blaxall	Abt Associates Inc.
25. Research and Development Effectiveness Model.	Mr. Robert H. Rea Mr. Thomas W. Synnott Mr. Ambrose B. Nutt	U.S. Air Force.
26. Systems Development Planning Structure (for Air Force Systems Command).	Mr. Robert H. Rea	Abt Associates Inc.
27. Activities Allocation Model (Penn Jersey Transportation Study).	Dr. David R. Seidman	Delaware Valley Regional Planning Commission.
28. Simulation of the Venezuelan Economy	Dr. Edward P. Holland	Simulmatics Corporation.

The major portion of quantitative economic research in the United States has been done on the national, macroeconomic level. This is primarily a result of data availability and the preferences of most economists for work on the national aggregate level. Until recently most U.S. Government data, the major source for national economic research, has not been disaggregated below the national accounts level. Those data which are collected on a microunit level, particularly with regard to the firm, are not easily available for research purposes, due in part to the privacy and political constraints to which the Government must adhere, and in part to the lack of local and regional administration set up for data collection. Furthermore, questions of national policy, such as unemployment, inflation, and economic stability, are dealt with on a macroeconomic scale, and Government policymakers are accustomed to forecasting policy impact on the basis of these national account magnitudes. Data are now available for quarterly econometric models, whereas in the past only annual data could be used. This permits significant advances in the state of the art of modeling. Table 3 indicates the preponderance of the U.S. Government as a data source, and the preponderance of national level macroeconomic data.

Table 4 indicates the scope and major objectives of the models surveyed. The majority dealt with the U.S. economy for policy planning or forecasting purposes. A smaller number deal with a particular economic sector, such as Professors David and Holt's investigation of labor force participation decisions in the unemployment market, and Professor Houthakker's projection of consumer demand for 84 categories of consumer goods and

TABLE 3. SOURCES OF DATA FOR ECONOMIC MODELS IN PERCENT OF MODELS SURVEYED

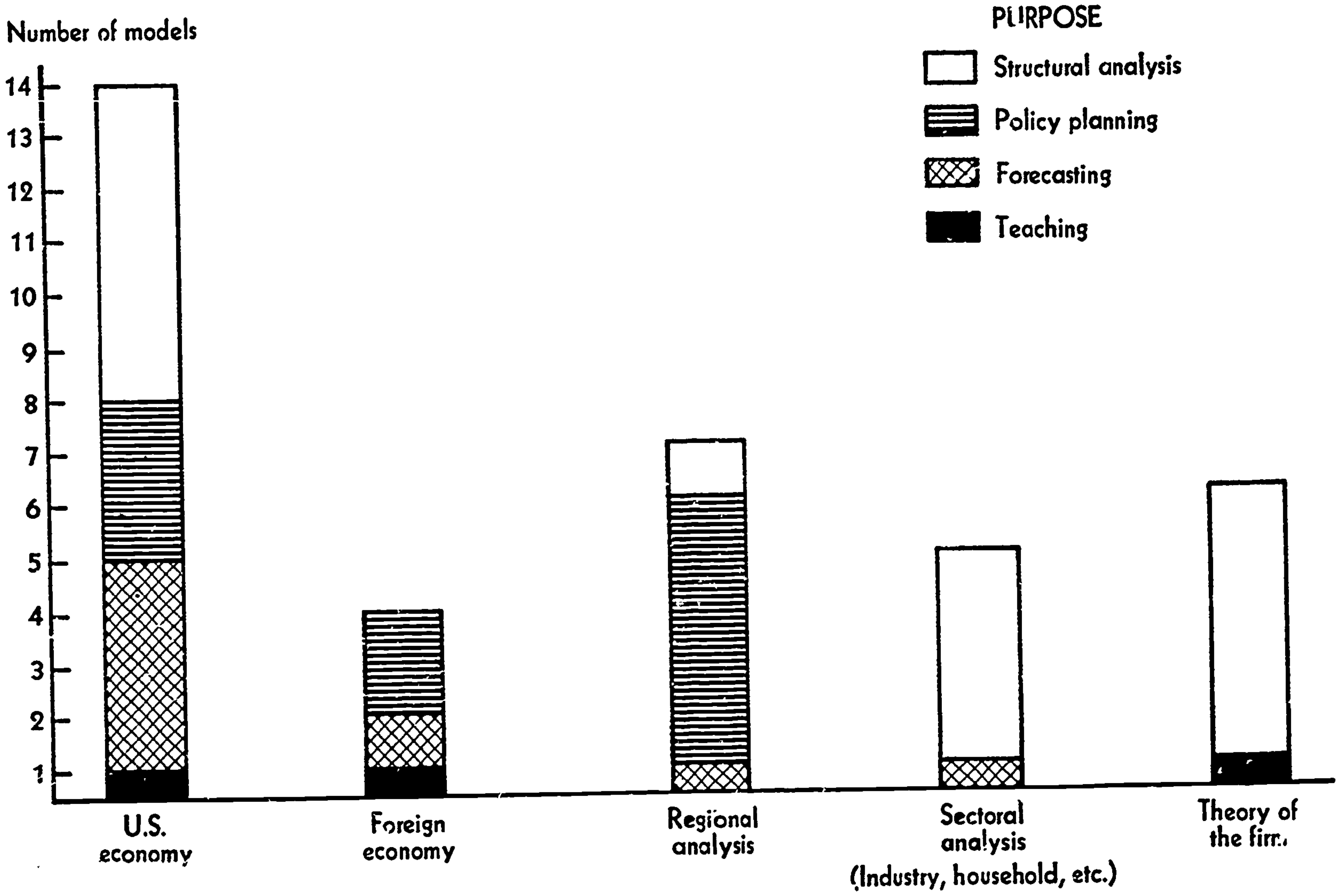


services. Several (CONSAD Corp., A. D. Little Inc.) were developed to cope with regional and urban planning problems of both a forecasting and resource allocation nature, and some of the national models were constructed in such a way as to deal with the entire economy on an interregional framework. Leontief's model evaluates the impact of an arms cut on the industrial composition and regional distribution of employment in the continental United States. The Harvard Transport Center's model, though national in scope, was constructed to evaluate alternative transportation investments in an underdeveloped country, taking into account interregional development problems and programs.

At least four of the models dealt explicitly with the behavior of the firm: Professor Friedman's game about decisionmaking patterns of duopolies and oligopolies; Professor Buchin's HARBETS Model at the Harvard Business School; Professor Churchman's innovation reception game; and Professor Dhrymes' model of the interaction between dividends, internal financing, and investment decisions in a firm. All of these models try to analyze the behavioral pattern of decisionmakers under certain specified conditions, and three of them were developed as games; that is, they require role-playing by actors who represent businessmen in real or simulated business conditions. In the Harvard Business School's HARBETS simulation, for example, each team requires four players for a 2-week period, during which time each player assumes the role of either marketing vice president, manufacturing vice president, director of research and engineering, or comptroller.

During this 2-week simulation exercise, in which every day equals a 3-month operating period, each officer controls his area of the business on a profit-maximizing basis. Each executive decision is programed into a computer which determines the effects of the decision on company welfare, and feeds the information back to the management team. Factors considered include capital markets, competition, worker productivity, product quality, and many others. At the conclusion of the exercise, the participants compare the results of their decisions with the potential out-

TABLE 4. SCOPE AND PURPOSE OF ECONOMIC MODELS SURVEYED



come for the firm, had no policy changes been made from those recommended to them by the umpires.

The purpose of this simulation is twofold. First of all, valuable information is obtained about the process of decisionmaking and responsibility in a medium-size firm. Executive behavior patterns can be analyzed as a means of gaining an insight into the behavior patterns of executives performing in real business situations in the outside world. Also, one can observe in which areas and techniques of management control executives are least qualified for effective decisionmaking purposes. The type of question to be asked, for example, is: Could Mr. A have made a more profitable choice of alternatives in the second quarter if he had had adequate training in statistical decision theory?

Secondly, simulation methods provide an excellent teaching-training device for businessmen in decisionmaking positions. Where else can they have the experience of operating in an actual business situation, see the end results of their choice of decisions, and compare this set of alternatives with other possibilities put forth by the computer? The techniques of man-machine games for business and government training purposes is promising in its applications and should be pursued with much greater effort as a valuable educational tool.

Educational games for learning purposes have been applied in primary and secondary schools with some success. In a game called MANCHESTER, developed for the senior high level by John Blaxall of Abt Associates, students divide into teams representing farmers, laborers, and millowners in England during the industrial revolution. By evaluating the opportunity cost of of remaining in the countryside after enclosure instead of moving to the city to become a factory worker, the students become aware, at least implicitly, of the theory of supply and demand. They find that as more people migrate into the cities and towns, the wage rate there becomes lower. They also find that there are advantages to be gained from using large-scale machinery rather than small, as well as the costs associated with overcapitalization.

All of the gaming simulations are submodels of certain salient processes from larger scale economic phenomena. MANCHESTER represents only a microsection of economic life in England during the 18th century, yet it effectively portrays the essence of socioeconomic problems of the yeoman-turned-laborer at the time of the industrial revolution. The several games dealing with behavior of the firm pick out selected behavioral interactions which they wish to explore, and they do not attempt to evaluate all the other elements involved. Only the larger models have adopted the general equilibrium approach of dealing with all the interactions in the economic system being defined. Most of these are the large national models, although there are three regional and one urban simulation included. The San Francisco Community Renewal Project model is concerned only with the forecasted housing requirements and construction for San Francisco and is therefore classified as a partial equilibrium in this study. Table 5 presents an arbitrary classification of the major models into a comprehensive/specific/behavioral matrix by type of model.

Table 6 indicates the distribution of models by type of design. Human gaming and microanalysis techniques are relatively uncommon methodologies for economic analysis, compared to econometric regression models and interindustry flow tables. The latter were first developed in the 1930's and 1940's in response to national level problems concerning employment, income, investment, etc., and except for several specific elements to be discussed below, the advances in these modeling techniques are more quantitatively than qualitatively oriented. Large scale computers have allowed the expansion of these models to hundreds of equations, although methods of data collection and statistical inference techniques have improved at a less spectacular rate. The Brookings-SSRC model, for example, with over 400 original equations, is more than five times as large as any currently existing econometric model. And the FUSEG model, which is still being developed in the universities, will involve about 300 equations. Such levels of disaggregation allow much more satisfactory and detailed research into the structure of the economy than was previously possible, but whether their forecasting capabilities, for Government aggregate purposes, have greater

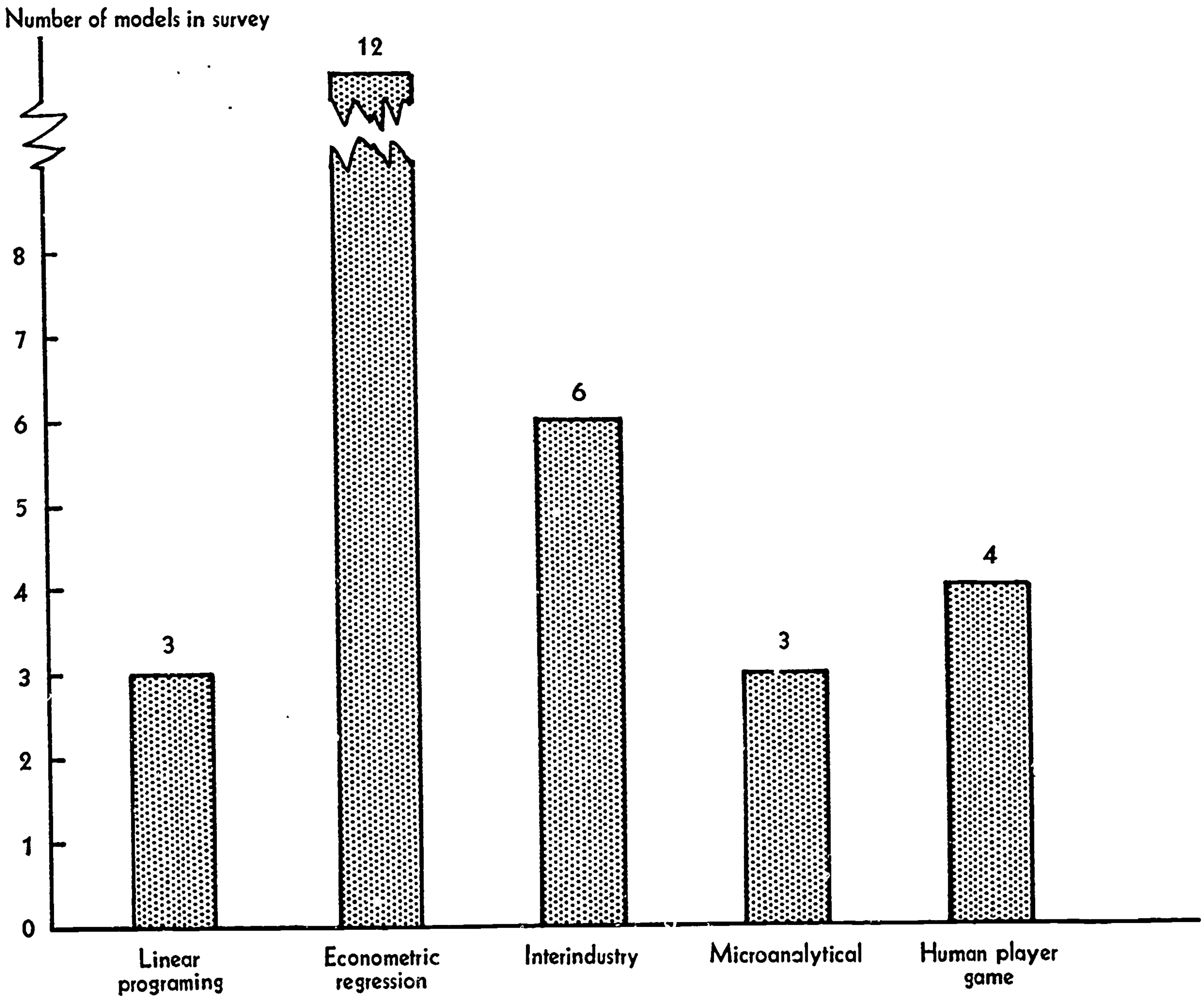
TABLE 5. DIFFERENT TYPES OF ECONOMIC MODELS

Economic models	Comprehensive models	Models dealing with specific processes	Behavioral models
NATIONAL MODELS	Brookings—SSRC (Fromm, Duesenberry, Klein and Kuh) FUSEG (Tobin, Solow) Department of Commerce (Liebenberg, Paradiso) PARM (Wood, NPA) Inter-Industry Forecast (Almon) Bureau of Labor Statistics (Alterman) Indian Planning Models (Eckaus) Harvard Transport Model (Meyer, Kresge, Martin, Warden) U.S. Econometric Model (Suits) Microanalytic Model (Orcutt)	Consumer Demand Projection (Houthakker)	
REGIONAL MODELS	DEEP (Wood, NPA) Multi-Regional Model (Leontief) Ohio River Basin Model (Stern, A. D. Little)	Activities Allocation Model (Seidman, Delaware Valley Regional Planning Commission) Penn Central Merger Simulation (Steger, Graves, CONSAD)	
URBAN MODELS	Pittsburgh Urban Renewal Simulation Model (Steger, CONSAD)	San Francisco Community Renewal Project (Herman, Robinson, A. D. Little)	
DECISION ALLOCATION MODELS	Systems Development Planning Structure (USAF)	Research and Development Effectiveness Model (Rea, Abt Associates Inc.)	
INDUSTRY		MANCHESTER (Blaxall, Abt Associates Inc.)	
FIRM		Investment Behavior of Firm (Dhrymes)	Innovation Simulation (Churchman) Harbets Simulation (Buchin) Duopoly and Oligopoly (Friedman)
HOUSEHOLD		Lifetime Income (Summers)	Household Sector (Zellner) Household Sector (David and Holt)

utility than that of the Department of Commerce model with only 50 equations, is not a priori clear. The size of a model is a significant advantage only in terms of the purpose for which it was constructed. To disaggregate beyond a given level may involve unnecessary effort which might be better utilized in improving the qualitative aspects of the model.

There is a certain amount of discussion about the utility of linear or nonlinear functions in economic models. There are two arguments with respect to this position: The first supports the contention that in the real world relationships between variables, such as investment in plant and equipment and total output, are not linear. There are certain points along a production function curve where capital investment is required for capacity utilization purposes, but where such investments are not necessarily undertaken. Numerous factors may intervene. If decisionmakers' expectations in the next period are pessimistic, they may feel it worthwhile to take a short-run loss on unfulfilled demand rather than make a large long-term investment which they see no opportunity of recovering. On the other hand, if expectations are favorable, capital investment may take the form of plant and equipment in a large scale expansion drive. It is difficult to predict these discontinuities (though Professor Eisner at Northwestern has done superior work on investment realization equations), and therefore, some economists claim linear relationships are as good an approximation to reality as complex discontinuous functions. However, there are certain threshold techniques which may be used with linear functions to introduce discontinuity and asymmetry. Such techniques have been included in the price formulation equations of the Brookings model to account for the discrepancy in response of certain variables to price and expecta-

TABLE 6. TYPES OF ECONOMIC SIMULATION



tions' changes, and in the Department of Commerce model to explain the nonlinear relationship between production capacity and output.

If great care is taken in construction of a model to insure replication of real world processes in the decision logic of the model, and revision of coefficients and parameters takes place on at least an annual basis, as with Professor Suits' econometric model of the United States, then linear functions can be included with less probability of forecasting error. The costs and benefits of various model designs must be considered, as well as the projected purpose which the model is expected to fulfill. For a short term forecasting model, constant returns to scale without capital investment is a reasonable structural assumption; with intermediate and long-range models, nonlinearities and discontinuous mathematical relations must be introduced to avoid serious errors in policy decisionmaking.

The large scale effort required to supply data requirements, develop statistical estimation techniques, and construct models has generated a new element in model building, namely, "modeling by committee." Over half of the economists interviewed in this survey were connected in some way or another with a group of research economists, all contributing their expertise to the final product. In one sense, this reflects the large amount of time and money poured into such efforts as the Brookings, FUSEG, or Interagency Growth Study Models, but in another, it also indicates the degree to which specialization of labor has occurred in the model building field. Dr. Alterman has enlisted the services of several university professors for detailed research on the Interagency Growth Model, which itself is a joint effort between the Bureau of Labor Statistics, the Council of Economic Advisers, the Bureau of the Budget, and the Department of Commerce. This model is basically an input-output model based on the 1958 published version of the Department of Commerce's Input-Output Table. The Bureau of Labor Statistics has developed estimates of employment-output relationships on an industry basis, and has converted the interindustry output requirements per dollar of final demand into employment requirements. With both these estimates, and projected changes in productivity and total output, the Bureau can undertake planning efforts to meet manpower requirements expected in the future. Professor Houthakker of Harvard has constructed a model, to be integrated into the Interindustry Growth Study, which forecasts consumer demand for 84 categories of goods and services. Other sections of the research have been subcontracted to the Bureau of Mines, the Harvard Economic Research Project, and the National Planning Association.

FUSEG is being developed at both MIT and Yale under Professors Solow and Tobin. A long-run econometric forecasting model, FUSEG will attempt to estimate the "principal global measures" of U.S. economic activity, giving particular emphasis to expected cyclical developments in capital investment and employment. Though not as large a model as the Brookings effort, FUSEG is expected to have over 300 equations.

The Social Science Research Institute at the University of Wisconsin sponsors a number of research projects using micromodels of the decision-making units in the economy (households, firms, markets) to try and understand the functioning of the national economy. The Institute is developing a set of data file programs to aid in the estimation of micromodels and is in the process of building a library of research data. It is engaged in compiling ambitious computer programs for simulation studies of microanalytic models, and under Professor Orcutt's direction serves as a clearinghouse for research on microanalytical techniques.

The Brookings-SSRC model, of course, is the prototype of collective model-building efforts. More than 20 experts on all parts of the economy have participated in its construction and solution. The project itself was jointly sponsored by the Social Science Research Council and the Brookings Institution, and its main direction came from four different institutions: James Duesenberry at Harvard, Gary Fromm at Brookings, Lawrence Klein at the University of Pennsylvania, and Edwin Kuh at MIT.

These committee undertakings indicate that vast knowledge and experience go into the development of a model designed to "explain the variations in GNP and its major components, as well as major price movements, employment, and wage rates."[1] The magnitude of the effort on this and other ambitious modeling projects cannot be supported, either intellectually or financially, by individual researchers working in isolated laboratories. The day of the "general practitioner" may be at an end, and so may be the day of all-purpose economic model builders. This is not to say that these economists are intellectually incapable of individual projects, or that single economists can no longer be expected to introduce revolutionary concepts and theories. Rather, given the computation capabilities and expense, the legwork of data collection and preparation, the delicateness of statistical estimation and model construction, and the race to finish a project before it is hopelessly obsolete, the task of economic model building for national planning, forecasting, or research purposes is beyond any single analyst's capacity.

One of the most significant observations in any study of economic models is the divergence between

[1] Duesenberry, James S. and Lawrence R. Klein, "Introduction: The Research Strategy and Its Application," *The Brookings-SSRC Quarterly Econometeric Model of the U.S. Economy*, Rand McNally & North-Holland, 1965, p. 3.

the two methodological techniques for simulating the national economic system: The macro approach of most large scale econometric and interindustry models and the microunit approach of the microanalytical school. As we have already pointed out, the U.S. Government, which supplies the bulk of the data for model building purposes, publishes it in national statistical accounts form—gross national product, total consumption, total investment, etc. Some census data are disaggregated, but they are more demographic in character than economic. In consequence, data availability has perpetuated macroeconomic model building and macroeconomic forecasting for policy-planning purposes. This is a useful methodology which should not be underestimated. However, it is important to have an equal understanding of the microanalytical technique, which, if data were available for the individual decision-making units of the economy, could become a valuable complement to macroeconomic forecasting and structural analysis.

The purpose of Professor Orcutt's microanalytical model is to apply the knowledge of institutions and decision units gleaned at the microlevel to predictions about national aggregates and their responses to Government policy measures. The basic hypothesis underlying Orcutt's theory is that "predictions about aggregates should be obtained by aggregating the behavior of elemental units rather than by attempting to aggregate behavioral relationships of these elemental units."[2] The question the policymakers want to answer is how the dependent variables in an economic system depend on policy elements. They cannot derive this information from macroanalysis with total accuracy since macroanalysis supplies only the mean behavioral pattern. With microanalytical techniques—examining behavior of households, individuals, and firms and the transactions among them—the policymaker is able to understand and forecast much better the range of possible behavioral patterns resulting from any given analytical framework. And since microanalytical models include a high number of observations for each parameter being tested, there is a high probability of obtaining a relatively unbiased distribution. Finally, by means of a computer simulation, the policymaker may obtain a fairly accurate prediction of how the actual economy will behave.

The major obstacle to microanalytical modeling is the unavailability of data in disaggregated form. The Consumers Surveys Series published by the University of Michigan each year is the major source of data at the present time, although there are some indications that the Federal Government may begin to make some of these data available on a micro basis for researchers in this area. Only when sufficient data are available can the real value of microanalytical techniques be determined.

The increasing need for disaggregated data for model construction must be linked with the need to build problem-oriented models—models that will serve as an insight into the processes of complex economic and behavioral interactions or models whose output will serve as guidelines for better forecasting and policy planning decisions. Table 7 indicates the current and potential applications of the models surveyed in our study. If one excludes the research category as primarily including those models still under construction, it can be seen that the potential uses of modeling techniques are almost as great as their current applications.

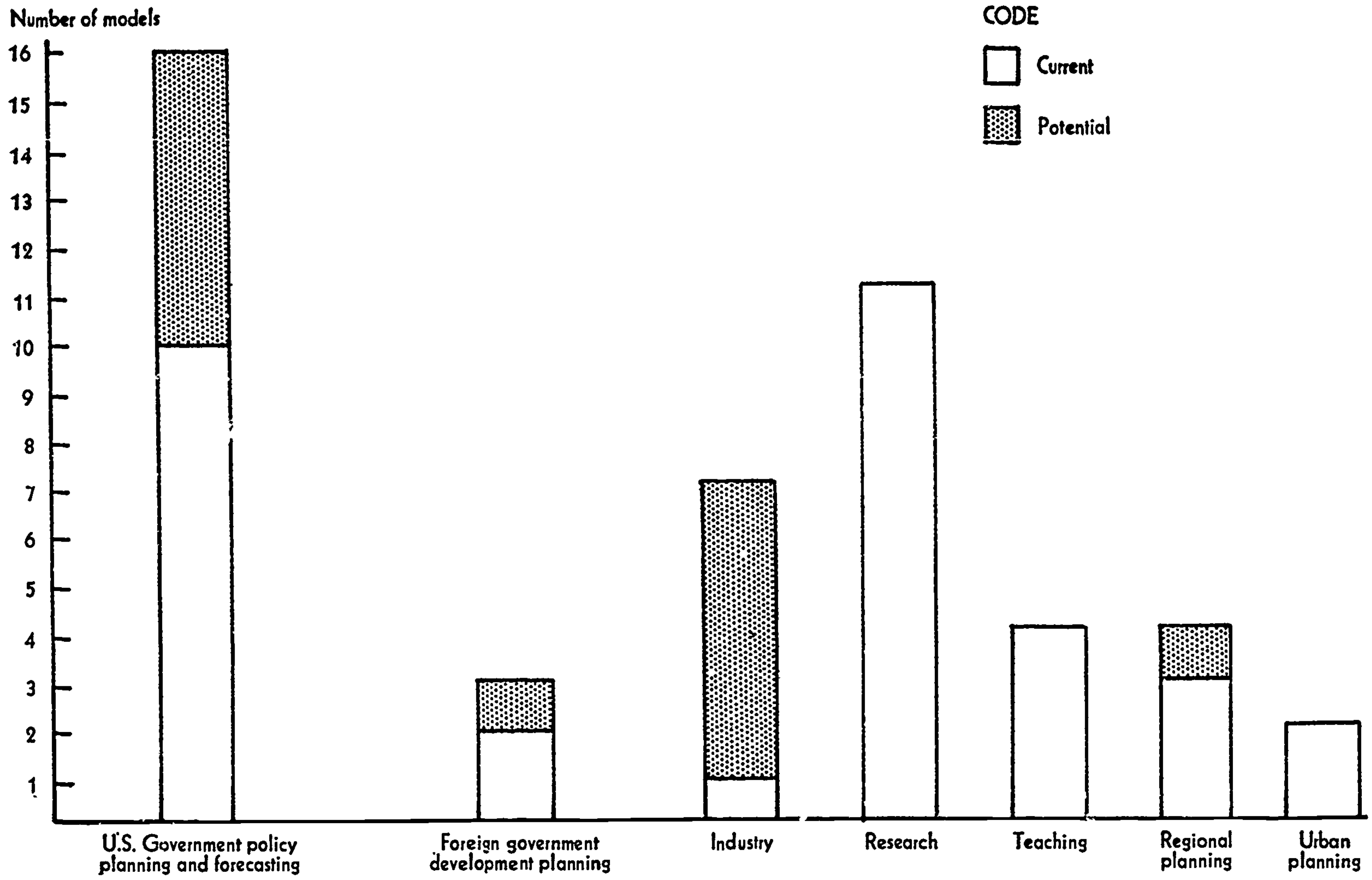
The pressures of overcrowded metropolises and the introduction of urban renewal schemes demand the development of new analytic tools for urban planners. Arthur D. Little, Inc., has developed a simulation model of the housing market as a means to predict and evaluate the composition, quantity, price, and demand for San Francisco's housing. The model will be used by San Francisco's officials and planners to improve their decisionmaking ability in selection of alternative public investments, using a computer simulation to trace the effects of any proposed policy action. It is intended that an understanding of the housing system will generate ideas for new programs not previously considered.

Dr. Wilbur Steger's simulation model of the Pittsburgh Urban Renewal project, while similar in intent, is much more ambitious in scope and objectives. This model attempts to simulate the entire metropolitan area, including land uses, employment flows, residential and commercial patterns of movement, and industrial growth and development. Though much too complicated to be summarized in a few sentences, the Pittsburgh model is representative of the new types of problem-oriented models being developed.

The regional planning models are also indicative of this trend. Those examined for this report have definite questions which they must answer. The DEEP (Dynamic Evaluation of Economic Programs) model of the National Planning Association attempts to evaluate the economic effects of different levels of war damage on the United States, on a regional basis. The Leontief model, as mentioned earlier, is an effort to evaluate the impact of an arms cut on the industrial composition and regional distribution of employment in the United States. And the Arthur D. Little model of the Ohio River Valley forecasts the level of industrial activity in the Ohio River Basin, in order to estimate total water resource requirements up to the year 2000.

[2] Orcutt, Guy H., Martin Greenberger, John Korbel, and Alice Rivlin, *Microanalysis of Socioeconomic Systems: A Simulation Study*, New York, Harper & Brothers, 1961.

TABLE 7. STATED CURRENT AND POTENTIAL APPLICATIONS OF ECONOMIC MODELS ACCORDING TO 27 RESPONDENTS[1]



Note: Magnitudes represent number of respondents indicating particular applications, not the number of current or potential applications.

[1] Total is more than 27, because some respondents remarked on several applications.

A novel application of simulation was used to evaluate the economic feasibility of the proposed merger between the Pennsylvania Railroad Co. and the New York Central Railroad Co.; a computer simulation of the freight flows in the New York and Pennsylvania regions covered by the two railroads was constructed to ascertain whether the economy of Pennsylvania would be adversely or favorably affected by such a merger. This undertaking represented a "pioneering effort to apply computer science and modern analytical techniques to the complex decisions of administrative law."[3]

Similarly, the Activities Allocation Model, begun as a *Penn Jersey Transportation Study* in 1964, contributes significantly to the technology of modeling. Essentially a transportation model, the Activities Allocation Model will be used for examining the circular relationship between the economic growth of certain regions and the availability of (new) transportation service. It will explain locational and land use behavior as a function of a number of economic and demographic variables in the region. The overall model consists of seven major submodels,[4] each of which determines either the location of a given type of activity or the amount of land that this activity uses. The model will be used to project regional growth and corresponding transportation needs up to 1985, using a series of recursive 5-year progressions.

Professor Almon has applied input-output techniques in a novel manner—as a long-range business forecasting tool for the firm. Almon believes that many fundamental business decisions require an integrated analytical approach—one which considers a variety of factors at the same time, such as expected growth in a *number* of industries or potential future supply of certain key input commodities, over a period of 5 or 10 years hence. Almon's interindustry matrix, disaggregated into 90 industries, provides a framework for evaluating a wide range of business decisions, such as capital investment decisions, product development decisions, diversification decisions, portfolio decisions, regional planning, and manpower development decisions. The value of Professor Almon's

[3] Steger, W. A., and F. M. Graves, *Digest of Statement Before the Interstate Commerce Commission*, Finance Docket No. 21989 (Intervention of Commonwealth of Pennsylvania in Joint Application for Merger of the Pennsylvania Railroad Co. and the New York Central Railroad Co.), p. 1.

[4] Residential location model, residential space consumption model, manufacturing location model, manufacturing space consumption model, nonmanufacturing location model, nonmanufacturing space consumption model, and street area model.

approach is its inclusion of the interconnectedness among different industries—a factor which takes account of both direct and indirect effects of multiplier/accelerator activity in the economy and therefore allows a general equilibrium analysis.

There is a critical need for resource allocation models which can evaluate the utility of alternative investment decisions, given certain constraints and objectives, and arrive at optimum allocation decisions. Several such models have in fact been developed, two of them in linear programing format by Robert H. Rea of Abt Associates. The first model, a Research and Development Effectiveness Model, was built in 1962 at the Air Force Flight Dynamics Laboratory, Wright-Patterson Air Force Base, Ohio, by Mr. Rea, Thomas W. Synnott III, and Ambrose B. Nutt. The model has been operated and used to assist with the allocation of resources to research and development projects for the last 3 years. The actual allocation optimization is achieved by the use of a modified linear program that is constrained to select only a single level of effort for the acceptable projects. Resource constraints and project costs are expressed in several different categories of both funds and manpower. Project value is measured in terms of expected rate of progress, the degree of contribution to objectives of the laboratory, the relative importance of these objectives, and the timeliness of the expected product of the project. Data and evaluations are supplied by all levels of laboratory management and by supporting organizations according to their respective responsibilities. Data are collected for a projected 10-year time period and form the basis for 5-year allocations recommended by the model. The model considers data for 5 levels of effort for over 200 research tasks and 5 resource types for each year. After the actual allocations are made, followup actions are taken to compare actual and expected progress. The model is directly applicable to the many other Government and industrial organizations that are faced with the difficult decisions of proper allocation of research and development resources.

A second model, similar to the first, is currently being developed by Mr. Rea at Abt Associates Inc. for the Air Force Systems Command. This decision model will assist Air Force long-range planners to select those weapon and support systems which should be given increased emphasis for future development. The results expected from its use include further study of the most promising systems, new programs to overcome technical problems standing in the way of future development decisions, or action toward acquisition. The model will permit comprehensive examination of the many factors that must be considered in this decision process, such as national military policy objectives, military functions, technological feasibility, costs, and resources expected to be available in the future. Mathematical algorithms are used to relate system performance to objectives, and optimization techniques are used for the allocation of resources by fiscal year over an extended time period to competing system concepts. The planner is able to "converse" directly with the computer with the use of a remote console operating a computer in a time sharing fashion. The model has a hierarchical structure, and therefore can be used to assist with any resource allocation problem in either Government or industry where program costs and expected values to the objectives of the organization can reasonably be estimated.

Two of the models surveyed relate specifically to foreign economies. Dr. Holland of the Simulmatics Corporation is leading the development of a simulation model of the Venezuelan economy. The model is being used experimentally, under an arrangement with the Venezuelan Government Planning Agency, to check "the consistency and reasonableness of certain assumptions and projections used in the 4-year Plan de la Nación, 1965–68."[5] The policy questions which the simulation is designed to answer are basically fiscal in nature: How to determine the optimum rate of growth attainable without inducing either a foreign exchange crisis or a severe domestic inflation; and how to decide on the magnitude and composition of a government expenditure program to achieve that rate of growth.

The interesting features of the project are the shift in emphasis from comprehensiveness to flexibility during the model's construction and the high correlation between the model's performance and historical reality. The original intention was to develop an extremely complex model which would be applicable to all kinds of problems within one framework. As work progressed, however, it was decided to adopt instead a more flexible and adaptable model formulation, using interchangeable components.

The second foreign economy model (or, more accurately, set of models) was by Professor Eckaus of MIT and Professor Chakravarty of Delhi University. The two long-term and two short-term models are related specifically to Indian planning efforts, and use a somewhat modified standard linear program to allocate resources among sectors of the economy in successive time periods under various constraints. Although a standard program is used, the models are of special interest owing to their explicit consideration of intertemporal as well as intersectoral relations. Adaptations of the original models are being developed which focus on import substitution in

[5] Holland, E. P., *et al.*, *The Development of a Simulation of the Venezuelan Economy* (prepared for Centro de Estudios del Desarrollo by Simulmatics Corporation), New York, April 1965, p. 2.

India and Nigeria, and on industrial location in Brazil.

The wide range of substantive and methodological accomplishment included in this report attests to the confidence of model-builders in the utility of their technique. One cannot dispute the value of this empirical research in enhancing our knowledge of the economic structure of the Nation and its microunits. Nor can one belittle the significant contribution made by the regional and urban renewal planners, given the serious need to conserve water resources, maximize public transportation facilities, and design, at the same time, both functional and esthetic metropolitan areas. The usefulness of their research efforts in the development of economic theory should also be stressed.

There are still serious theoretical gaps in our understanding of economic systems however, and the direction which quantitative research chooses to take will have considerable effect on the rate at which this theory is developed. More and better research is needed to differentiate policy impact in disparate regions of the country and on distinct socioeconomic groups. The War on Poverty dictates the need to develop disaggregated methods of analyzing Government fiscal expenditures to determine whether or not these measures actually work against the spread of poverty in the most effective manner. The primacy of improving education at all levels throughout the country requires quantitative models able to evaluate the opportunity costs and benefits of alternative educational expenditures. It also requires modeling and simulation methods able to assess the external economies of investment in education—its socioeconomic contribution which is so difficult to measure in quantitative terms. Dr. Arnold Heyl at the Office of Education is now in the planning stages of developing such a model.

The Bureau of Labor Statistics in its Interagency Growth Study is making valuable inroads into the difficult problem of unemployment, technological change, and manpower planning. The interindustry employment model does take into account expected changes in technology and labor productivity, and Dr. Anne Carter at the Harvard Economic Research Center is doing detailed work on this subject with regard to input-output tables. However, an understanding of the effects of technological change on the economy is essential for effective manpower planning, and there is a great need for the development of both theory and analytical techniques to deal with this issue.

The factor which seems most important in limiting this development, not only for technological issues but for all aspects of economic modeling, is the unavailability of data. We have already mentioned this problem with respect to microanalytical models, but its existence is felt elsewhere, as well. Even the national accounts data are not wholly adequate for macromodels; they are available in quarterly and even monthly series, though with a significant lag, but their coverage is not complete. There are many processes in the economy for which very little data are available at all. And though the development of theory and the data collection problems are obviously interrelated, each demands separate attention for both qualitative and quantitative improvements.

Probably the most outstanding result of a survey of the state of the art of economic modeling is the uncovering of significant gaps in our knowledge of, and our methods for dealing with, economic phenomena. At the most, we can ony project economic trends on the basis of past information and do our best to apply mathematical and statistical techniques to improve our analytical abilities. "Indeed, if an econometric model is nothing else, it is a highly sophisticated method of observing the past operation of the economy and systematizing the information obtained."[6] Our conclusion can only reemphasize the need for more and better research in economic theory, data collection, and economic modeling.

The economic models surveyed have been supported at an annual funding level of approximately $2 million. Assuming that the average length of time these models have been in progress is 2 to 3 years and that funding levels during this period have remained approximately constant, the economic models surveyed here have cost in the vicinity of $5 million; and their total anticipated cost is in the vicinity of $10 million.

The majority of these funds are allocated to the direct labor of professional personnel; as a rough estimate these models involve the effort of a total of 150 to 200 professionals. Assuming that this survey considered at least one-half of the national effort in economic modeling, it is extremely unlikely that the total economic modeling effort in this country costs more than $4 million per year or directly involves more than 400 professionals.

[6] Suits, Daniel, "Forecasting and Analysis with an Econometric Model," *American Economic Review*, vol. 52, March 1962, p. 131.

6. Social and Political Models

Subjects

The subjects of the 29 social and political models examined in the survey included coalition formation (5), political resource allocation (4), international conflict (4), social conflict and conformity (4), domestic political conflict (3), information flow (4), education (3), resource flow (3), voting (2), insurgency (1), and psychological conflict (2). (Some of the models overlapped several categories.) Many of the models included representations of decisionmaking processes (12), and interpersonal and interorganizational bargaining (8). Most of the models were descriptive (20). Of the nine normative models, five were maximizing and four were of the satisficing type.

Purposes

Most of the models were designed for research purposes (23), and many of these were also intended for teaching (10). (Very few models are intended for teaching but not also research.) Six models were intended for structural analysis or for very specific research objectives. Only five were intended for planning; only three, for forecasting. Three were directed toward coordination of diverse activities as well as research. Only one was directed specifically toward alternative policy generation, although several of those intended for policy planning could be used for this purpose. It may be concluded that most social and political models are being developed for research and teaching purposes, with only a small fraction being directed toward planning and forecasting.

Applications

Most current and planned applications are in research (15) and teaching/training (14), but about one-third (9) are being or may be used for policy planning.

Potential Government Applications

The potential Government applications mentioned were diverse, but "Generation of Policy Alternatives" received attention by the largest number (9), with "Allocation of Resources" (5) and "Training" (5) second, and with "Psychological Warfare" and "Education Policy" third. Policy decisions on organization design, identification of systems problems, and strategy development were also mentioned, each by one or two respondents.

Data Sources

Although the data were self-generated in experiments in many cases (16), the U.S. Government and the universities were a source of data in 7 and 8 cases, respectively. Foreign governments (4), State or local governments (3), or international or private organizations (1 each) sometimes also provided data.

Data Characteristics

The time periods employed in the data were primarily variable (9), or years (7), or models were event-sequenced (that is, used no time periods) (8). Few models used weekly time periods (3), and only one used daily ones. The data's reliability was assessed as moderate in half the number of cases (9), while it was considered unimportant in others (9). In half the models, almost all the information in the data base was qualitative. The methods used to quantify qualitative data were scaling (8), expert judgment (7), reduction to probability distributions (5), content analysis (2), factor analysis (1), or not done (5). There was a wide variety of responses concerning the time needed to collect data, in terms of man-months of effort. The time ranged from 150 man-months down to less than 1 man-month in a fairly uniform distribution. Half the respondents (13) believed that they could obtain the needed real world data, while 8 believed it to be very difficult to obtain. Concerning "what should be done to obtain the needed data" for those who expressed difficulty in obtaining them, two thought there should be further model development; four favored field research; and two favored classifying the project.

Simulation of Values

About 80 percent of the models considered attempted to simulate human values, the use of opinion questionnaires in games being their most common form. Other techniques include preference and ordinal scales, conversion to corresponding policy choices, and value matrixes.

Stochastic Elements

Dependence on stochastic (or probabilistic) elements ranged from very low to very high in most models, while absent entirely in eight.

Validation

The predominant validation technique was human judgment, in the form of checks for plausibility (8). Comparisons to the real world were made more explicitly in six cases. Many models were not validated (9), and of these the designers of five models felt that validation was not applicable. The results of validation efforts were split between generally satisfactory replication (8), and sufficiently unsatisfactory replication of reality to require at least some redesign (8).

Funding Sources

Two-thirds of the models surveyed (19) were supported by U.S. Government funds. Of these 19, 10 were supported by agencies of the Department of Defense (predominantly ARPA), 6 by the National Science Foundation, 2 by National Institutes of Health, and 1 by the Office of Education. Of the one-third not sponsored by the Government, five were funded by private nonprofit foundations and five were funded by universities. Most of the funds were generally spent on professional labor, rather than on computer processing.

Costs

Opinion was divided on whether or not funding was sufficient for maximum progress, with 9 believing funding sufficient and 14 believing it insufficient. The stated level of funding for "optimum" progress for individual model programs ranged from as little as $5,000 per year to as much as $300,000 per year, with an average and a median both of about $100,000 per year. The minimum believed necessary for the survival of individual programs ranged from $2,000 per year to $150,000 per year, with an average of about $30,000 per year. The total anticipated costs per program ranged from $10,000 to $1,500,000, with an average cost of $200,000 and a median cost of about $100,000. (Total costs for individual programs to date ranged from $2,000 to an estimated $1 million.)

Duration

Duration of model development programs ranged from 1 to 120 months to open, with an average of about 36 months (3 years).

Personnel

Numbers of professional staff involved ranged from 1 to 10, with an average of about 3½. Most model teams had three or four members, most of them part-time on the model project. The most common skills stated as essential were computer programers (14), political scientists (11), sociologists (11), theoretical psychologists (8), information scientists (4), mathematicians (3), economists (3), philosophers (2), and historians (2). They ranged in age from 20 to 50, with from 1 to 30 years of experience. The age and experience distribution was often bimodal, more modelers being in their twenties and forties than in their thirties. This probably results from the typical "professor and graduate students" modeling team. The leaders of most groups had doctoral degrees in the substantive field of their models.

Total National Level of Effort

The social and political models surveyed have cost a total of about $4 million to date (December 1965) and their anticipated total programs cost is about $6 million. Annual expenditures are running at about $1 million. About 100 professionals are working on these models, an average of half time each.

These numbers give at least an approximation of the minimum scale of the total national effort in social and political modeling. The maximum current level is extremely unlikely to be more than double these figures. The survey, while not exhaustive, is believed to have covered well over half the total U.S. social and political model population. Thus the probably maximum level of the current national effort is $2 million per year, and an anticipated total programs cost of $10 million, with no more than about 200 professionals involved.

Social and Political Models: A Qualitative Summary

The state of the art of social and political modeling is already far enough advanced to be considered seriously as an aid to Government planning. This qualitative summary is intended briefly to discuss the ways in which the surveyed models can be applied to planning functions. Among the questions which planners ask are: What will happen if present trends in a given area continue? (asked in order to uncover possible undesirable patterns); what do we want to happen instead? (asked to define the goals for desired outcomes); how do we make it happen? (asked to define the nature of an action program); and how do we make the program acceptable? (asked to facilitate converting the desirable into the feasible). The models included in the survey make varying contributions to answer these questions.

The first set of concerns, those of projecting present trends, is of least direct concern to the respondents in the survey. In contrast to the economic modelmakers, forecasting is of limited interest to social and political modelmakers. Perhaps forecasting represents an advancement of the state of the art beyond that which is widespread in the social and political disciplines. Forecasting requires either a well-defined theoretical base to develop a model of processes or a readily obtainable and manipulable empirical base covering broad past experience. Social and political theory has not yet been often married to the modeling technique for the direct purpose of forecasting, and empirical data bases have been manipulated in models too simplified or too remote in purpose to be included in the survey. There is one exception in the survey, Bolt's model of the feedback of doctoral candidates to higher education. This model forecasts in the same sense as does an economic model. Quite possibly forecasting was made easier by the limits placed on the scope of the model and the readily identifiable unit of analysis, the Ph. D. degree.

In general, social and political modelmakers come to their task with immodest demands to deal with large scale social systems. The very purpose of modeling is to help reduce large systems to manageable proportions, but even the more simplified proportions are sufficiently complex to make modelers shy away from declaring that their research tools are also reliable forecasting tools.

A second reason for the lack of social and political models whose avowed purpose is forecasting for planning is an artifact of the way social modelers use the term. Many modelers thought that their work would be useful for generating alternative plans because their models use "if-then" logic. For a given set of "if" statements, a matched set of "then" statements could be made. This logic is essentially the same as that of forecasting models, and models that had an acceptable level of performance could easily be adapted to forecasting purposes by making the "if" statements correspond to the starting conditions of the forecast.

At present, most models in our survey have research and teaching purposes and are not directed toward forecasting as an aid to planners. This deficit in application is in part a limit of the state of the art. If the modelers themselves do not feel comfortable making predictions, then they are probably good judges of their own limits. However, the state of the art is within reasonable distance of forecasting attempts, and encouragement of the art might well result in improved performance.

The planner is also faced with the question of identifying goals to define directives for planning. In this area there has been much debate about whether human values are subject to quantification and the cold calculation of an electronic device. The survey has uncovered a number of ways in which simulations of values may be done. While some of these means may be still imperfect, at least we can now debate in concrete terms about specific shortcomings which must be overcome.

The quantification of values was achieved in an operational context in Duke's METROPOLIS. This game places the student in significant community roles, requiring decisions on major public or private investments which influence urban growth. The emphasis is on capital improvements, the effect of sociopolitical issues, player interaction linkages, and timing of events; all players are provided with factual background data. Within the framework of this "environment for learning," all value judgments must be made by the player himself. A second generation version (M. E. T. R. O.) is designed as a plan-effectuation instrument. Using an abstracted envirorment and employing a reduction of time span and dynamic interplay of current decisions with fixed policies, this man-machine simulation is intended to generate growth patterns resulting from alternative decision chains by the players, and enable their comparison with planned growth patterns.

Several models place values in a quantitative form, just as verbal descriptions do when they say "more" or "less" desirable. For example, the TEMPER model expresses national values on numerical scales and the differences in values from one nation to another are expressed relative to each other. A human puts these data in the machine; subsequently he can change his estimate and change the machine's data. A panel of judges or an opinion survey can, and have been used to set these judgments into the machine. Where the values cannot easily be calculated, human judgment can at least be expressed quantitatively and simulations can thereby replicate the judgments of the real world.

At present, the state of the art includes the use of human values in defining goals for planning. This inclusion is usually on the basis of a transposition or translation of human judgments expressed in machine language. No modeler suggests that these values are fixed. The games and simulations that deal with preferences have values placed in such a way that they can be altered subject to the desires of the players. The important feature is that these preferences are able to be included in some fashion and the planning function is aided by their presence.

The greatest interaction potential between planner and modeler comes when both parties address themselves to the action questions of making events happen. In the cases of heuristic models, training is seen as a way of increasing a man's competence to make the proper decisions in planning. The training arises from the application of games and simulations to real world problems and the learning from vicarious experience the application gives to the players. The overwhelming number of models incorporate this training potential to help men become more effective actors. In these cases, the interaction of man with game is the intermediate step to effective action. These models do not give direct answers to planners, still relying on the calculations of a human performer.

However, these training models also have research purposes and the research is used to generate propositions which may have a more direct applicability. Thus, the widely used Internation Simulation has uncovered patterns of political decisionmaking behavior, and these patterns are being examined for validity in the historical and theoretical materials. No doubt there will always be problems of validation of game behavior, just as there is difficulty in verifying one historian's or analyst's account of events. The limit of validation applies to the states of many arts, and social and political modeling is no exception.

Some models have less difficulty in verifying their results. In areas where there is quick and unambiguous feedback, as in predicting the outcome of elections and comparing the model's results with the actual results, validation comes more readily. The Pool, Abelson, Popkin simulation of the 1960 and 1964 elections is a good example. One may still be right for the wrong reasons, but careful checking can alleviate some of these problems.

While most models rely on testing the outcomes of modeling against the broad test of plausibility, several of the models examined used more detailed tests by placing sensitivity tests on the variables in their model. Kaplan's model of international affairs tests propositions about the balance of power and places checks on the interacting variables to determine the key factors. The Duke model uses past statistics of a case study of a real city to set its test of merit. Usually some range of outcomes is prespecified by modelers and the narrowness and accuracy of that range are a function of the subject matter at hand.

Social-political modeling deals with statements about prior conditions leading to a specified outcome. One of the significant limits of the state of the art is in validation. The uncertainty here, however, is probably not any less than found in the verbal statements of planners. Models can only be as good as the knowledge of these planners and researchers, but the models do provide a format for improving tests of validity and rigorous analysis.

The last major area of contact of our survey with the problems of planning is in the area of making a program acceptable. The subject matter of the greatest number of models has to do with group conflict and other forms of human interaction. As might be expected of social-political modelers, their interest is in the pattern of human relationships under different conditions of groups performing tasks and working for gain. Successful implementation of plans requires knowledge of likely receptivity to such plans and of the best way to cast them in order to induce people to work for them. Models such as Kramer's resource allocation models for campaigning and Coleman's model of community conflict are applicable in their style, if not in their subject matter, as aids to relating plans to public support. There are many games of coalition formation which exercise capabilities for building support for projects. In these areas the state of the art of social-political modeling has become quite advanced. At a minimum, participation in gaming and simulation makes one sensitive to the factors involved in community acceptance of plans. The maximum to be desired would be specific and concrete policy recommendations. The state of the art has not often reached this level. There is much uniqueness in human relations and the general statements of modelers may yet still be too general to fit specific cases at the level of detail desired by planners. However, there are still ways of applying these general statements in the concrete cases where planners must make the final assessment themselves. Models do not replace field experience; they are designed to augment it where they can and to train the man in the field to be sensitive to general factors which his specific or limited experience may not include.

In sum, the survey of the state of the art has uncovered a number of models which deal both in substance and method with some of the critical problems of planners. The state of the art is not far enough advanced, and it probably never will be far enough advanced, to qualify as the sole undisputed technique for planners. However, it is quite clearly in a growth phase. This phase is now heavily focused on research. The research is close to payoff in some areas of complex human interaction and is in need of more work in other areas of specific application to social problems of immediate concern to planners.

7. Computer Simulations

Once a model has been developed, it is desirable to compare its performance with reality to determine how closely the model describes the reality. To accomplish this, the model is exercised or "cycled," and its output is termed a simulation of the reality.

As models increase in complexity, manual simulation becomes more arduous and time-consuming. To facilitate simulation of complex models, high speed computers are frequently employed. Such simulation is especially effective when the model is expressed in explicit quantitative or logical relationships. This section of the report is concerned with answering two questions regarding computer simulations:

What models are simulated with computers?

What are the characteristics of these simulations?

Models Simulated on Computers

As previously mentioned, computer simulation is most appropriate when the model processes are complex (especially those involving large quantities of data), and can be explicitly stated in a set of quantitative or logical relationships. Economic models almost invariably satisfy these requirements. The survey findings confirm the fact that nearly all of the economic models considered either now have, or will have, computer simulations.

The situation with social and political models, however, is significantly different by virtue of the processes which such models attempt to describe. These models, although they may be equally complex, sometimes lack the explicit quantitative or logical relationships for which computer simulation is most appropriate. As a result, social and political models are often simulated initially in the form of a game (see section 8). The manual game is sometimes used to identify quantitative and logical relationships which may have been obscure. Once the manual simulation has achieved this goal, the processes modeled may be more readily quantified, permitting later simulation by computer. The survey shows that such two-stage development of social and political models is not unusual. Of the 11 social and political models which have computer simulations, 5 also have manual simulations.

Characteristics of Computer Simulations of Social, Political, and Economic Models

Computer simulation of social, political, and economic models is usually done on general-purpose, high-speed digital computers (e.g., IBM 7094 and CDC 1604). These machines provide sufficient storage space for both computer programs (which specify the quantitative and logical interrelationships of the model) and model data base (values of the model variables).

Since such computers calculate at extremely high speeds and have rapid access to the model data base, computer simulations of extremely complex systems take a relatively small amount of time. (A typical model of the U.S. economy requires approximately 5 minutes to simulate a year of real-world time, broken into four 3-month intervals.) The actual time required for a computer to complete a model cycle is, of course, dependent on the scope and degree of detail of the model and the efficiency of the programing.

Another important characteristic of computer simulation is the computer programing language employed. In actual operation the computer responds to numerically coded instructions, described as machine language. In recent years, however, computer software development has advanced at such a rapid rate that a wide variety of automatic programing languages (FORTRAN, ALGOL, JOVIAL, IPL, SNOBOL, etc.) may be used in preparing computer simulation programs. These languages are then automatically converted into appropriate machine language. Such software developments permit substantive experts to function effectively in the computer simulation aspects of model development.

In addition to automatic programing languages, there are also available a variety of simulation languages (e.g., SIMSCRIPT, DYNAMO, CSL, SOL). These languages were developed with the intention of providing general purpose vehicles to be used in developing computer simulations. To date they have not been employed to a very wide extent. It appears that each simulation group prefers to develop its own "general purpose" simulation language providing specialized features which the group considers to be especially important.

The information on computers, programing languages, and storage requirements is summarized in table 8.

TABLE 8. SUMMARY OF COMPUTER SIMULATION CHARACTERISTICS

Number of models

	Economic	Social and political
Model type:		
Have or will have computer simulation	25	17
Computer used: [1]		
IBM 704	5	------
IBM 7090	8	8
IBM 7094	6	2
CDC 1604	2	1
CDC 3600	3	------
Philco 2000	------	4
Other	1	10
Programing language used:		
Algebraic:		
FORTRAN	21	6
ALGOL	------	4
Other (MAD, JOVIAL, AUTOCODER, etc.)	2	4
List processing:		
LISP, SLIP, etc	------	6
Computer storage requirements:		
Under 5,000 locations	------	4
5,000–9,999	2	2
10,000–29,999	8	3
30,000–49,999	10	4
50,000+	4	2

[1] Several models have been simulated on more than one computer, so totals may not match.

8. Manual Simulations—Human Player Games

As mentioned in section 7, social, political, and economic models may be simulated "manually," that is, by human players or by "hand" rather than by machine. Such simulations are often referred to as games; when a simulation involves a combination of manual and computer features, it is often referred to as a man-machine game.[7] The majority of the games considered in the survey concern aspects of the social and political sciences rather than economics, since hard quantitative data of the type needed for computer simulation are often not available in the first two fields. (Of the 28 economic models, only 2 are manual simulations, and 3 are man-machine games; whereas 10 of the 29 social-political models are manual games and 5 are man-machine games.)

The survey findings indicate that most games can accommodate a variable number of players. Limits on the allowed number of players vary from 2 to 200, with 5 of the models having upper limits of 30 or above, and 4 having minimum levels of 10.

The player roles range from bargainers[8] (present in 3 models), planners (present in 2 models), representative legislators (2), investigators,[9] police, press, planners, politicians, heads of state, decisionmakers, government - insurgent - village groups, etc. These roles are often hypothetical (8 games), but sometimes are historical (2 games), and in 1 game the player assumes his real-world role. Most models are dependent on player personality to varying degrees: "Highly" (4 models), "sometimes very" (2), and "quite" (2).

The credibility of the player roles is considered to be "very high" for 6 games, "high" for 3 games, and "moderately high" for 2 games.

The average length of a game varies considerably, with seven games taking 1 to 3 hours, one requiring a full day, and two requiring considerably longer periods of time (e.g., one semester). Those games which are conducted over such protracted periods are not run continuously. Instead they are broken into segments of 2 to 4 hours and are conducted on frequent (usually weekly) intervals. Most of the games are composed of standard move cycles, usually approximately 20 move cycles per game. The majority (7) of the games require some degree of role-playing as well as scenarios (7).

Most games are nonzero sum, that is, complex mixtures of competitive and cooperative behavior. In several (7) games there are individual winners, while in a few (4) there are both team and individual winners. In approximately 50 percent of these games however, the individuals and the teams have different win criteria. These criteria also vary from model to model. In some (2) games the goal is to maximize money returns, in some (2) to maximize satisfaction points, in still others the goal is maximization of prestige, power, etc.

Most of these games have been developed for both research and/or education, and investigate a variety of hypotheses. The games exercise experimentally various hypotheses; for example, on the effect of saliency and effect upon information processing, global consequence of major policy, relevant variables of prerevolution, community macroeconomic interactions, local political election coalition building, and personal career choices in an education system.

[7] Until recently computer systems technology could not efficiently accommodate man-machine games. With the advent of time-shared computer systems, such games will find increasing application in model development and simulation.

[8] Bargaining usually also included decisionmaking.

[9] The first four roles in this list were represented in more than one model.

9. Staff, Time, and Money Requirements

This section is concerned with answering four questions regarding the models and simulations considered in this study. These questions are:

1. Who is doing the work (groups, disciplines, education, experience)?
2. Who is supporting the work (Government, nonprofit organizations, private industry)?
3. What is the magnitude of the work (level of effort, duration)?
4. How close to completion is the work (availability)?

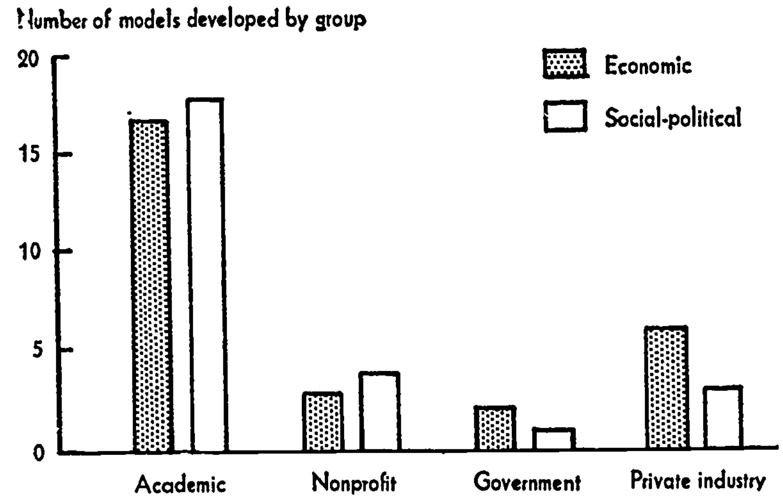
Who Is Doing the Work?

In answering this question, it is worthwhile to distinguish between the organizations working in this field and the individuals within these organizations who are actually performing the work.

Organizations. The results of the study indicate that there are four major groups conducting significant and relevant modeling and simulation activities in the social, political, and economic fields (see table 9):

Academic groups, including universities and their associated research institutes.
Other nonprofit organizations.
Government.
Private industry.

TABLE 9. GROUPS CONDUCTING MODELING AND SIMULATION WORK



Individuals. All of the models considered are being developed under the direction of substantive experts, that is, primarily economists, sociologists, or political scientists. These individuals are, in addition, familiar enough with computer systems requirements to take charge of the modeling and simulation efforts.

It is interesting to note that although computers play a major if not indispensable role, computer systems specialists seldom play a major role. This is in part a reflection on the state of the art of computer software development and model-maker sophistication.

It should not be inferred from this that all substantive experts in the social sciences can step into model and simulation building roles with little or no difficulty. Rather it highlights one of the primary prerequisites of those who are to fill such roles. They must have an appreciation of the interrelations of the various elements which comprise their systems; and they must be capable of expressing these interrelationships in explicit, precise terminology to permit computer programing.

This requirement is in large part responsible for the present state of the art of models and simulations in the social, political, and economic fields. The emphasis which economics has placed on quantitative explanation of economic realities has greatly facilitated the development and integration of models in this field. (This, in turn, is related to the availability of data essential to the development and validation of economic models.) Unfortunately, the social and political sciences are much less advanced in the level and extent of their quantitative analyses, as well as the availability of prerequisite data. As a result, most of the economic models now being developed very seldom touch upon the social or political aspects of the real world which they attempt to describe.

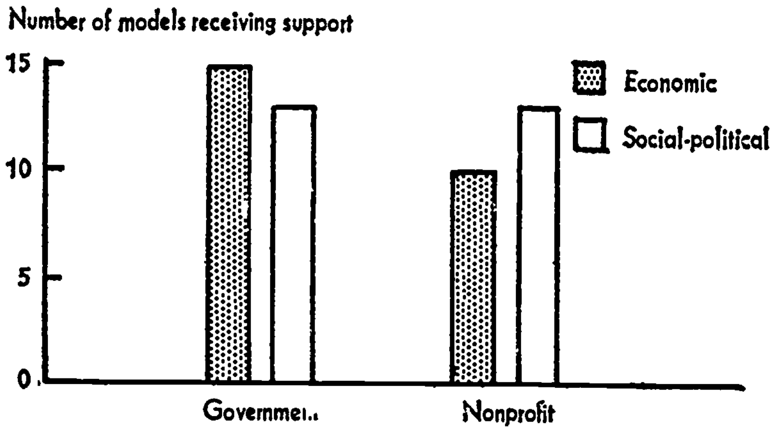
Who Is Supporting the Work?

The modeling and simulation work considered in this survey receives its principal financial support from two sources:[10] the Federal Government and the major nonprofit organizations. Often

[10] Private industry also supports some of this work. This support, however, is much smaller and is oriented primarily toward improved planning and control of company operations, or toward development of models for future sale to the Government.

both sources support work on the same model. (See table 10.)

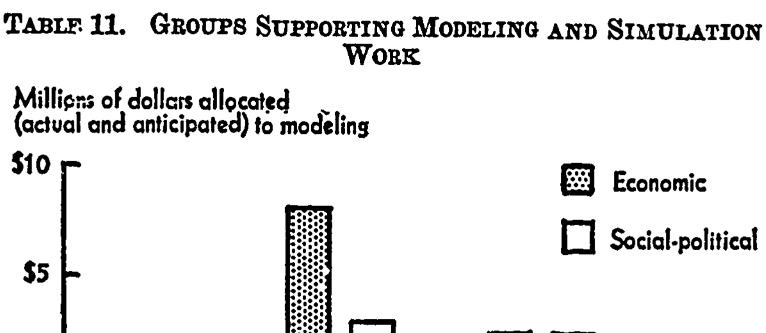
TABLE 10. GROUPS SUPPORTING MODELING AND SIMULATION WORK



Federal Government. There are two essentially different types of financial support provided by the Federal Government. First, there is support for those activities being conducted by the Federal Government itself in several of its departments and agencies. Second, there is support for those activities being conducted by independent organizations (academic, nonprofit, and private industry) through the support of such Government groups as the National Science Foundation, the Agency for International Development, and regional Government groups.

The support provided by the Federal Government through both of these channels is substantial with respect to both the number of dollars allocated and the number of models benefiting (see table 11).

TABLE 11. GROUPS SUPPORTING MODELING AND SIMULATION WORK



Major Nonprofit Organizations. Several of the major model and simulation efforts receive substantial support from a small number of nonprofit organizations, principally the Brookings Institution, Carnegie Foundation, Ford Foundation, and Rockefeller Foundation. In most cases, these efforts also receive support from the Federal Government.

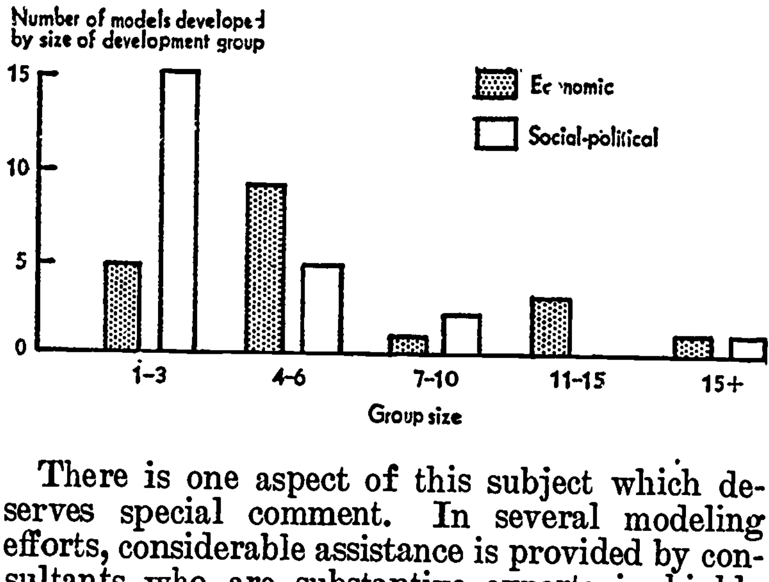
Usually both sources provide simultaneous support; occasionally, however, support is provided by only one source at a time.

What Is the Magnitude of the Work?

The magnitude of the modeling and simulation efforts considered in this survey connotes the interrelated factors of manpower, time, and money.

Manpower. The survey indicates that most modeling efforts are being conducted by small groups. Among academic groups, there are seldom more than six major contributors, with additional support provided (to the extent required) by graduate students. The nonprofit, Government, and private industry modeling groups are slightly larger but seldom number more than 10 (see table 12).

TABLE 12. SIZE OF MODEL AND SIMULATION GROUPS

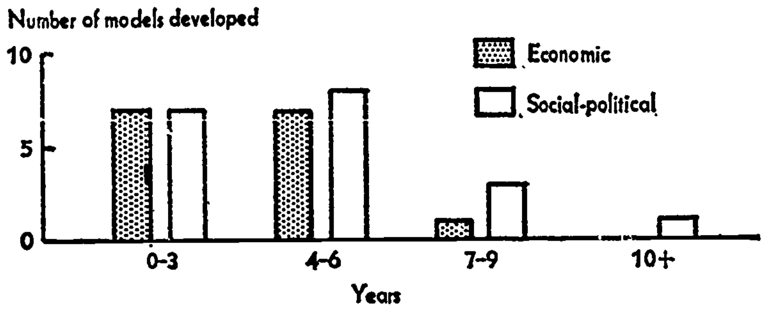


There is one aspect of this subject which deserves special comment. In several modeling efforts, considerable assistance is provided by consultants who are substantive experts in highly specialized areas. Notably, in one major model (Brookings-SSRC) the major development was accomplished through the combined efforts of a large number (20 to 30) of consultants devoting several weeks at a time in a modeling team effort. To be effective such efforts require that special attention be devoted to good communication among contributors. Only in this way will everyone understand precisely what he is expected to provide and what will be provided to him. Such large team modeling and simulation efforts require that special emphasis be placed on full communications regarding explicit definition of input and output for each segment of the model, as well as complete agreement and understanding regarding the interpretation of the variables used in the model.

Perhaps this severe communications requirement is one reason why modeling groups generally remain small in numbers. Funding limitations and availability of qualified personnel may, of course, be equally important.

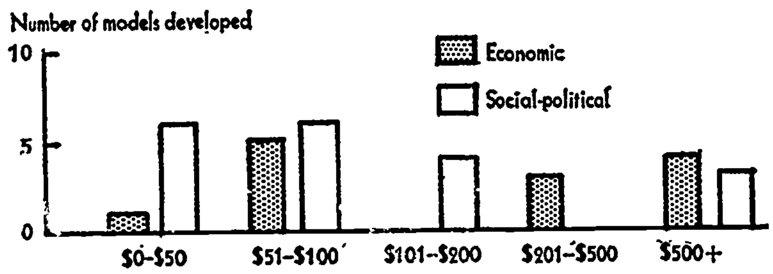
Time. The number of calendar years required to build a complete model or simulation is another measure of magnitude. Since this survey was concerned with large scale models, it was expected that at least 2 years would be required to construct such models (see table 13).

TABLE 13. TIME REQUIRED TO BUILD MAJOR MODELS



Money. The third element considered in evaluating the magnitude of modeling efforts was the total dollars required to build a model or simulation. This information was not always readily available; usually only rough estimates were provided. As would be expected, the total cost is closely correlated with the total time required to build the model, and with the size of the group conducting the work. Model development cost generally varies from $25,000 to $2.5 million. The distributions are show in table 14.

TABLE 14. DOLLARS IN THOUSANDS REQUIRED TO BUILD MAJOR MODELS

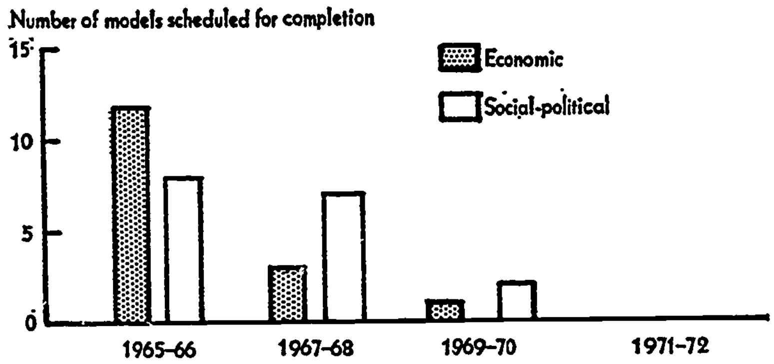


Interpretation of Magnitudes. Considerations of model magnitude—especially time and money—may lead one to conclude that at some future date no more time or money will be devoted to a given model. Such a conclusion would be erroneous. Many models will continue to be involved in future studies. As additional knowledge is gained, these models may require appropriate modification. Therefore, there is no clear-cut termination to most of this work. The total time and money required to build these models should be interterpreted as the minimum required to achieve a major level of completion.

How Close to Completion Is the Work?

The applicability of these modeling efforts is related, of course, directly to their degrees of completion. The majority of the modeling efforts considered in this survey have been in progress for at least 2 years. Bearing in mind the comments in the preceding paragraph, several of these models will be complete within the next 2 years. The survey findings on this question are shown in table 15.

TABLE 15. MODEL COMPLETION DATES



It should be cautioned that these estimates are those of the model project leaders, and may reflect their own time horizons. Also, increases or decreases in funding could reduce or increase the time required for completion. Finally, "completion" is only a relative term, indicating some point in time when the model is accomplishing much of its major purpose. To paraphrase Hemingway's remark about writing novels, one doesn't finish a model, one abandons it.

10. Conclusions and Recommendations

Evaluation Criteria

Modeling and simulation are scientific means of theorizing about, explaining, experimenting with, and observing complex processes that are impractical to experiment with in full-scale reality. As such, the state of the art of modeling may be assessed according to:

How faithfully the processes of interest are represented (VALIDITY);
How comprehensively the processes of interest are represented (COVERAGE);
How clearly and understandably the processes of interest are represented (COMPREHENSIBILITY);
How readily the processes of interest may be experimentally manipulated under varying conditions and assumptions to answer specific questions (EXPERIMENTAL UTILITY);
How relevant the model is to the understanding and control of the processes of interest modeled (APPLICABILITY).

In this survey, we have been concerned with the applicability of social, political, and economic modeling to public policy planning. We have sought models with enough experimental utility to be useful tools for public policy decisionmaking, by aiding Government decisionmakers in the planning, prediction, control, and evaluation of alternative programs. We have sought models which rendered the complex interactions of large-scale socioeconomic processes and programs more comprehensible, so that decisions concerning them can be made more rationally and convincingly by generalists as well as by specialists. If a decisionmaker cannot comprehend the logic of a model, he is unlikely to have enough confidence in it to use it. Models were sought with enough coverage of the relevant problem areas to identify relationships among interacting aspects. Finally, the question of validity was investigated to determine how reliably and how precisely the models represented the reality of problem areas relevant to public policy decisions.

This section will attempt to evaluate the state of the art on the basis of the above five criteria. It will also attempt to answer the following questions of applicability:

Are modeling and simulation useful to public policy planning and decisionmaking?
What are the capabilities and limitations of the current state of the art with respect to Government applications?
Where in Government can current modeling activities be best applied?
What can be done by Government to improve the modeling art in those areas where potential applications exceed current capabilities?

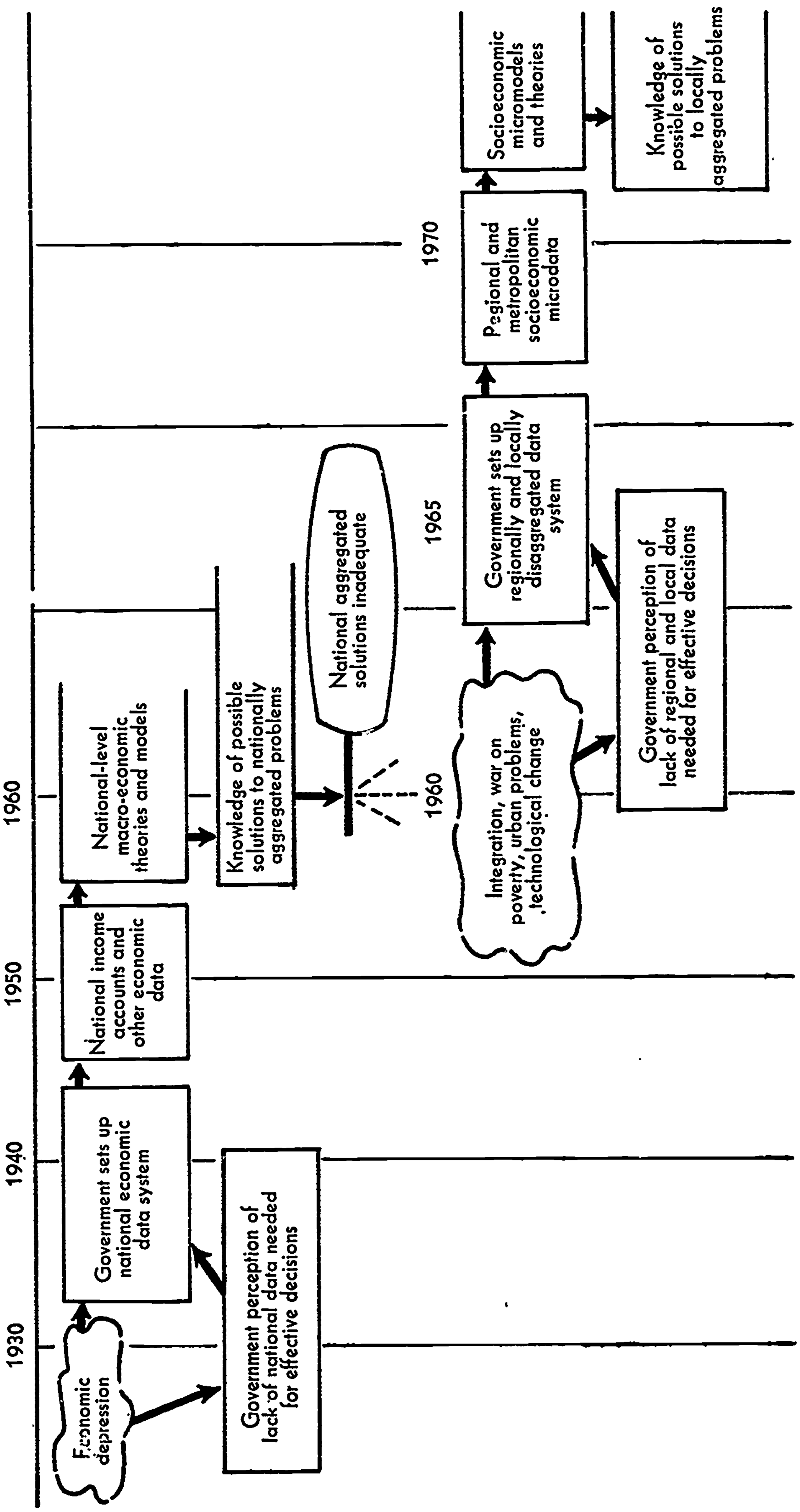
Applicability

Applicability is both current and potential. Current applications indicate conservatively the minimum possible applications. Current applications of economic models to public policy planning include national income and employment forecasting, regional industrial and population forecasting, water use and transportation planning, and urban land use forecasting and planning.

The most highly developed economic modeling art is at the national level, in response to the availability of national-level economic data, and the encouragement of national economic analysis by Government legislators and executives. The socioeconomic crisis of the depression in the 1930's led to the Government's establishment of national income accounts data collection, which encouraged, primarily, macroeconomic analysis and economic modeling on a national aggregate scale. Thus the Government's decisions of several decades ago about the type of data to be collected, made on the basis of its own awareness of its information needs for responding to the depression, have determined the scope and direction for a large part of U.S. economic theory developed since.

The tremendous influence of data availability on the state of the art of economic theory (and modeling as an expression of theory) is most important today. A decisive period of social change is again occurring in American history. The drive for social equality by disadvantaged racial and socioeconomic groups is being responded to by massive Government programs in welfare and education. The integration crises and antipoverty programs of the 1960's bear some resemblance to the unemployment crises and welfare programs of the 1930's. (See table 16.) Once again the Fed-

TABLE 16. A HISTORICAL PARALLEL



eral Government finds itself short of the necessary information for making effective decisions concerning these massive socioeconomic policy responses to large scale socioeconomic change. Once again, means are sought to collect this information, and once again, the means chosen will influence decisively the entire development of social science for the next generation.

The economic data collected and disseminated by the Federal Government today, and the economic models that use them, are an at least partially successful and highly relevant response to the economic problems of the 1930's. Unfortunately, the currently available economic data and economic models are not wholly applicable to currently pressing problems of socioeconomic change. Aggregated national economic and census statistics say nothing about pockets of poverty, depressed communities, sick industries, or deprived social groups. These are averaged out, and so long as the averages appear favorable, there is no indication of, or data on, regional or local problems. To make economic modeling more applicable to the pressing problems of poverty, social change, and social conflict—and to make it more effective on even the national aggregate level—regional and local microeconomic models must be developed. Essential to the development of such regional and local microeconomic models are detailed, disaggregated social and economic data on a local and longitudinal [11] basis.

Until economic models (and the data which support them) are available for regions and localities, as well as for the Nation as a whole, many of the most important public policy problems will continue to be unsolved. Technological change and industrial and labor dislocations, regional transportation, regional depressions, local socioeconomic conflicts, urban housing, land reclamation, and education system inadequacies are only a few examples of economic problems to which the majority of the current microeconomic models are not applicable.

A hopeful sign that this "applicability gap" in economic modeling is being corrected is a small number of recent attempts to model specialized aspects of regional and urban economics. The Ohio River Basin and Pittsburgh studies are examples. Regional and urban economic modeling appears to be the fastest growing element in the current economic modeling art. The major limitation on more rapid and pervasive development is the unavailability of economic data on a regional and metropolitan area basis.

The applicability of social and political models to current public policy problems is quite different from that of economic models, both quantitatively and qualitatively. None of the surveyed social and political models are currently being applied directly to Federal domestic programs. Few of the social and political models currently in development are likely to find direct application to Federal public policy planning when completed, due to the local or small group scope of most of them, or to the unknown reliability of correspondence to reality in the few models of national scope. The "applicability gap" in social and political modeling is in part the converse of that for economic modeling. The substantive focus of most of the social and political models is on the microstructure of bargaining and decisionmaking behavior of individuals or small groups. Where national-level processes are modeled, they incur at best the "black box" limitations of aggregation of the macroeconomic models, or the uncertain validity of human player games (which are wonderfully educational for the players, but of quite unproven predictive value about the events simulated).

Yet, many of the current social and political models deal with processes that must be better understood for effective public policy planning and evaluation. National resources cannot be allocated efficiently among competing Government programs unless their relative cost-effectiveness can be forecast or measured, and effectiveness can only be measured in terms of detailed social, political and economic effects on human beings. Thus the better understanding of such sociopolitical processes as individual belief systems, education system recruitment, group conformity, distorted perceptions, career choices, interpersonal bargaining and communications, local political coalition building, and organizational growth, by sociopolitical micromodels of the types here surveyed is essential to the systematic evaluation of public policy programs.

The mismatch between the primarily national-level macroeconomic models and the primarily local or small group microsociopolitical models inhibits the development of integrated social-political-economic models at consistent local, regional, and national levels of aggregation. It is such interdisciplinary modeling that is required for estimating and experimentally testing by model simulation the "across-the-board" effects of alternative public policies. A hopeful indication of an increasing awareness of this problem is the incorporation of some social variables in the more advanced regional and urban economic models, and an increasing use of economic variables and economic theories [12] in social and political models. This convergence on interdisciplinary methods may have been accelerated by the trend

[11] "Longitudinal" is a term used to describe information about changes over time of the same individuals in a population, as contrasted with aggregated time series such as the U.S. Census, in which only changes in total populations are given.

[12] See, for example, the "exchange" theory of social behavior which is essentially an economic conceptual model expounded by the sociologist George C. Homans in his *Social Behavior*, Harcourt, Brace & World, New York, 1961.

toward "modeling by committee" found in some large-scale computer model simulation programs.

Experimental Utility

Models should make possible the experimental manipulation of social, political, and economic processes of interest for the purpose of answering specific questions about the effects of specific public programs and policies. The more varied the experimental manipulability of models, the greater their experimental utility in replacing impractical or too costly real world experimentation with policies. The ideal model of a complex process, from the aspect of experimental utility, is one that replicates all the essential structural and decisionmaking elements of the real world process modeled. Thus an ideal model for experiment, observation, and theory building is transparent, in the sense of its structure being both highly relevant to its purpose and being observable in action.

The worst kind of model for experimental theory building purposes—worst but not necessarily useless—is the so-called "black box" model. A black box model is so named because its internal operations cannot be observed, or even if they can, they are not intended to replicate the detailed structure of the process modeled. A mathematical expression relating several highly aggregated economic variables such as GNP, national unemployment, and consumption on the basis of the correlation of the results with actual historical experience is an example of a "black box" model. A correspondence exists only between the black box model's inputs and outputs, and the modeled reality's starting and ending conditions, not between model decision structure and reality's decision structure. Such "black box" models are useful in short-term forecasts of complex processes for which historical statistics are available, provided that no significant structural changes occur in the real world processes.

Most economic models are macroeconomic, "black-box" models. This is in part the result of the complexity of the national processes modeled defying detailed structural (microeconomic) replication. A contributing factor is the implicit and reasonable assumption that macroeconomic processes on a national scale are fairly stable structures. If the structure does not change much, then its operating characteristics may be represented in aggregated, simplified mathematical forms corresponding to statistically determined relationships.

The emphasis often placed on the prediction rather than on the comprehension of macroeconomic phenomena has also contributed to the almost total preponderance of "black box" economic models. The decisionmaker recruiting the aid of the professional economist is usually more interested in results than in methods.

Unfortunately, macroeconomic "black box" models do not have much experimental utility in the analysis of the social and political effects of economic changes. There is almost no quantitative historical data on the relationships among social, political, and economic changes, so that statistical models cannot be developed. Social and political behavior is often of a microstructural nature—that is, inexplicable on an aggregated basis—so that it cannot be integrated into aggregated macroeconomic models. Even for purely economic predictions, the discontinuities introduced by large-scale technological and social changes limit reliable forecasting to a few years ahead (perhaps 5). Microeconomic models of the national economy, on the other hand, might integrate social, political, and technological factors and thus be capable of longer term forecasting, as well as being capable of more detailed forecasts of socioeconomic interactions.

Many social and political models are "transparent," attempting to replicate at least in part the internal microstructure and behavior of the interpersonal processes simulated. The complexity of human interactions, however, severely limits the scope of such microstructural models, given the usual time and effort constraints on feasible model complexity. More structural detail is bought at the cost of substantive scope, given a model complexity relatively fixed by resources or simulation technology.

The metropolitan and regional economic models possibly offer the most promising design compromise between "black box" aggregation models with their dependence on statistical data and resistance to cross-disciplinary problems, and transparent microstructural models with their very modest substantive scope. Metropolitan and regional socioeconomic models promise the most experimental utility, both because it is believed feasible to design them in "transparent" microstructural form since socioeconomic interactions are clearly visible at this level, and because at least partial validation by real-world experimentation seems still possible on this scale. (The unavailability of regional and metropolitan-level economic data will continue to limit such efforts, because "natural" boundaries are difficult to define at any level below that of the Nation.)

Comprehensibility

Models must be understandable by generalists as well as by specialists. Government decisionmakers, who are more often generalists than specialists, are unlikely to trust models enough to use them as aids to decisionmaking unless they can understand them. Thus, model simplicity is very relevant to the chances of a model's being actually used, and must be traded off against the complexity necessary to replicate the essentials of the processes of interest.

The "black box" macromodels have some aspects of the desired simplicity in the sense that the types of statistical relationships on which they depend may be rapidly explained. On the other hand, the significance of the statistics on which such models are based is a much more complex matter, and is not easily explained (even among specialists). In contrast, the micromodels with their transparent structure are, for a comparable substantive scope, much more logically complex. They incorporate many more theoretical assumptions about detailed relationships, and require a great deal of study to understand. However, once understood, if the microstructure seems convincing, there can be an end to doubt by the model user. With "black box" macromodels, the user's confidence is a function of his faith in the structural stability of the processes modeled, and the completeness, accuracy, and relevance of the statistical data used.

Coverage

The coverage of subjects relevant to public policy planning and decisionmaking is impressive among economic models, no doubt because many such models have been specifically intended to be policymaking aids. There is apparently much agreement among economists about what the most significant variables are, since these variables are common to most economic models, with variations chiefly in the scope and aggregation of the data. The most common economic subjects—and model variables—are those of classical economics: Production, investment, income, consumption, and employment.

Perhaps because sociology, social psychology, and political science are less well defined disciplines than economics, social and political models cover a much more diverse group of subjects. However, compared to the number and diversity of sociopolitical subjects relevant to public policy, the coverage of social and political models is rather scant and scattered. The logic of the social and political models is usually concerned with human perceptions, communications, bargaining, decisionmaking, or combinations of these.

Validity

Model validity is not used here in the general sense of model "quality." The survey has made no attempt to assess the "quality" of individual models, whatever that term may mean, although types of models have been evaluated in terms of the above five criteria. Any evaluation of individual model quality, to be fair and do the designers justice, requires much more study of the individual models than a survey of some 60 models in 60 days could possibly accomplish.

The survey has been concerned with how the model designers deal with the problem of validity, and what model validation they have achieved according to their own estimates. Validity is considered to be essentially the degree of model correspondence to the reality modeled. The economic models are considerably ahead of the social and political models in validation, probably reflecting the greater maturity of economics as a formal discipline with its greater agreement on terms, and the much greater availability of quantitative data. The validation of economic models is accomplished in most cases by quantitative comparisons of model behavior and historical real world behavior. The validation of social and political models is more often a matter of judgments concerning plausibility, except where quantitative models (such as those predicting voting behavior) permit quantitative comparisons.

Models are always at least partly the expressions of the designers' point of view. Thus the economists who design economic models tend to apply economic criteria to the validation of economic models: Parsimony, accuracy, and stability. The sociologists, social psychologists, and political scientists who design social and political models are concerned more with human attitudes and social relations than with large quantities of commodities. They deal with a more complex and still largely qualitative set of variables; thus they tend to judge model validity more on the criterion of richness of insight into the processes modeled. They tend to evaluate their models more on the basis of what they learn from them than on the basis of accuracy of prediction. This seems reasonable enough, since understanding is usually required before prediction can be scientifically achieved.

Since certain models are like basic research, a way in which some researchers talk to themselves—seeing explicitly what they say, asking themselves and answering themselves their own questions, it seems hardly surprising that many of the model designers tend to find their models valid.

Objective validation requires widely accepted standards. These are emerging but will require many more years to be accepted unless specifically directed efforts are made to assess and apply models on the basis of specific criteria. Measures of modeling effectiveness, including both realism and heuristic criteria should be developed, which treat models as scientific instruments for the explanation, observation, measurement, prediction, and control of complex social, political, and economic processes.

Are Modeling and Simulation Useful to Public Policy Planning and Decisionmaking?

The survey suggests answering a qualified "yes" to this question. Models have already been extremely useful to military planners concerned with complex and large-scale systems interaction processes involving military, economic, technological, and political factors. There is no reason why the same modeling techniques cannot be equally useful to domestic public policy planning and decisionmaking. There is no other scientific way of analyzing the relative costs and effects of complex Government programs operating in complex socioeconomic environments.

The qualifications that must be made concern the reality of the current state of the modeling art operating within the current skill and funding constraints. Only a few economic models and a very few political models have demonstrated predictive capabilities, and these are of a short-term nature (about 1 year). The state of the modeling art and its supportive data bases is not such that any great confidence can yet be placed in long-term prediction capabilities. Most model designers agree that more skilled professionals, better data, and more time and money can improve significantly the predictions capability of social, political, and economic models. No one will ever find out whether they are right or wrong unless the accelerated attempt is made.

The utility of some models for some applications may have been, and probably will continue to be, exaggerated. However, "overselling" in some cases should not result in avoiding opportunities for useful applications.

What Are the Capabilities and Limitations of the Current State of the Art With Respect to Government Applications?

The capabilities of current economic models include short-term forecasting on a national aggregate, macroeconomic level, early indications of sensitive aspects of the national economy, indications of some of the likely consequences of alternative Government economic policies, and clarification of relationships among macroeconomic variables.

The limitations of current economic models are their general inability to deal with regional, metropolitan, and many industrial economic problems; their too great aggregation for the integration of important and sometimes decisive local sociopolitical factors; their inability to analyze the longitudinal (over time) economic changes of specific populations; and their inability to show or explain the interaction of even large-scale social, political, economic, and technological changes. These limitations are very largely the consequences of the limitations of the available economic data.

The capabilities of current social and political models are generally much less than those of current economic models in prediction, but greater in the uncovering of significant socioeconomic microprocesses. Human behavior in individuals and small groups is less predictable than in very large groups where anomalies cancel, and this truth is reflected here. However, just as the study of individual human behavior is more useful than the study of large aggregates in indicating perceptions, motivations, and decision criteria, social and political models and games have improved greatly the understanding of the sociopolitical-economic microprocesses that, in the aggregate, make up the macroprocesses. Models aspiring to long-term prediction of these macroprocesses probably require the incorporation of these micromodels. How the great discontinuity in data and theory is to be overcome is a major research problem.

Models consist of theory, data, and in the case of computer model simulations, computer programs (software) and computers (hardware). The principal limitations on current progress are available data and testable theory, not computer hardware or software.

The collection, sorting, storage, and dissemination of quantitative social, political, and economic data most useful to modeling are very much a money-limited problem.

The development of quantitative model-able sociological, political, and economic theory is very much a people-limited problem. It is also indirectly a money-limited problem, since generous research grants could attract and help educate the necessary professional manpower over a period of years.

Another important limitation on current model applications to government policy planning and decisionmaking is the relative lack of sophistication (concerning models) of many potential users. Naive overenthusiasm or unreasonable pessimism (sometimes as a result of disenchantment following overenthusiasm) both inhibit the aggressive and realistic exploitation of modeling in many potentially useful applications.

Where in Government Can Current Modeling Activities Be Applied?

Identification and specification of objectives;
Observation and description of complex processes;
Quantification of qualitative variables;
Measurement of critical process variables;
Data collection requirements identification;
Integration and sorting of data;

Early warning and economic forecasting of crises;
Political forecasting;
Public response forecasting;
Social change forecasting;
Technology forecasting;
Program requirements identification and forecasting;
Generation of alternative plans;
Financial requirements forecasting;
Cost-effectiveness evaluation;
Resource allocation optimization;
Program scheduling;
Measurement of program achievements;
Trend indication;
Data collection and sorting;
Coordination of diverse efforts;
Analysis of organizational structures;
Education;
Training.

What Can Be Done by Government To Improve the Modeling Art in Those Areas Where Potential Applications Exceed Current Capabilities?

More money can usefully be spent. The current national expenditure on social, political, and economic modeling may be estimated in tens of millions of dollars per year, based on the representative interviews of the modeling population.[13] Probably less than 1,000 professionals are at work on specifically modeling problems. Particularly, social and political modeling suffers from low funding—less than $2 million per year.

Microeconomic data on metropolitan areas and regions can be collected or sorted and disaggregated from nationally accumulated data.

Sociological and political data on metropolitan areas and regions can be collected, and integrated with disaggregated economic data. (Privacy of data can be assured by very small aggregations.)

Longitudinal data, tracing individual or small socioeconomic group changes over time, can be collected, sorted, stored, and made available to modelers of socioeconomic change.

Interdisciplinary studies of socioeconomic communities can be conducted to provide the empirical basis for microsocioeconomic models, which could then be used as building blocks for regional and national-scale micromodels.

Professionals with model design experience from several disciplines can be recruited into Government data collection agencies to assure the collection of the most useful data and useful data formats for modeling.

Since quantitative models of social change are almost nonexistent, even crude efforts and "black box" models would advance the state of the art. These can be encouraged by grants to universities and contracted interdisciplinary research.

The considerable redundancy and repetitiveness of modeling efforts suggest the utility of providing at least the informational basis for an informal division of labor. This can be accomplished by annual, widely disseminated state of the art surveys.

More precise statements of public policy problems can be made with the aid of systems analysis techniques, making for better communications between Government users of models and model designers, and more fruitful model applications.

Priority support can be given to problem-oriented modeling efforts with testable outputs.

Increased on-line time shared computer programing capacity can be made widely available, to reduce computer model simulation programing time. The current computer storage limitations in time-sharing can be eliminated by the purchase of larger time-sharing oriented memory systems now technologically feasible.

The limited availability of large-scale computers having even current time-sharing features results in unnecessary delays in the development of many computer simulation efforts. Such computers are now beginning to be commercially available and should be used by modeling projects as quickly as possible.

A central sociopolitical-economic data library with data retrieval by teletype, linked to a time-sharing computer, can be developed and made available to all builders of public policy-relevant models.

The microstructure of disaggregated local census data can be preserved, stored, sorted, and disseminated, even if the same data also continue to be aggregated for national accounts. Most of the information in the data would thus not be destroyed by aggregation.

A system of national, regional, and metropolitan social accounts can be established, to provide a framework for socioeconomic data collection, the modeling of social change, and the computation of the relative social cost-effectiveness of alternative Government policies and programs. Regionalization of data is essential to regionally useful models.

[13] This estimate has no special statistical significance but is a "best guess" of current magnitude.

Appendixes

APPENDIX 1

List of Respondents

CALIFORNIA

RAND CORPORATION, Santa Monica:
- M. Geisler
- O. Helmer

STANFORD RESEARCH INSTITUTE, Stanford:
- A. Shapero

STANFORD UNIVERSITY, Palo Alto:
- R. P. Abelson
- R. Brody
- B. P. Cohen
- K. Colby
- R. C. North
- R. Textor

SYSTEMS DEVELOPMENT CORPORATION, Santa Monica:
- J. Bratten
- J. Cogswell
- J. Gullahorn
- S. Rome
- G. Shure

UNIVERSITY OF CALIFORNIA, Berkeley:
- C. W. Churchman
- G. Dantzig

UNIVERSITY OF CALIFORNIA, Los Angeles:
- G. Brown
- J. Marshak

WESTERN BEHAVIORAL SCIENCE INSTITUTE, Santa Barbara:
- W. Crow
- H. Sprague

ILLINOIS-MICHIGAN-TEXAS-WISCONSIN

NORTHWESTERN UNIVERSITY, Evanston, Ill.:
- R. Eisner
- L. Jensen
- R. Strotz

UNIVERSITY OF CHICAGO, Chicago, Ill.:
- Z. Griliches
- M. Kaplan
- H. Thiel

UNIVERSITY OF ILLINOIS, Urbana, Ill.:
- R. Ferber

UNIVERSITY OF MICHIGAN, Ann Arbor, Mich.:
- W. Gamson
- B. Horvath
- M. Kochen
- R. Meier
- A. Rapaport
- D. Singer
- D. Suits
- E. Swanson

UNIVERSITY OF TEXAS, Austin, Tex.:
- J. C. Loehlin

UNIVERSITY OF WISCONSIN, Madison, Wis.:
- M. David
- R. Day
- A. Goldberger
- C. Holt
- A. Zellner

MARYLAND-WASHINGTON, D.C.

JOHNS HOPKINS UNIVERSITY, Baltimore, Md.:
- J. Coleman

AMERICAN UNIVERSITY, Washington, D.C.:
- R. Boguslaw

BROOKINGS INSTITUTION, Washington, D.C.:
- G. Fromm

BUREAU OF LABOR STATISTICS, Washington, D.C.:
- J. Alterman

DEPARTMENT OF COMMERCE, Washington, D.C.:
- M. Liebenberg
- L. Paradiso

NATIONAL PLANNING ASSOCIATION, Washington, D.C.:
- M. Wood

OFFICE OF EDUCATION, Washington, D.C.:
- A. Heyl

BUREAU OF STANDARDS, Washington, D.C.
- W. Cushen

NEW ENGLAND

YALE UNIVERSITY, New Haven, Conn.:
- H. Alker
- J. Friedman
- M. Nerlove
- J. Tobin
- D. Hester

Bolt, Beranek & Newman, Cambridge, Mass.:
- R. Bolt

Arthur D. Little Inc., Cambridge, Mass.:
- G. Kimball
- P. Vintiades

Harvard University, Cambridge, Mass.:
- C. Almon
- J. Bruner
- S. Buchin
- H. Houthakker
- D. Kresge
- W. Leontief
- G. Orcutt
- H. Raiffa
- T. Schelling
- P. Stone

Massachusetts Institute of Technology, Cambridge, Mass.:
- R. Eckaus
- F. Fisher
- E. Kuh
- I. Pool
- R. Solow

NEW YORK

Diebold Associates, New York City:
- F. W. Wanzenberg

IBM, Yorktown Heights:
- H. Krasnow

McKinsey & Company, New York City

University of Rochester, Rochester:
- G. Kramer
- W. Riker

PENNSYLVANIA

University of Pennsylvania, Philadelphia:
- P. Dhrymes
- R. Luce
- T. Reiner
- R. Summers

Carnegie Tech, Pittsburgh:
- H. Simon

Consad Research Corp., Pittsburgh:
- W. Steger

Delaware Valley Regional Planning Commission, Philadelphia:
- D. Seidman

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BACKGROUND, GUIDELINES, AND RECOMMENDATIONS FOR ASSESSING EFFECTIVE MEANS OF CHANNELING NEW TECHNOLOGIES IN PROMISING DIRECTIONS

Prepared for the Commission

by

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PURPOSE AND SCOPE

This paper is directed to the question of assessing the most effective means of channeling new technologies in promising directions. No single "most effective means" is recommended, since that ideal probably does not exist. Certainly too little is known about the complex process of technology transfer to permit any such sweeping judgments at this time.

To prepare the paper, the authors conducted depth interviews with personnel in the agencies that currently have significant technology transfer and technical information dissemination programs. A comprehensive literature search was also completed.

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Backgrounds, Guidelines, and Recommendations For Assessing Effective Means of Channeling New Technologies in Promising Directions

Conclusions and Recommendations

Devising means of channeling new technologies in promising directions—and bringing about the utilization of new technology for significant purposes other than the immediate use for which it was developed—has become an activity ranking among the most intellectually challenging of our time. It is recommended that Government agencies and private organizations alike encourage talented people from the many disciplines who can contribute to the work.

The transfer and utilization of new technology offer immense opportunity to the Nation. There is widespread agreement among those who have studied the issue that the knowledge resulting from public investment in R. & D. constitutes a major, rapidly increasing, and insufficiently exploited national resource. Its effective use can increase the rate of economic growth, create new employment opportunities, help offset imbalances between regions and industries, aid the international competitive position of U.S. industry, enhance our national prestige, improve the quality of life, and assist significantly in filling unmet human and community needs. It is recommended that more effective use of this technology resource become a national goal established at the highest levels.

Measures exist to show that a considerable portion of the technology resulting from military/space/nuclear work is relevant to needs outside those mission areas. It is recommended that those who can bring about or influence the use of this technology in the civilian economy be alerted to the relevance of the technology.

Traditional means of transferring technology—such as the intersectoral movement of knowledgeable people, corporate diversification, conventional library systems, the college classroom, and the technical journal—while still extremely important, are no longer wholly adequate. This is due, in part, to the sheer volume of new technology being generated, the rapid pace of its discovery, the increased complexity of the economy, and the technological gap between the military/space/nuclear sector and the main body of the economy. It is therefore recommended that complementary mechanisms be devised to aid in the channeling, transfer, and utilization of new technologies from sector to sector, industry to industry, region to region, discipline to discipline, market orientation to market orientation.

It is increasingly apparent that a communications gulf exists, as a derivative of the technology gap, between the principal generators of new knowledge and large bodies of potential users. This is not a simple problem of language, but a complex problem involving attitudes, values, goals, work patterns, orientations, environments, and other variables. This results in a need for intermediaries or couplers who can operate effectively at the interface between knowledge and need, and who can communicate effectively with those at both ends of the pipeline. It is recommended that professional societies, foundations, trade associations, and other groups aid in defining and developing necessary coupling mechanisms and locating and training people who can perform the function, with Government agencies continuing an active role.

Technology transfer is one of many areas in our economy where it is difficult to move programs forward because the responsibility is shared by the private and public sectors. The issue is complicated further by the fact that existing Federal programs to perform the function vary in their level of Government involvement by several orders of magnitude. It is recommended that a national policy be devised spelling out the conditions under which Federal agencies should conduct, foster, or support programs at each of the various levels.

The pressing nature of the problem tends to lead to proposed "solutions" of a sweeping, but impractical, nature. Several times it has been proposed that a "national system" be created. Far too little, it seems obvious, is known at this time to design a single national system, and it is unlikely that this would be the optimum solution in any case. It is recommended that serious and continuing analysis be given to the question, and particularly to the feasibility of designing a national capability made up of a multiplicity of coupled, user-oriented systems, with workable switching devices and the capability to tailor output for specific, but continually changing, groups with common needs or objectives.

Significant benefits can result from the application of technology generated by one Federal agency to the missions of other agencies. It is recommended that interagency efforts be encouraged and fostered, and where practical, that special skills of one agency be employed on an ad hoc basis by other agencies.

Federal expenditures for scientific and technical information are large and increasing. In order to reap the maximum rewards from this investment, there should be as much commonality as can be achieved among information handling systems in their languages, abstracting and indexing approaches, and other points of interlock, consistent with the overriding requirement for each to best serve its particular audience and to continue to advance the state-of-the-art in information handling.

The solution of pressing urban problems, from a technological viewpoint, and the enhancement of economic growth as a result of technological advance, rest on the ability of private companies to innovate. Thus, the focus for any broad-scale program to transfer technology must be the innovative technical community within private industry.

Technical information is a marketable commodity. True transfer programs add value to that information by abstracting, categorizing, separating out the significant, dividing the relevant from the nonrelevant, and by interpretation, analysis, repackaging, and provision of local access. The user of a system should therefore be expected to share in the cost of its operation.

Awesome opportunities for slippage exist at each stage in the processing of technical information. It is recommended that increased attention be devoted to the software aspects of mechanized systems and that special emphasis be given to education in abstracting, indexing, and the design of search strategies.

There is no substitute for the effect of a "personal champion" of new technology. Research should be undertaken to determine the characteristics of such people and the means of locating them. Users of new technology should attempt to find such people within their organizations and place them where they can work toward developing the maximum benefit for their organizations from the technology resource.

New technology has no value until it is recognized. To glean the optimum knowledge from Federal R. & D. programs, it is recommended that all agencies with significant R. & D. budgets establish a means of identifying the new technology they create, inhouse and through contractors and grantees.

New technology has no value until it is used, and it cannot be adapted for use by an organization unaware of its existence. It is recommended that all those involved in programs to channel new technologies in promising directions spend some time on the marketing aspects of the business, communicating to prospective users the vast potential value of the knowledge resource and reacting to the needs of special groups of users by tailoring programs to fit their requirements.

New technology is best transferred intersectorally by those who comprehend it and perceive its secondary applications and ultimate implications. It is therefore recommended that Federal agencies generating significant new technology should perform central roles in bringing about the application of that technology.

Introduction

This year, more than $15 billion in Federal funds will be used to create new knowledge through research and development. We are generating more new knowledge in 1 year than we generated in a full decade less than half a lifespan ago.

In fact, looking upon the last 50,000 years of man's existence in terms of lifespans, the speed of progress—the pace of change—is readily apparent.

Eight hundred lifespans can bridge more than 50,000 years.

But of those 800 people, 650 would have spent their lives in caves or worse; only the last 70 had any truly effective means of communicating with one another; only the last 6 ever saw a printed word or had any real means of measuring heat and cold; only the last 4 could measure time with any precision; only the last 2 used an electric motor; and the vast majority of the items that make up our material world were developed within the lifespan of the 800th person.

Such has been our progress, but we have created equally awesome problems: We send men more than 160 miles above the earth's surface and return them safely, but we kill one another on our highways; we can create a comfortable living environment 300 feet below the surface of the ocean, but we breathe garbage-laden air in our cities.

How much of our available knowledge is really being used for all relevant purposes? How much of our new technology can be translated into improved products and processes to spur economic growth and improve our standard of living?

No answers can be given to such quantitative questions. But this study shows that there is much to be gained—both the quantity and quality of life—from better exploitation of available knowledge.

Technology As a Factor in Economic Growth

While this paper is concerned with means of making new technology available to those who can use it, it seems important first to ask if the benefits of employing new technology warrant an investment in the means of making it available. All indications are that it will.

Only recently have economists devoted much attention to causal relationships in economic growth. But throughout the literature, one can trace the awareness—by economists and policymakers—of the importance of science and technology in economic health.

More recently, economists have attempted to measure the contribution of technology to the rate and volume of economic growth.

Robert M. Solow estimated that of the total increase in U.S. output per man-hour from 1909–49, only one-eighth was due to the increase in capital investment while seven-eighths was due to technological progress.[1]

Solomon Fabricant has found that, during the 1871–1951 period, technological advance accounted for 90 percent of the rise in output per man-hour (versus 10 percent for capital formation).[2]

Benton Mossell, found that (during the 1919–55 period) technological changes accounted for approximately 90 percent of the rise in output per man-hour.[3]

Edwin Mansfield, in a study of innovation and its effect on the growth of individual companies, found that the innovative companies grew much more rapidly (during a 5–10-year period after the innovation occurred) than other firms in their industries. The average growth rate of the innovators was often twice that of the others.[4]

Zvi Griliches asserted that:

> It is clear by almost any conventional method of measurement that productivity increase has been the most important component of economic growth in the United States in recent decades. The growth in productivity in turn can be divided into two parts: (1) The improvement in efficiency due to the elimination of various disequilibria; and (2) the expansion of the boundaries of knowledge.[5]

[1] Solow, Robert M., "Technical Change and the Aggregate Production Function," *The Review of Economics and Statistics*, vol. 39 (Aug. 1957), pp. 312–320.

[2] Fabricant, S., "Resources and Output Trends in the United States since 1870," *American Economic Review*, vol. 46 (May 1956).

[3] Mossell, B. F., "Capital Formation and Technological Change in U.S. Manufacturing," *The Review of Economics and Statistics*, vol. 42 (May 1960), pp. 182–88.

[4] *Reviews of Data on Research and Development*, No. 38 (National Science Foundation, Washington, D.C., March 1963). See also: Mansfield, Edwin, "The Expenditures of the Firm on Research and Development," Cowles Foundation Discussion Paper No. 136 (Yale University, 1962).

[5] *The Rate and Direction of Inventive Activity: Economic and Social Factors*, Report of the National Bureau of Economic Research (Princeton University Press, 1962).

Edward Denison predicts that advances in knowledge will be the most significant stimulus for economic growth during the 1960–80 period.[6]

It is apparent to even the most casual observer that advancing technology has drastically transformed the character of man's activity. A century ago, men and animals provided nearly all the musclepower in industry. Machines supplied about 1 horsepower per production worker. Machines now provide more than 10 times that amount of energy. The farm population, in that time period, has decreased from 8 in 10 to less than 1 in 10, thanks to increased farm mechanization. And since 1860, the average lifespan has jumped from around 40 to around 70 years, owing to medical advances in the prevention and cure of disease and to gains in sanitation and nutrition.

It is clear that the infusion of new technology can speed the rate of economic advance. But the importance of new technology to society cannot be measured solely by its contribution to our gross national product. GNP measures, with limitations, the output of goods and services in the national economic system. But any realistic assessment of economic performance must also consider how that output is distributed, the ability of the system to make the generation of that output personally rewarding, and the environment—or the quality of life—created by the system. GNP does not measure the economic system's performance in terms of giving people what they really want.

Much of the benefit of the infusion of new technology into the economy is not reflected in measures of productivity. For example, if technology permits the making of a better product without a corresponding change in production costs, the result is not reflected in statistics of output—but is a decidedly beneficial action.

One approach to the full realization of the benefits of new technology, it appears, would be to arrange for its effects to be more widely felt—to be diffused into more industries, more governmental missions, and more regions of the country. In others words, programs to channel new technologies in useful and satisfying directions can have the effect of notably enhancing the rate of economic growth—though the full effect of such programs would likely not be measured by conventional methods.

Denison has shown that differences in levels of formal education attainment create significant differences in productivity.[7] It follows that differences in practical professional knowledge acquired after completion of formal education can have a similar effect. In other words, the scientist, engineer, or businessman who continued to accu-

[6] Denison, Edward, *The Sources of Economic Growth in the United States and the Alternatives Before Us*, Supplementary Paper No. 13 (New York: Committee for Economic Development, 1962).

[7] *Ibid.*

mulate new knowledge—via being somehow updated in the latest R. & D. results in his field—would be more productive than the one who was not. If that logical assumption were indeed proved true, then investment (public or private) in programs to identify, evaluate, and utilize new technology would pay significant dividends in productivity improvement at the level of the firm or end user of the technology.

Many studies of the contribution of technology to economic growth have concentrated on the economic impact of major inventions and innovations. But the most important contributions to economic growth may be stimulated by widespread adoption of incremental improvements.

John Jewkes noted that:

> There is no evidence which establishes definitely that technical or economic progress receives greater contributions from the few and rare large advances in knowledge than from the many and frequent smaller improvements. Economically, it might for a period well pay a community to starve its scientific and major technical work and to devote resources to the most thorough and systematic gathering together and exploitation of all the immediate and tiny practical improvements in ways of manufacture and design.[8]

Students of the question see many serious economic and social implications in this situation. Among the difficulties mentioned as growing out of this problem are:

Regional economic imbalances. With the three States of California, New York, and Massachusetts obtaining approximately half of total Federal funds for performance of research and development, there is a tendency for industry in those regions to reach a level of technological sophistication far above that possible in some other States. But if the technology resulting from R. & D. performed in California could readily be channeled into those industries in other areas, the chances for regional imbalances in technological capability would be lessened.

Industry imbalances. The current pattern of R. & D. fund distributing could also tend to create serious interindustry imbalances. For example, consider the machine tool industry. Its technological health is important to the national defense posture and to the ability of other industries to reach high levels of productivity. But nearly every significant new advance in metal cutting and metal forming has been developed by a firm not traditionally part of that industry. It is argued that a better means must be developed to channel the technical advances made in the aerospace and related industries to the machine tool industry and other basic industries, where such technical advances can be commercialized and in turn contribute to the technical and economic health of still other industries.

Timelag. Enlarging the use of new scientific and technical knowledge, it is argued, would contribute to economic growth by reducing the timelag between discovery of new knowledge and its economic exploitation.

International competitive position. Early and effective utilization of new technology will logically have a beneficial effect on the U.S. balance of payments via increased exports of U.S. goods. This comes about in several ways: (1) Cost reductions enabling U.S. goods to be more price competitive in international markets; (2) new products and product improvements can expand overseas markets; and (3) creation of entire new industries whose output can be sold worldwide (e.g., commercial jet aircraft and computers).

Perhaps none of the specific arguments in themselves make a conclusive case for the fact that channeling of new technologies in promising directions will significantly speed economic growth. But the arguments that have been put forth by various students of the question—when examined in composite—make a formidable case for the theory.

Briefly, the individual arguments are:

- The use of new technology can reduce production costs, thus increasing productivity.
- The use of new technology can sometimes permit the output of a wider range of customer-satisfying products and services without a corresponding increase in capital investment, thus raising the return on invested capital and/or permitting price reductions.
- The use of new technology can shorten the timelag between the development of new knowledge and its widespread applications, thus spurring the growth process.
- The use of new technology can enhance the international competitive position of U.S. industry, thus improving our balance of trade.
- The use of new technology in the civilian sector—because such new technology will generally be adapted and coupled with other technology to create another sheath of new technology—can in turn provide new technological input to Government programs in space and defense, thus enhancing our defense posture and aiding our international prestige.
- The use of new technology in some areas—medical research, urban design, mass transportation, to name a few—can improve the quality of life.
- The use of technology in one sector that was originated in another can help to provide a balance in the economy in terms of technological capability, thus avoiding problems that might—though would not necessarily—be created by the concentration of research and development effort

[8] Jewkes, John, David Sumers, and Richard Stillman, "The Sources of Invention" (St. Martin's Press, New York, 1959).

in a relatively few companies within a few industries in a few geographical regions.

- The use of new technology can stimulate the production of new products, thus creating new jobs.
- The use of new technology can reduce the cost (and, hopefully, the price) of producing existing products, thus freeing purchasing power for the acquisition of other products, creating additional jobs in those areas.

Is Technology Available for Transfer and Utilization?

It seems clear that more rapid and more widespread use of available new knowledge would have many benefits. It would, for example, tend to speed the national rate of economic growth, smooth out regional and interindustry imbalances, and enhance the U.S. position in international trade.

But is new technology available for use? And—importantly—is the new technology relevant to the needs of society? This section is devoted to answering those questions.

Sources of New Technology

This paper emphasizes new technology developed as a result of Federal programs, since only that portion of new technology is sufficiently in the public domain to be made available for widespread use via channeling and coupling mechanisms.

The Federal Government is currently supporting research and development programs at an annual rate of more than $15 billion. That is double the outlay in 1960, triple the amount expended in 1958, and 15 times the outlay in 1950.

Since 1940, Federal spending for research and development has risen at an average annual rate of nearly 20 percent, from $74 million in 1940 to $15.2 billion in 1965.

For every $100 spent by the Federal Government this year, approximately $15 will be spent for research and development. That compares with $10 in 1960, $5 in 1955, and $1 in the mid-1940's.

Federal spending for R. & D. is also increasing far more rapidly than total economic activity. Before World War II, federally supported R. & D. was equivalent to a few tenths of 1 percent of the gross national product. By 1953, it equaled 1.4 percent of GNP and is now close to 3 percent.

Three agencies—Department of Defense, National Aeronautics and Space Administration, and Atomic Energy Commission—account for nearly 90 percent of Federal R. & D. spending. The nature of the missions of these agencies demands that the funds be spent across the full spectrum of R. & D.—from the most basic type of research to the most applied kind of development (which is really closely akin to plant engineering). Table 1 shows the sources of Federal R. & D. funding by agency.

TABLE 1. BUDGET EXPENDITURES FOR RESEARCH AND DEVELOPMENT, 1954–66 (IN MILLIONS OF DOLLARS)

Fiscal year	DOD [1]	NASA [2]	AEC	D/HEW	NSF	Other	Total
1954	2,487	90	383	63	4	121	3,148
1955	2,630	74	385	70	9	140	3,308
1956	2,639	71	474	86	15	161	3,446
1957	3,371	76	657	144	31	183	4,462
1958	3,664	89	804	180	33	220	4,990
1959	4,183	145	877	253	51	293	5,803
1960	5,654	401	986	324	58	315	7,738
1961	6,618	744	1,111	374	77	356	9,278
1962	6,812	1,251	1,284	512	105	409	10,373
1963	6,849	2,540	1,335	632	142	490	11,988
1964	7,516	4,171	1,503	791	197	496	14,674
1965	7,222	4,900	1,569	801	208	655	15,355
1966	6,880	5,100	1,557	936	266	706	15,445

[1] Includes civil functions.
[2] National Advisory Committee for Aeronautics prior to 1958.

SOURCE: National Science Foundation.

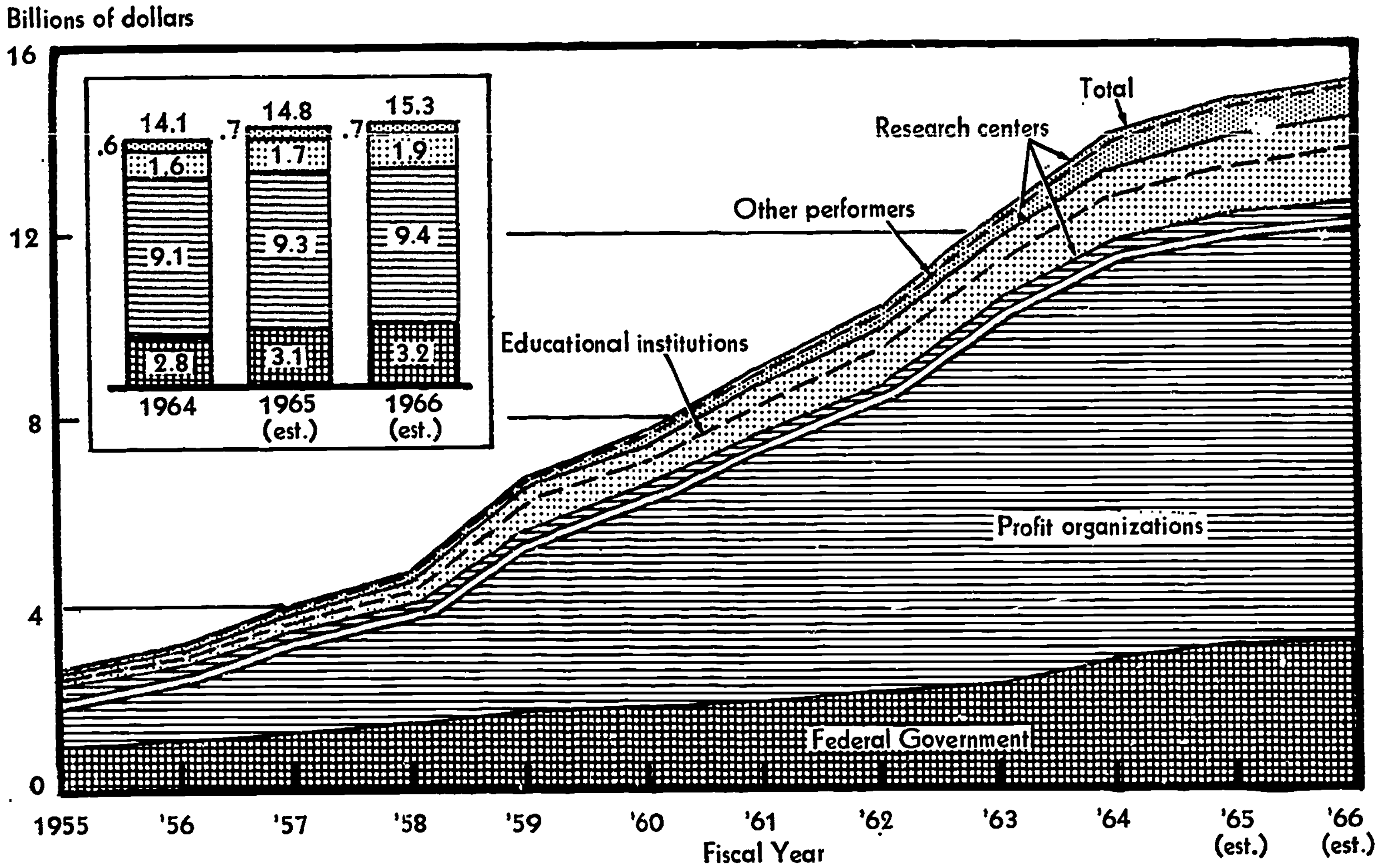
In the last 10 years, Federal funds have paid for more than $88 billion worth of R. & D.—more than 60 percent of it as a result of defense requirements. More recently, R. & D. in support of space exploration has risen to a place of importance nearly equal to that of the defense realm. And continued expansion of R. & D. by the Department of Health, Education, and Welfare is bringing that agency into a funding position as important as the Atomic Energy Commission was in 1960.

Most R. & D. continues to be performed by private industry, with the bulk of new technology generated within profitmaking corporations (see fig. 1). Thus any effective program aimed at channeling new technologies in promising directions—or any program aimed at finding secondary uses for the results of federally funded R. & D.—would have to incorporate some means of identifying and reporting new concepts, inventions, innovations, and other useful information generated within a diversity of corporate entities. The implications of this requirement will be discussed later.

There is no indication that Federal funding for R. & D. has reached a peak; in fact, all signs point to continued growth of such outlays. While no rapid growth in Federal spending for defense R. & D. is likely, continued expansion in such areas as health, space, and socioeconomic areas seems likely.

One writer suggests that, by 1995, if present trends continue, there will be 8 times as much scientific and technical information available as exists

FIGURE 1. *Trends in Federal Obligations for Research and Development, by Performer*



SOURCE: National Science Foundation.

today.[9] Numerous measures exist to show the volume of new technology being generated via U.S. Government programs. Among the measures are:

- Around half the scientists and about one-third the engineers in the United States are currently employed in research and development or its administration and management (the others teach, work in production, etc.).[10]
- The United States currently accumulates more than 100,000 Government reports each year, plus 450,000 articles and countless books and papers. On a worldwide basis, the literature is growing at the rate of an estimated 60 million pages per year.[11]
- On December 31, 1962, the U.S. Government owned 13,671 patents and the number was increasing at the rate of about 1,900 annually. A survey disclosed that around 10 percent of the inventions assigned to the Government also reached a stage of commercial utility.[12]
- In January 1963, NASA reported that its work, conducted both in Government laboratories and private facilities, had led to 786 inventions. By August 1964, the number had increased to 2,500; and by May 1965, that number had doubled to 5,000.

But volume of technology alone is an insufficient basis for justification of an effort to channel technology into the civilian economy—although it is one necessary indicator. As H. G. Barnett pointed out:

> The size and complexity of the cultural inventory that is available to an innovator establishes limits within which he must function. The state of knowledge and the degree of its elaboration during his day, the range and kind of artifacts, techniques, and instruments that he can use, make some new developments possible and others impossible. The mere accumulation of things and ideas provides more material with which to work. A sizable inventory allows for more new combinations and permits more different avenues of approach and problem solution than does a small one.[13]

It is clear that Federal support of R. & D. has in recent years generated "a sizable inventory." But how relevant to the needs of society are the items of knowledge stocked in that inventory?

Certainly, man's capability to accumulate and retrieve information has always paced his progress. But the sheer volume of information available to-

[9] Hines, William, "A Scientific Data Moratorium?," *Washington Evening Star*, Apr. 27, 1965.
[10] Rosenbloom, Richard S. "Technology Transfer—Process and Policy," National Planning Association Report No. 62, July 1965.
[11] Watson, Thomas J., Jr., testimony before the ad hoc Subcommittee on a National Research Data Processing and Information Retrieval Center, U.S. House of Representatives, May, July, and September 1963.
[12] Holman, Mary A., "Government Research and Development Inventions—A New Resource?," *Land Economics*, August 1965.
[13] Barnett, H. G., *Innovation: The Basis of Cultural Change* (McGraw-Hill Book Co., New York, 1953).

day—unless properly managed in an organized system that permits the right information to be found by the right person at the right time—may be tending to inhibit progress.

The man who has been forced, in the course of his work, to seek out that available information which is relevant to his objective will readily attest to the maze of paths—most of them unmarked—which he must follow to uncover even a small portion of the information that is potentially relevant. And in the process, he is likely to be forced to sift through a great deal of information that is not relevant.

While sig[illegible]t strides in information management have [illegible] made in the last 5 years by such groups as COSATI, AEC, NASA's Scientific and Technical Information Division, the Science Information Exchange, the L[illegible]rary of Congress, the Defense Documentation Center, and others (including a number of nongovernmental organizations), the state of the art in information retrieval (as distinct from document retrieval) is still woefully inadequate.

The size of the inventory of information in a quantitative sense is best illustrated by pointing to some standard measures of information volume:

- The last issue of the *World Bibliograph of Bibliographies* lists more than 100,000 separately collated volumes of bibliographies.
- More than 30,000 scientific and technical conferences are held each year throughout the world. Many publish proceedings.
- There are nearly 1,900 independent abstracting and indexing service organizations dealing in scientific and technical fields throughout the world, with 365 of them in the United States.
- *Scientific and Technical Aerospace Reports* (STAR), the NASA indexing guide to the world's unpublished reports in aerospace, carries about 30,000 new listings annually. The companion journal, *International Aerospace Abstracts*, which lists published articles in the aerospace field, contains about 28,000 new entries annually.
- *Technical Abstracts Bulletin* (TAB), the listing of new accessions in the Defense Documentation Center (DDC), carries nearly [illegible],000 new entries each month.
- In the last 12 months, the Science Information Exchange added 100,000 records of ongoing research tasks to its information bank.
- The National Science Foundation lists Federal obligations for scientific and technical information for fiscal year 1966 at $258,673,000. However, total Federal expenditures for scientific and technical information processing are far greater. For example, NSF reports total obligations of the AEC for this type of work at $5,474,000. The AEC, however, estimates its total expenditures in this area for fiscal year 1966 at $28,842,000. Of the total, formal budget items account for only $1,522,000.

Obviously, the volume of Government-generated scientific and technical information has reached the stage where, without systematic information management and dissemination, the odds that an interested scientist and engineer could obtain needed information would be very low indeed.

The question then becomes: Is the available information sufficiently relevant to the needs of society to justify investment—either public or private—in the means of making the right information available to the right person at the right time?

Is Government-Generated Technology Relevant?

It is obvious to even the casual observer that an extremely large technological base has been generated by the research and development programs of the Federal Government, principally the DOD, AEC, and NASA. But does this knowledge have any value in the context of meeting community and human needs?

Critics of existing programs to transfer technology from one industry or one discipline to another generally state the proposition this way: "If we spent billions of dollars to develop better home appliances, would we, in the process, get a man to the moon or build a better ballistic missile?"

The answer, obviously, is "no." But the wrong question has been asked.

Rephrasing the question to recognize the nature of R. & D. efforts of NASA, AEC, and DOD, we would ask: "If we spent billions of dollars in research and development in every scientific and engineering discipline, is it likely that the new knowledge thereby generated might find wide applicability in helping to meet the problems of an industrialized society?"

Now the answer, obviously, is "yes."

Of course, if major R. & D. programs were initiated specifically to seek solutions to given problems outside the space/defense/nuclear realm, the odds in favor of generating specifically useful new knowledge would very likely increase.

But the priorities have been assigned. The Nation is already committed to major R. & D. in support of defense, space exploration, and utilization of nuclear energy. For the purposes of this paper, then, the question is whether the results of that R. & D. might have secondary utility; whether the problems and objectives outside the space/defense/nuclear realm in any way overlap those within that realm.

Certainly, there is overlap.

nized until 1939.[15] An English patent for a "machine for transcribing and printing letters" was issued in 1714. Not until 150 years later—when Remington bought the patents of Latham Scholes—did the typewriter become commercially available.

These examples illustrate the generally experienced timelag between the discovery of new knowledge or articulation of a new concept and its practical application.

Even with a modern climate that permits provision of some Government development funds and an available defense market, there is a notable time lag. For example, it was 6 years from the invention of the transistor to the commercialization of the first transistorized amplifier.

That there should be timelags is natural. Technology does not spring forth in full bloom from the genius of a single discipline or single generation. It moves forward step by step, building on experience, drawing from a multiplicity of individual endeavors and growing steadily more complex, drawing its strength and applicability from an ever-widening range of human skills and an ever-expanding pool of scientific knowledge. Occasionally, several of technology's life sources converge, resulting in a quantum jump.

But in a society as complex as ours, there are considerable elements of luck and coincidence in the meeting of the producer of new knowledge with the potential user. But to rely on mere chance to bring about utilization of new knowledge would seem to be a most inefficient means of obtaining the maximum return on our large national investment in research and development.

Since early and widespread use of new technology can provide numerous national benefits, it seems in the national interest to effect means of shortening the time gap between the discovery of new knowledge and its use. To do that requires systematizing communication between those who generate new technology and those who can apply it to meeting unmet human needs.

And in a society structured such as ours—a structure that encourages increased specialization—traditional means of communicating no longer suffice. When new knowledge was generated in smaller amounts and fewer fields, the professional journal provided an admirable means of communicating it. When our industrial structure was less complex, the trade magazine provides a channel for communication of comprehensive information within industry. But specialization within disciplines and fragmentation of manufacturing activities have not only made it increasingly difficult to communicate across industry and disciplinary lines—it has become extremely difficult to communicate among fields of specialization within a single industry or discipline.

And just as one innovation or bit of new knowledge can have applicability in numerous areas so also the development of a new device or system may require inputs of knowledge from a multiplicity of endeavors. Knowledge is not provincial—but people sometimes tend to be. While new technology may have utility in diverse areas, it is likely not to be recognized unless deliberately brought to the attention of innovative people working in those areas, in an understandable form, and at a time when it can be given sufficient evaluative attention.

Because a capability exists does not mean it will be used. When Baird called on the Marconi Co., he was told they could find no reason to be interested in television. Optimum utilization of new knowledge will not take place as a natural process.

The discoveries of extreme magnitude, those that lead to the creation of whole new industries, for example, have sufficient inherent force to bring about their own exploitation. Like the gold coin in the coal bin, they are easily distinguished. But the incremental improvements in technology, which individually have seemingly lesser significance but which in composite underpin our industrial might, are less easily brought to the attention of all who can use them. It seems clear that any mechanism created to transfer technology should devote some emphasis to identifying and communicating incremental advances.

It is also apparent that only a relatively small amount of new technology will be rapidly transferred and utilized for secondary purposes without the existence of mechanisms specifically created to perform that function.

Or could the generators of the new technology themselves effect rapid and widespread utilization of that technology? The answer appears to be "no." For one thing, not all of them have either the skills or the inclination to bring about the application of that knowledge. Also, many of the generators are located—both geographically and in terms of professional and market orientation—some distance from the focal points of effective utilization. As James Webb pointed out:

> People performing the actual work in the NASA centers and in the plants of NASA contractors are in the best position to recognize new departures in technology and techniques and to indicate the areas of potential application. But we must still rely on the business community to supply the "profile of industrial or consumer needs."[16]

The situation is aggravated by the fact that Federal funds for research and development are heavily concentrated among a relatively small number of organizations within a few industries

[15] Dryden, Hugh L., "Interaction Between Space Exploration, Science, and Technology," Speech before the Twin Cities Section of the American Institute of Aeronautics and Astronautics, Minneapolis, Mar. 11, 1965.

[16] In *Business Horizons* (Indiana University), fall 1963.

concentrated in a few geographical regions. If the generators of new technology were encouraged to bring about its commercial utilization without the assistance of disseminators deployed geographically and industrially, the tendency would be to accentuate whatever regional and interindustry economic imbalances are brought about by the initial concentration of R. & D. performance.

Obviously an effective means of spreading new scientific and technical knowledge is through the migration of people possessing such knowledge. In the 16th, 17th, and 18th centuries, the movement of large groups of people was, in fact, the mechanism by which the diffusion of new technology took place. But the rate of diffusion was painfully slow.

At least 35 years after Abraham Darby had successfully burned coke in his iron-smelting blast furnaces, for example, many English smelters were under the impression that only wood could be used. Frenchmen first melted glass in coal furnaces almost a century after an English innovator had done so, and they acquired the secret of making flint or lead from the English after a lag of more than a century and a half.

Historically, the diffusion of technology by the mass movement of informed people was obviously effective. Equally obvious, it was slow.

Any modern governmental atempt to encourage mass movement of skilled technologists across regional and industry lines would seem to be politically untenable.

But the generators of new scientific knowledge and technological advances must cooperate in any program to channel new knowledge to its points of potential use. It is in their best professional interests to do so.

The case has been stated in the famous Weinberg Report:

> Transfer of information is an inseparable part of research and development. All those concerned with research and development—individual scientists and engineers, industrial and academic research establishments, technical societies, Government agencies—must accept responsibility for the transfer of information in the same degree and spirit that they accept responsibility for research and development itself. The technical community generally must devote a larger share than heretofore of its time and resources to the discriminating management of the ever-increasing technical record. Doing less will lead to fragmented and ineffective science and technology.[17]

The scientist or engineer working in the defense/space/nuclear community has an additional motivation for aiding in the technology transfer process. The civilian applier of his principles and techniques may, in the process of application, develop additional technology of value to the defense/space/nuclear community.

That point was well made by H. Roy Chope of Industrial Nucleonics Corp.:

> Techniques and products which have been invented and created for industrial processes in turn provide unique solutions to defense or space problems. Extension of this self-funded R. & D. has now been applied to (1) precision mission tracking; (2) measurement of space radiation; (3) measurement of cryogenic fuels in missiles; and (4) guiding aircraft and helicopter.[18]

Hence, a full circle has been made. A federally created technology (nuclear technology) was further developed and applied to peaceful purposes with private funds. The extension of the peaceful applications then provided new space uses which may not have been dreamed of by the practitioners of the original technology.

The point is clearly stated by Robert A. Solo: "The value of information increases directly in proportion to the speed and breadth of its dissemination."[19]

It might be useful to think in terms of "value added by transfer," much in the same sense as we recognize value added by transportation, communication (publishing, broadcasting, etc.), and retailing. Certainly, information has no value to a potential user unless he is aware of its existence. Further, its value increases as the information is assembled and delivered in terms of the user's language, interests, outlook, points of reference, set of values, and experience. And when the information is combined with other information that complements and supplements it—and the full package is delivered rapidly and in a meaningful form (related to the needs and objectives of the potential user), its value increases still more.

One measure of the economic value of having the right information available for the relevant purposes at the opportune time has been made by Allen and Andrien.[20] They found, in studying four Government-funded, parallel, R. & D. projects, that between 13 and 14 percent of total time spent by the teams was devoted to information gathering.

It seems clear that numerous significant economic and social benefits could be derived if mechanisms could be developed to effectively channel new technologies to the points where they could be applied to public benefit.

The Transfer Process

Commercial utilization of Government-generated technology is a very old story indeed. About

[17] *Science, Government, and Information*, Report of the President's Science Advisory Committee, Jan. 10, 1963.

[18] Testimony before the Senate Commerce Committee on June 10, 1965, in support of the State Technical Services Act of 1965.

[19] Solo, *op. cit.*

[20] Allen, Thomas J., and Maurice P. Andrien, Jr., "Time Allocation Among Three Technical Information Channels by R&D Engineers," Report on an MIT research program in the management of science and technology under NASA and NSF grants, August 1965.

3000 B.C., Sumerian metal smiths saw how a new weapon, the ceremonial battle mace, made the royal bodyguards invincible against their foes. But history indicates it was more than a century before the religious mystique which surrounded the ornamentation and design could be discarded and someone was able to abstract the essential concept: Namely, that a long handle with a bronze head enabled the warrier to smite his enemy harder than the foe could strike back with his stone hand axe. At that point—the "eureka" point in the transfer process—bronze hammers with long handles were introduced to replace hand-held stones for metalworking.[21]

Rosenbloom cites other examples: Food canning was first developed to preserve supplies for Napoleon's army. The electronic computer was invented and improved in a World War II military project.[22] These were cases of "spinoff" and "fallout." The transfer occurred largely by chance and seemed to take place in a short time interval only in the cases of extremely significant advances in technology—advances of the importance of the computer and food preservation. "The modern temper," says Rosenbloom "seems to demand more rapid evidence of civilian benefits." [23]

As has been indicated, that demand stems largely from increased concern with spurring economic growth coupled with a growing awareness that Government-generated technology can be applied to civilian needs. In so doing, both the rate of economic and growth and the quality of life can be raised. Increased governmental concern with creation of jobs also contributes to the demand.

The process by which the transfer of technology occurs can be simply stated:

> Technology utilization . . . involves the use of technology developed for one purpose to fulfill a need elsewhere. It requires: (1) The knowledge that an advance has occurred in one field; (2) the recognition of its significance in a different field; and (3) the capability to make the required adaptations.[24]

The effective channeling of new technologies, then, demands more than document dissemination, and even more than communication of information from one point to another. For the assumption is that knowledge will not only be transferred; it will be utilized. The process, it is hoped, will take place over a short timespan with resulting significant benefits.

Therefore,

> a change of approach must be in the offing. A change from an approach that views the transmission of the results of space/military research into industrial application as a happy instance of spillover to one that views it as part of an immensely difficult task of social engineering.[25]

Clearly, no one transfer technique will be suitable for technology of such variety as that being federally generated in the second half of the 20th century.

In an early study of the NASA technology untilization program, the Denver Research Institute noted six types of contribution to the commercial sector: (1) Simulation of basic and applied research; (2) development of new or improved processes or techniques; (3) improvement of existing processes; (4) increased availability of materials, testing equipment, and laboratory equipment; (5) development of new products; and (6) cost reduction.[26]

Sumner Myers has pointed to a more fundamental—and seemingly very significant—type of transfer. He sees such activities as the space program setting new standards of achievement for the entire technical community. He asserts that "the space program may be stimulating the process of technological innovation by changing professional norms and general attitudes," and suggests that "the very existence of the space program as a model of technological achievement may prove more important to the economy than either the multiplier effect of its investment or the spillover of its technology." He points out that "people are influenced by and tend to accept as their wants those goals and values shared by their reference groups. Space scientists and engineers are a reference group for industry's staff professionals." [27]

The space program and, to a lesser degree, the atomic energy program above established a new environment for innovation. This is important, for the climate must be conducive to entrepreneurship if any technology transfer program is to be effective. The innovator, or changemaker, must be accepted—even encouraged—by society if new concepts are to be exploited in the areas where they have the most promising potential.

Even with the right climate, transfer of technology is difficult. While a great deal has been learned from experimental programs conducted by AEC, NASA, SBA, the Department of Commerce, and others, these programs have not covered a very broad spectrum of transfer techniques and channeling mechanisms in relation to the number that might be usefully attempted.

For example, little has been done to effectively foster the utilization, in the civilian economy, of the methods and concepts used to solve military/

[21] Gadberry, Howard M., "The Need to Borrow Ideas from Other Industries," paper presented at the Valve Technology Seminar, Midwest Research Institute, Kansas City, Mo., Oct. 21, 1965.

[22] Rosenbloom, Richard S., "Technology Transfer-Process and Policy," National Planning Association Report No. 62, July 1965.

[23] *Ibid.*

[24] *Transference of Non-Nuclear Technology to Industry, op. cit.*

[25] Solow, Robert A., "Gearing Military Research and Development to Economic Growth," *Harvard Business Review*, November–December 1962.

[26] Denver Research Institute, *The Commercial Application Missile/Space Technology*, September 1963.

[27] In *The Impact of the U.S. Civilian Space Program on the U.S. Domestic Economy, op. cit.*

space problems. David Allison and others have suggested:

> The most important derivative of this [military/space] R. & D. effort is likely to be a new ability to solve problems. Not strictly technical problems, but those involving a mix of components: Technical, managerial, psychological, social, political. If this is true, then we are unwise to watch for spunoff gadgets. Instead, we must develop the means and the wisdom to transfer an intangible.[28]

Some of the problem-solving ability has been transferred, of course, in the process of transferring items of technology. Most such transfer demands some degree (often large) of adaptation on the part of the receiver of the technology. At that point, there is often intensive communication between the purveyor of the technology and its recipient. In the process, the recipient gains additional insight into the problem-solving and managerial concepts employed by the technology generators.

Sumner Myers takes a similar view:

> The NASA experimental programs often involve firms that would not ordinarily seek out technical help of any kind. Some interesting results have emerged through this process. These firms have had some of their problems solved—often with nonspace information. They have also been shown that they have solvable problems they didn't know they had. The NASA program also provides a good setting for serendipity. For example, one R. & D. manager—after declaring in no uncertain terms that he couldn't use any of the space technology offered his firm—went on to relate how one of the men he met at a NASA-sponsored conference led him to the solution of a problem that had been bothering him for years. One is reminded that to discover anything you've got to be looking for something. The various transfer programs get people looking for something. This may not seem to be an efficient way to transfer R. & D. information but as yet no one knows how to organize the information-innovation linkage more effectively.[29]

Significant transfer simply seldom occurs in the sense that a piece of hardware developed for military/space/nuclear use can be transplanted intact to another application. More often, it occurs by imitation or analogy.

Because effective transfer demands degrees of imitation, of concept displacement, of "imagineering," "adaptioneering," innovating, knowledge association, and extrapolation—because it is a process to which many diverse disciplines can contribute—and because it demands hard work on the part of both purveyor and receiver for its effectiveness, there are obvious barriers to its acceptance. Likewise, incentives are required.

"The real barriers," in the words of Dr. Charles Kimball, "are neither financial nor technical. The barriers are outdated institutional practice, lack of entrepreneurship, and of reluctance to accept new ideas and new practices." He sees barriers to the transfer of technology in four major areas: (1) Within corporate management—an unwillingness to take risks, the absence of adequate mechanisms to deal with all the implications of new products and new processes, an unwillingness to render existing plant and organization obsolete by adoption of the new, a concentration on the short term rather than the long term, and lack of knowledge of the Government sources of new technology; (2) within the scientific community—the Ph. D. who cannot communicate his findings or who has little economic understanding or drive, the inability to distinguish between the transfer of information and the transfer of documents, the confusion between publication and communication, the orientation of some scientists who seem to regard research as a special privileged way of life, and the scientist's inadequate appreciation of management's skills and functions; (3) in institutional factors—the lack of rapport between industry and universities, the unwillingness of some academics to relate their research to the needs of industry, the geographic separation of the generators of new knowledge from those who could employ it; (4) within the human mind itself—creativity is generally thought of as an essentially individual endeavor but American society has moved in such a way that most things are done in groups. We have not yet learned how to provide the climate that fosters creativity, and there is a need for more people to become "innovation prone." [30]

Another compilation of the barriers to utilization of new technology frequently encountered in private companies has been made by Philip Wright.[31] The barriers were brought to light when Mr. Wright invited companies being offered new NASA technology to state their views about the difficulties involved in the effective transfer of new technology for the purposes of its commercial utilization in industry. The barriers he cites are:

- The discouraging effect of abortive reviewing of technical information.
- Difficulties of evaluating advantage.
- Difficulties of assimilation.
- Inhibiting effects of companies' new idea receptive procedures.
- Cheerless effect of the high cost of evaluation.
- Frustration owing to delays in response to questions.

[28] Allison, David, "Civilian Technology Lag," *International Science and Technology*, December 1963.
[29] From *The Impact of the U.S. Civilian Space Program on the U.S. Domestic Economy*, Report of the National Planning Association, July 1965.
[30] Kimball, *op. cit.*
[31] In a report to the NASA Office of Technology Utilization on activities of the Office of Industrial Applications at the University of Maryland, a NASA regional dissemination center.

- The impediment of the difficulties of locating.
- Adverse effects of inadequate disclosures.
- Adverse results of unfavorable economics.
- Barriers owing to educational deficiencies.
- The obstructing consequences of inadequate finances.
- Adverse influence of government policies.
- Obstructions owing to impractical nature of innovations.
- Difficulties owing to inappropriate orientation of the presentation of technical information.
- Discouraging effects of limited applications.
- Inhibiting effects of the absence of information about applications.
- Hampering situations created by company disinterest in nonexclusive licensing.
- Adverse effects of inability to devote time to evaluation.
- Deterrent effect of obsolescence.
- Impending outcome of weak patents.
- Handicaps due to poor communications.
- Deterrent effect of proprietary design ownership.
- Obstructing impact of security regulations.
- Preventative effects of fear of lawsuits.

The findings of these and other investigators point up the importance of the social environment in acting as a stimulus or barrier to innovation. The problem must be recognized, or the objective defined, or the goal established if innovation is to be applied without considerable suasion. All the technology necessary to providing the optimum means of controlling air pollution can be available but it is not likely to be applied until society recognizes air pollution as a major problem; people communicate their desire to have the problem solved to those who can influence action; those who are influential recognize the availability of the technology; the economics are found to be permissive; and the balance of power among those who influence the decision swings in favor of an early and effective solution to the problem.

That is, of course, a gross simplification of an extremely complex and dynamic situation. But the central point needs emphasis: The specific social environment must be receptive—and preferably active—for technology to be effectively transferred and applied.

From the foregoing, four conclusions can be stated:

(1) For technology to be effectively transferred, the climate must be receptive to innovation and change. Thanks partially to the space program having become widely accepted as a standard for achievement or a reference point for scientific and technological excellence, such a climate does exist in the United States today, at least to an acceptable degree.

(2) For technology to be efficiently transferred, there must exist recognizable specific social needs to which it can be applied. Certainly, the list of social needs frequently cited—higher rate of economic growth, pollution abatement, improved mass transportation, better health care, more effective crime prevention, more systematic and sanitary means of wastes disposal, improved education and training methods—are recognizable to the majority of U.S. city dwellers and a great many rural residents as well.

(3) The process by which technology can be transferred from its point of origin to utility in another context is extremely complex. Too little is known about the total process; no readily accessible body of knowledge exists. But empirical knowledge is being generated by existing experimental programs.

(4) An awesome list of barriers to acceptance of innovation has been compiled by those who have practiced transfer or studied the transfer process. Some of the barriers will likely always exist and need only be recognized in the design of transfer programs. Others, once recognized, can be prevented by designing transfer methods that avoid them. Still others can only be changed by evolution of the environment. And some perhaps appear as barriers only because we know too little about creativity, innovation, human behavior, group dynamics, and the processes by which ideas become accepted within organizations.

What Is Government's Role?

If we accept that it is in the national interest to attempt to channel new technologies in promising directions, we must ask who will perform the channeling function.

No firm recommendations will be made here on the extent to which this function should be conducted in the public sector. But the authors will raise some of the questions, attempt to define some of the issues, and report on the degree of Government involvement in some past and present programs of this type.

A central issue is the degree to which the Federal Government should accept responsibilities for direct action programs to stimulate economic growth.

Another issue is the degree to which the Government should accept responsibility for the active development of national resources. Logical arguments can be made that technological knowledge has become as important to regional and national economic health and growth as were natural resources in the past. Those favoring substantial Government involvement in programs to transfer technology argue that the precedent for such Federal involvement is in past and present Government programs to make rivers navigable, to aid in the exploration, use, and conservation of the Nation's mineral supplies, and other such programs.

A third question concerns regional balances. Arguments have been made in favor of Government support of technology transfer programs on the basis that such programs will tend to offset regional imbalances in technological sophistication resulting from the concentration of Federal R. & D. funding in a relatively few States.

A fourth and thorny question involves the issue of whether Government support of programs to transfer technology to the private sector would tend to work in favor of the marginal producer. The argument is that such Government involvement would interfere in the private economy because it would tend to bring to the marginal company a partial capability that must otherwise be gained through relatively high investment on the company's part.

A fifth debate centers about historical precedent for Government involvement in programs to promote scientific activity and technological achievement and to bring about the diffusion of science and technology throughout the economy. A few events of that type are mentioned here.

One of the first patent applications under the patent law of 1790 was for "a mixture which was supposed to help make salt water fresh [through a distilling process]." Thomas Jefferson, who was then Secretary of State and as such was also the administrator of the patent law, proved by experiment . . .

> That the fresh water came from the distilling process, long known and used at sea, and that the mixture added did not enhance its efficiency. Nevertheless, Jefferson suggested to Congress that instructions for building an evaporator be printed at Government expense and distributed to all shipmasters.
>
> That Jefferson should propose the dissemination of the knowledge thus incidently called to his attention suggests that the Federal Government had a duty to promote the general welfare by broadcasting this useful bit of information.[32]

That example is from among scores of Federal ventures into the application of science. Clearly the Federal Government has long been involved, and the mandate has not been based solely on military preparedness. Instead, from the beginning, there has been the implied, and often expressed, conviction that science and knowledge should be exploited by and for all mankind.

One of the more forceful arguments for Government involvement in programs to channel new technologies into civilian applications rests on the dual points that (1) the Government is the generator of the vast bulk of new science and technology; and (2) a significant potential use for the new technology is in activities generally considered to be wholly or partially in the public sphere. This case was stated as follows by the National Academy of Sciences:

> It is clear that with increased urbanization and industrialization, our country is developing a number of problems that can only be faced on a national basis—for example, education, air pollution, water resources, weather forecasting and control, pesticides, radioactive wastes, public recreation, natural resources, air traffic control, highway safety, and urban transportation. The degree of Federal responsibility in these areas will always tend to be a matter for political debate. However, there is greater consensus on the Federal Government's responsibility for seeing that the foundations of knowledge are laid in these areas than on its operational responsibility. Research related to social goals tends to be recognized as a Federal responsibility even when operation or regulation is delegated to the State or local level or left to private enterprise.[33]

Another frequently heard argument is that the Federal Government should support vigorous efforts to transfer technology because it has a responsibility to the taxpayers to ensure the optimum return on the public investment in research and development. While the goal is desirable, the logic of the argument is debatable. If the secondary beneficiaries of the new technology can make optimum use of it without artificial stimulation, then Government assistance would not seem warranted. History shows, however, that optimum use is not likely to occur naturally. And history proves quite emphatically that there will likely be a longer timelag between development of new technology and its civilian application via natural processes than would occur with some form of catalytic action.

Although the existence of some Federal responsibility in this area seems beyond doubt, there is a serious question of degree. Since two-thirds of all R. & D. work is supported by Federal funds, the Government clearly has a responsibility to make the results of this work available for the widest possible use. However, how far should the Government go, not only in making findings available, but also in selecting and tailoring reports for most effective use by private enterprise

[32] Fairand, Max, "The Records of the Federal Convention of 1787" (New Haven, 1911–1937), p. 12, as taken from *American State Papers*, misc., I, 45.

[33] *Basic Research and National Goals*, a report by the National Academy of Sciences to the Committee on Science and Astronautics, Washington, D.C., March 1965.

and even in promoting the receptivity of private enterprise for utilizing the advanced technology?

Science and technology can flourish only if each scientist interacts with his colleagues and his predecessors, and only if every branch of science interacts with other branches of science; in this sense science must remain unified if it is to remain effective.

Inasmuch as the Federal Government now supports three-fourths of all science and technology in the U.S., the Government bears heavy responsibility to prevent our scientific-technical structure from becoming a pile of redundancies or contradictions simply because communication between the specialized communities or between members of a single community has become too laborious. Moreover, since good communication is a necessary tool of good management, the Federal Government, as the largest manager of research and development, has a strong stake in maintaining effective communication.

Almost everyone who has seriously studied the question agrees that the Federal Government has some responsibility in bringing about secondary applications of technology generated via public funds. The question is the degree to which the Government should go. This is one of the many areas in our economy where it is difficult to get programs underway because of the confusion between the proper roles of the public and private sectors. These difficulties seem greatest in areas where the responsibility is shared. Technology transfer is clearly one of them. And the precedents for successful sharing are few.

With the hope that existing programs might, in composite, show some pattern of legislative understanding of the degree of public responsibility in this arena, the authors spent considerable time examining the more significant ongoing programs in the various Federal agencies whose statutory responsibility embraces technology transfer efforts to any significant degree. Programs were studied in the following agencies:

Department of Agriculture.
Office of Science Information Service, National Science Foundation.
Defense Documentation Center.
Atomic Energy Commission.
National Aeronautics and Space Administration.
Clearinghouse for Scientific and Technical Information, Institute for Applied Technology, National Bureau of Standards, U.S. Department of Commerce.
National Library of Medicine.
Office of Technical Resources, National Bureau of Standards, U.S. Department of Commerce.
Science Information Exchange, Smithsonian Institution.
National Referral Center, Library of Congress.
Small Business Administration.
Government Printing Office.

The various programs currently underway within Federal agencies range, in degree of Government participation toward achievement of technology utilization, over a very broad spectrum. In fact, several orders of magnitude in terms of level of effort and level of support involved separate the programs of some agencies from those of others. And within some agencies, several different levels of effort are apparent.

Obviously, there is a need for a more clearly defined national policy in regard to technology channeling efforts. Let us pose the potential role of Government in the process in terms of eight distinct levels of effort, all representative of ongoing programs in one or more agencies at present.

Should the responsibility of the Federal Government end with:

Publication, i.e., making the results of research and development available (as in libraries, depositories, and journals) for interested parties, but placing the full burden of discovery and use on the potential user?

Bibliographic control, i.e., making it easy for the interested parties to seek out relevant publications?

Dissemination, i.e., actively delivering relevant publications to interested parties?

Communication, which implies some personal (versus only paper) involvement in defining the needs and objectives of the user and seeking to match specific technical information to those needs, so that understanding is achieved?

Education, which implies not only communicating specific information but also building the background of the recipient of the information to a level where the relevant information can be more effectively utilized?

Encouragement, i.e., actual continuing consultation with the user of the information to promote utilization (versus transfer, per se) of the technology?

Assistance, i.e., Government aid in adapting technology generated for a Government mission to make it useful for nongovernmental purposes (or one Government agency adapting its technology for the use of another Government agency)?

Development assistance, which implies Government action to add to the knowledge base and develop new technology specifically to meet needs and objectives in the civilian economy?

National policy in regard to technology utilization programs has been established in an ad hoc manner. Perhaps the time has come to reexamine all such ongoing programs to determine the value of each in relation to the accepted or recommended responsibilities of the Federal Government.

It is not recommended that any national policy limit governmental involvement to any one of the eight levels of effort outlined above. To do so would be to place undue emphasis on some sources and uses for technology and too little emphasis on others. Certainly, it would seem that the Federal Government has a legitimate role in developing weather satellites and medical research equipment (the ultimate level of Government involvement) and at the same time it has some responsibility for making available (perhaps only by storage) the results of its seemingly least useful R. & D.

What is recommended is that a national policy spell out the conditions under which Federal agencies should conduct, foster, or support programs at each of the various levels.

But before any such policy can be established, certain questions should be considered. Among these are:

- To what degree, if at all, can known innovators employed by Government agencies be diverted from their primary missions to assist in the transfer of technology—by, for example, speaking at seminars (dissemination); by conducting short courses (communication); by serving on task forces to adapt mission-generated technology to uses by other Government agencies (interagency assistance); by giving advice and counsel to scientists and engineers in private companies and other governmental bodies who have a demonstrated capability to utilize it (encouragement); by sabbatical leave to champion an area of technology; by personal in-house development of innovations not oriented to the mission of the employer agency (development assistance)?
- To what degree should control of technology transfer efforts be centralized? This question apparently cannot be answered on the basis of available information and should be the subject of detailed and careful study.
- How can technology relevant to the problems and objectives of external groups be identified by the originating agency? This function is, of course, mandatory for the success of a technology transfer program. One approach used by NASA—stationing "technology utilization officers" at facilities responsible for the generation of technology—has been effective. Should other agencies be encouraged to select capable personnel to perform a similar role?
- Much of the science and technology generated by Government is of a very complex and sophisticated nature. In its primary form—the technical report—it frequently is readily understandable only by scientists working in the same specialty. But external utility might be in industries or disciplines much different from that of the researcher who generated the technical report. Should Government serve an interpretive function in such cases?
- Efforts to effect the utilization of new technology for economic advancement would be greatly enhanced by a better understanding of the processes and varying modes by which new ideas become accepted and innovations adapted in various organizations expected to use the results of Government research and development. Sufficient fragmentary evidence exists to permit the formulation of several hypotheses. Detailed analysis should be made of the innovative process and searching study of the environmental factors that contribute to entrepreneurship. The results would be extremely useful in developing the most effective means of channeling new technologies in promising directions.
- Smaller businesses, which generally have limited scientific and technical resources, pose a special problem for those concerned with the nongovernmental utilization of Government-sponsored research results. NASA, for example, has designed its technology utilization program in such a way that much of the dissemination activity will eventually be self-supporting (i.e., paid for by the beneficiary rather than the originator of the technology). But smaller businesses have difficulty justifying expenditures for this purpose—even though the cost is relatively low. (The larger organization generally not only has better inhouse capability to interpret and understand the implications of new scientific information but also has a broader technology consumption pattern, i.e., its technical interests are less specialized, generally, than those of the small company.) Effective, low-cost means of serving the needs of smaller businesses—without subsidizing them in opposition to the principle of open market competition vis-a-vis the large companies they compete with—should be explored. Currently, NASA and AEC have underway joint experimental programs with the Small Business Administration. These programs may provide some understanding of how to cope with the seemingly special needs of smaller business.
- In effecting technology utilization it is important to have a thorough definition of what technology is available for use. This demands efforts to pinpoint innovations and new knowledge, to describe such innovations and knowledge in terms understandable to potential users in many industries and disciplines, and to arrange all such knowledge in a system that permits the potential user to find what he wants without having to sort through a lot that he does not want. (Because of sheer volume, this argues for computerized systems and for switching devices among various systems.) This is necessary for even the lowest levels—publication and bibliographic control—of Government involvement in true technology transfer (as differentiated from mere publication).

- The most effective forms of technology utilization demand a personal champion of the technology. This argues for wider use of a type of specialized information center not commonly found, i.e., a center staffed by articulate, knowledgeable, adaptive, extrapolative "missionaries" who can communicate an understanding of new technology and encourage its use. While the cost of such efforts should be borne in large part by the users, the initial investment is heavy. Should the Government help with "startup" costs?
- Most potential users of Government-generated technology seem unaware of the channels through which such technology can be made to flow to them regularly. There appears to be a need for local or regional "referral centers," to which any qualified seeker of knowledge can turn for guidance in obtaining that knowledge. Such centers might function as pipelines to smooth and expedite the flow of new technology into promising potential applications.

No readymade answers of substance exist for any of those complex questions. All demand careful study which should probably involve the technology's originators (for example, DOD, AEC, NASA, NSF, and NIH), its potential users (private industry, Federal, State, and local government, and universities), those with experience in transferring technology (for example, research institutes, universities, and publishers), and those who must, in the end, determine policy (legislators).

When a national policy has been decided upon, the question may still remain as to where ideally to house the function or functions within the Federal Government.

It is highly likely that a single agency to perform the function would not be the best solution. Too many different levels of activity and kinds of mechanisms will be required for effectiveness to permit such an easy answer. Centralizing the responsibility would also probably place the obligated agency in a most uncomfortable position vis-a-vis other Federal agencies. To transfer technology, one must have some technology to transfer. For one agency to police the activities of others to the degree necessary to ensure the reporting of new technology would seem to place the entire program in jeopardy. (Discussions relevant to this issue have occurred in relation to the establishment of a National Research Data Processing and Information Retrieval Center[34] and to the oft-proposed establishment of a department of science.)[35]

[34] Hearings before the ad hoc Subcommittee on a National Research Data Processing and Information Retrieval Center of the Committee on Education and Labor. U.S. House of Representatives, May, July, and September, 1963.

[35] This proposal has been debated at various times for 85 years. In the 1880's, it was proposed and the issue resolved by the Allison Commission, a Joint Congressional Commission, which concluded that the Government's scientific establishment and the scientific community in the universities had already grown too complex for such a change in organizational structure.

While it might readily be feasible to assign some abstracting, indexing, publishing, referral, and document dissemination functions to a central agency, intensive efforts that demand inhouse adaptation and development as well as thorough understanding of the technologies involved are probably best left to the agencies originating the technology.

Between those two extremes (represented on the one hand by the Clearinghouse for Scientific and Technical Information and on the other by the Atomic Energy Commission's fostering of civilian nuclear energy generating capability) lies much ground for debate. It is possible that social inventions of a high order will be needed to meet the requirements of effectiveness and efficiency. Certainly, such recently established efforts as the AEC's Office of Industrial Cooperation, NASA's Office of Technology Utilization, and the Commerce Department's State Technical Services Program will provide valuable empirical evidence some years hence of the relative effectiveness of various experimental approaches. Meanwhile, interagency cooperation and exchange of knowledge gained should be encouraged, and organizations such as COSATI might be assigned some responsibility for collecting and synthesizing the knowledge gained through these programs.

Some Existing Programs

This section reports on some existing Federal programs to channel technology or technical information or documents from originator to potential user.

While no existing program shows promise of becoming a full answer to the need for a mechanism to channel new technologies in promising directions, several programs are providing valuable experience in the design of better systems. Some of them can likely become components of a national system that might be designed at a future date.

Following are reports on some of these programs:

Science Information Exchange. A component of the Smithsonian Institution, SIE is funded principally by the National Science Foundation. It is primarily an inventory of current and ongoing research tasks. It can therefore tell a practicing scientist or engineer who is working in his field and supply a brief sketch of what these investigators are doing.

SIE's main method of operation is to obtain copies of detailed proposals or work statements for R. & D. from various Federal agencies, write descriptions of tasks expected to be performed, and categorize the tasks in terms of the various disciplines and topics to which the research might be relevant.

SIE was established to serve R. & D. program managers in Federal agencies, helping them to avoid duplication, establish priorities, maintain balances among related research fields, locate special research capabilities, and perform other useful tasks.

The existence of the information, however, allows SIE to perform a kind of technology transfer function in that SIE will tell any qualified scientist or engineer who is working in specific fields of interest. SIE thus serves a referral or clearinghouse function—or acts as a coupling mechanism among technical men with similar interests in different disciplines, industries, sectors, and regions.

SIE got its start in 1949, when rapidly expanding Government programs in medical research caused several agencies (NIH, ONR, and others) to establish voluntarily, via interagency agreement, a Medical Sciences Information Exchange. In 1953, the mission was broadened to become the Bio-Sciences Information Exchange, and the Smithsonian Institution was asked to run the program. In 1960, the mandate was enlarged to include the physical sciences and the organization was renamed the Science Information Exchange.

Since 1949, the Division of Life Sciences has accumulated approximately 300,000 records of research grants, contracts, projects, and tasks. In 1962, the Division of Physical Sciences was organized and began the collection of information on current basic and applied research in chemistry, physics, mathematics, earth sciences, materials, electronics, and engineering sciences.

SIE differs significantly from library, documentation center, and technical reference service operations in a number of respects. SIE is concerned only with records of research, planned or in progress. It does not receive progress reports, abstracts, or other forms of *published* research results. All information is supplied to SIE on a voluntary basis.

Information about each research task is registered on a single-page Notice of Research Report by SIE professional analysts with the following information:

(1) The name of the supporting agency, supporting bureau or office, and, if it is multiply funded, the cosponsors; (2) a specific title for the project; (3) the names, departments, official titles, and locations of professional people engaged on the project; (4) the name and address of the institution conducting the research; (5) a 200-word summary of the proposed or undertaken work; (6) the specific location where the work is being done; (7) the startup date for the research and planned conclusion date; and (8) the annual level of effort in dollars.

The 200-word summary of the research is indexed with 1 to 45 descriptive words for each project.

In the life sciences, Dr. Monroe Freeman of SIE estimates that 90 to 95 percent of all the research underway—45,000 to 50,000 tasks annually—that is of a federally funded nature is brought into the SIE information stream. Comprehensive coverage of the physical sciences has not yet been achieved.

In addition to its referral function, SIE provides other kinds of services. These are:

1. *Preparation of catalogs.* There are two types of catalogs: the first is a listing of all projects supported by a single agency with the projects indexed according to a predefined method established by the sponsoring agency. In the second type SIE has the job of collection and the major intellectual task of organization and editing. These catalogs are multiagency and multidisciplinary. A good example is the water resources catalog prepared at the request of the Department of the Interior and now being sold by the Government Printing Office. Catalogs are prepared by SIE for Government agencies only. However, at the option of the requesting agency, they may be provided to the public through the Government Printing Office or in some other fashion.

2. *Compilations.* These are computer printouts of work in a given field. For example, a job currently in progress involves preparing a compilation to show all work underway relating to the mobilization of urban resources.

3. *Specific topical searches.* Where a scientist or engineer wants to learn who is working in his specific field, SIE will provide a summary sheet for each ongoing project in that field.

4. *Name searches.* This is provided to program managers and project officers in Federal agencies to help them select grantees and contractors and allocate research priorities. For example, a program manager or an awards committee in a Federal agency may have 150 applications for grants whose names they send to SIE. SIE will conduct a computer search of all its information and tell how many ongoing research projects each grant applicant has, in what agencies, at what level of funding, how far toward completion they are, and other salient information.

During 1964, SIE answered 5,000 questions of the type 3 kind, and during the last 12 months, it supplied about 1 million full-text copies of summary sheets of ongoing work.

Atomic Energy Commission. Since its inception in 1946, the AEC has had a vigorous program for the dissemination of unclassified scientific and technical information to encourage industrial usage. The Commission has provided consulting services, training, and other assistance to the nuclear industry.

Recently, AEC decided to extend the boundaries of its industrial cooperation program to encourage consultation with respect to nonnuclear applications of its nuclear-oriented work and to allow the use of its facilities, equipment, and services in the performance of limited research and development work toward nonnuclear industrial applications.

For that purpose, AEC has established Offices of Industrial Cooperation to serve as a bridge between the laboratory and industry. The Offices are charged with carrying out the following functions:

(1) To actively search for items of information and disseminate this information to industrial organizations; (2) to be aware of the needs of particular sections of industry; (3) to encourage the industrial participation program; (4) to arrange industrial consultation and visits by industry representatives; (5) to work with such local organizations as now exist which will be suitable for its general purposes.

The major difference in the AEC's technology utilization activities since the establishment of Offices of Industrial Cooperation is that the laboratories where these offices exist can now make overt gestures toward industry to enhance the transfer of nonnuclear technology resulting from nuclear R. & D.

The following statement comes from the first semiannual report of the Argonne Office of Industrial Cooperation, January 1 to June 30, 1965:

> An observation which occurred quite early was that the size range of the transfer items in the companies to which technology can be transferred is very great. For example, a transfer item can be anything from an experimental boiling reactor to a thickness gauge; or anything from a voting machine to a Holmium Heat Sink. It can be a finished product ready for production or an idea. An entire new company can be created and therefore be a transfer item as is the man who takes a skill to the company. The industries involved in this business of technology transfer may range in size from General Electric or du Pont—companies with sophisticated research capabilities and interests—to a two- or three-man production shop with no research capability or interest. This means that the system which is set up to transfer technology from Government research to industry must be flexible and versatile enough to cover these wide ranges.
>
> It is also observed that there are two essential components of technology transfer. These are an automated information retrieval and dissemination system and a personal contact. The information pile-up has become so great that information is essentially lost unless a selective dissemination system is perfected. In addition to the identification and location of information, there must be a personal contact between the source of information and the industrial user. This personal contact serves several functions. He can help locate information, aid in adapting it for use, and probably more important, convince the industrial user that the available information could possibly be of use to him.

In the Atomic Energy Act of 1954, the Congress established policies that bear upon making available to industries, for nonnuclear uses, the results of the AEC's research, development, and industrial operations. Section I of the act declares it to be the policy of the United States that:

> The development, the use, and control of Atomic Energy shall be directed so as to promote world peace, improve the general welfare, increase the standard of living, and strengthen free competition in private enterprise. . . . The dissemination of scientific and technical information relating to atomic energy should be permitted and encouraged so as to provide that free interchange of ideas and criticism which is essential to scientific and industrial progress and public understanding to enlarge the fund of technical information.

In keeping with that national policy, the AEC strongly supports the objective of assuring the maximum availability of results of Government-generated research for beneficial use of the civilian economy. Reports Dr. S. G. English, assistant general manager for research and development, AEC:

> Our national laboratories and other principal contractors have been encouraged to take all reasonable steps to promote the transfer of the results of AEC technological developments to the civilian sector. In 1964, a copy of the implementation of this policy was extended beyond application for nuclear-oriented purposes into the area of potential use for nonnuclear purposes. This underscores our recognition that our ideas, inventions, developments, processes, techniques, materials, equipment, instruments, etc., which resulted in AEC research and development should be available for use throughout the national economy.

The AEC has been using 13 different means of transferring the results of its R. & D. efforts. These areas were recently reported upon in an AEC study of its technology transfer activities, and excerpts follow:

DTI Services. AEC's Division of Technical Information is the only AEC information program which has a specific "line-item" budget appropriation. Its most important services are:

> Publication of five quarterly Technical Progress Reviews dealing with civilian power reactor and isotope technology.
>
> Publication of the semimonthly *Nuclear Science Abstracts*, which is the world's most comprehensive abstracting and indexing service devoted to nuclear science and engineering.
>
> Publication of 12 to 15 books and monographs per year.
>
> Management of the Engineering Materials Program, which makes available drawings, specifications, and design criteria.

Management of AEC's publication distribution network.

Coordination with other Government agencies, including the Clearinghouse for Federal Scientific and Technical Information.

Topical Reports. AEC encourages contractors to publish topical reports, which are often annual reviews of the status of programs at the various sites.

Technical Journals and Meeting Papers. Almost all of AEC's contracts provide specific encouragement for scientists and engineers to publish unclassified findings in the open literature.

Trade Journals. Probably the most widely read items of technology are those which appear in trade journals. This is an attractive mechanism, for more than others it tends to get the right kinds of information to the right people. AEC-funded technology naturally appears in journals specializing in nuclear development. Only occasionally does it appear in others, such as those in the metal-working field or those more business oriented.

Seminars and Information Meetings. Almost all AEC facilities conduct regular seminars and information meetings. However, only a limited number of such meetings have been held for the express purpose of transferring AEC-sponsored technology to industry.

Advisory Boards. There are currently 21 committees and boards which provide advice and guidance to AEC. Most of these advisory committees are concerned with specific programs or problems, such as Nuclear Cross Sections Advisory Group, Computer Advisory Group, Reactor Physics, Biology and Medicine, etc. The members of the committees are leaders in their respective fields, and as such provide a subtle mechanism for the transfer of information.

Information Centers. At the present time there are 12 specialized information centers located throughout the AEC contractor complex. Each operates in a very specific, very narrow range and is designed to be the most complete repository of information in its field.

Consultation Services. AEC policy provides for several types of consulting services to industry on a nondiscriminatory basis. One type, offered without charge and more properly identified as a conferring service, is short term; for example, the need for clarifying information on requests for bids, or an inquiry relating to a published article. When formal consultation is required, such as involving the solution of a specific technical problem, a somewhat more regulated approach is used and costs are recovered by a system of fees established by AEC.

Work for Private Industry. To meet its own program needs, AEC has established certain unique facilities. AEC's policy as expressed in Immediate Action Directive No. 7600–2, September 14, 1964, encourages the use of these unique capabilities by private industry insofar as: (1) It would not adversely affect AEC's programmatic work; (2) it would be conducted on a nondiscriminatory basis; (3) it would be provided on a full cost recovery basis wherever practicable; (4) it would act to provide "effective" technology transfer; (5) it would apply only with respect to AEC's unique or special capability.

Access Permit Program. Since 1954 the AEC, under its Access Permit Program, has made available classified information to individuals and companies engaged in the civilian use of atomic energy. This is accomplished through plant tours, briefings, and the furnishing of reports and drawings. At the present time there are about 550 Access Permits in effect; in almost every case the permit holder must bear the cost of obtaining security clearances.

Vendor Subcontracts. The vendor-buyer relationship is an excellent means of technology transfer. To begin with, the circulation of requests for bids informs manufacturers of changing requirements. Although the direct know-how is transferred to the successful bidder, there is usually an appreciable gain in the state of the art for the entire industry.

News Releases. News releases by AEC and its contractors are an important method of information dissemination. While they do not contain detailed technology, they are useful to highlight the existence of new developments and provide references for further contact.

Patent Policy. The AEC's patent policy is to ensure that atomic energy technology developed with public funds is made available freely to all U.S. citizens.

NASA Office of Technology Utilization. The Space Act of 1958 charged NASA with the obligation to "provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof."

In response, NASA has evolved a program under an assistant administrator for technology utilization to identify new technology resulting from the agency's broad ranging R. & D. programs, to report it, where practical, in industrial terminology, and to communicate it to civilian organizations through several mechanisms, including regional dissemination centers.

The NASA Technology Utilization Program draws upon a resource provided by the Scientific and Technical Information Division, which collects (on a worldwide basis), abstracts and indexes, and brings under bibliographic control published and unpublished literature relating to aerospace activities. Thus, the information bank available for the NASA technology utilization effort is broader than the results of NASA research and development alone.

The NASA technical information collection now totals about 200,000 documents and is increasing at the rate of about 5,000 items per month.

At the same time that incoming reports are being processed for announcement, a copy of each report is microfilmed (on microfiche) by the NASA Scientific and Technical Information Division (STID). This permits the contents of 1,000 average-size reports to be contained in a shoebox.

The reports are indexed in great depth on magnetic tape to permit literature searching by computer. The tapes are updated twice monthly, permitting retrospective searching from a variety of viewpoints. This also forms the basis of the NASA Selective Dissemination of Information Program (SDI), a computer-based system for notifying individual scientists and engineers of new reports and journal articles of value in their particular work. SDI can be likened to a library run in reverse, where people (i.e., their specifically defined interests) are catalogued as well as acquisitions. As new reports are received, they are matched against the interests of individual users.

NASA is currently beginning an experimental program to examine the feasibility of giving scientists and engineers remote access to the computerized information bank to permit them to "browse" and search as they desire on a time-sharing basis via remote consoles connected to the central computer.

The major program elements of the NASA Technology Utilization Division are: (a) Identification of industrially relevant new technology; (b) evaluation of that technology to determine its significance and import; (c) publication of especially useful new information in industrially oriented language and format; and (d) dissemination of the information via traditional means and via regionally deployed contracting organizations (universities and research institutes) which match the new technology to the needs, interests, and objectives of organization in their regions.

The identification function is performed at NASA field centers primarily by technology utilization officers who monitor NASA research and development work at the centers and in contractor organizations to identify useful new technology. Important new technology is reported in the form of a "flash sheet" and described in considerable detail with potential nonspace applications suggested. The flash sheets are then sent to research institutes under contract to NASA where the reported innovations are evaluated to determine their significance, novelty, and industrial relevance. Innovations that pass this screening are published in one of two formats: (a) As Tech Briefs, one- or two-page bulletins; or (b) as Technology Utilization Reports, lengthier documents covering in detail innovations deemed especially significant and useful for secondary purposes. (Approximately 150 industrial inquiries are generated, on the average, by each Tech Brief.)

In addition, the NASA Technology Utilization Division publishes new technology information in (a) Technology Utilization Notes—collections of groups of innovations in a given field, such as *Selected Welding Tips;* (b) Technology Surveys—state-of-the-art reports on aerospace contributions to entire areas of technology, where the space program has brought about a significant increase in the available knowledge in a given area. Surveys published thus far include *Advanced Valve Technology*, *Inorganic Coatings*, *Plasma Jet Technology*, *Microelectronics in Space Research*, *Magnetic Tape Recording*, and *Hazardous Materials Handling* (surveys are prepared under contract by authorities in the fields to be covered); and (c) special publications—handbooks, conference proceedings, special studies, and selected bibliographies.

NASA's eight experimental regional dissemination centers are special coupling mechanisms at the local level. The centers are: (1) Midwest Research Institute, (2) Indiana University, (3) Wayne State University, (4) University of Maryland, (5) University of Pittsburgh, (6) North Carolina Science and Technology Research Center, (7) Southeastern (Oklahoma) State College, and (8) University of New Mexico.

Each center offers a variety of services to private companies or other organizations in their regions: Among the services are:

Application Engineering. Professional personnel in the regional dissemination centers (RDC's) help company technical people define their problems and objectives.

Retrospective Searching. Each RDC either has a computer or obtains computer service from another RDC. A corporate engineer can pose his question to the RDC, whose personnel will devise a search strategy and conduct a retrospective literature search via computer to seek relevant information.

Selective Dissemination. Each RDC builds an interest profile for its "customers." This is a description of each person's (or organization's) continuing interest in language compatible with the NASA Technical Information System. As each new computer tape with references to the latest NASA technical information is made available to the RDC, interest profiles can be matched against the descriptors on the tape and a set of references with abstracts will be called out by the computer for each person being served. Thus technical people can be continuously updated.

Other Services. RDC's also bring about the coupling of new technology and potential new application by conducting occasional conferences and seminars, which bring companies into contact with leading scientists and engineers in NASA centers, NASA contractor organizations, and elsewhere. The RDC's also perform a referral function, leading customer companies to sources of additional information and to individuals in NASA who can provide them with needed information in depth.

The dissemination portion of the NASA Technology Utilization Program is designed to be eventually self-sustaining via users' payment of fees for services rendered. Membership fees are based on company size, volume of service rendered, and other factors, and range from less than $500 to more than $15,000 per year. More than 130 companies are now paying annual membership fees at three centers. At other centers more than 100 additional companies have paid for seminar attendance, individual literature searches, and the like. More than 3,000 companies are receiving some measure of service from the centers.

Table 2 gives some other measures of the NASA Technology Utilization Program:

TABLE 2. SOME MEASURES OF EFFECTIVENESS OF NASA PROGRAM

Services	Fiscal year 1963	Fiscal year 1964	Fiscal year 1965	Fiscal year 1966
Tech Briefs published	0	123	300	[1]600
T.U. special publications published	0	9	11	[2]40
Active RDC's	3	7	8	10

[1] Projected on basis of first quarter, fiscal year 1966, processing and expected input from expanded contractor reporting.
[2] Projected on basis of first quarter, fiscal year 1966, production of publications and work in process.

Clearinghouse for Federal Scientific and Technical Information. Located within the National Bureau of Standards in the Department of Commerce, the clearinghouse is primarily a document sales agency, but also performs other information dissemination functions.

It was established in answer to a recommendation in 1964 by the Federal Council for Science and Technology that the Department of Commerce expand its clearinghouse functions, building upon the Office of Technical Services, then in existence.

The clearinghouse makes available, at low cost, copies of unclassified and unlimited R. & D. documents resulting from the work of many Government agencies. Its principal services are:

(1) Sale of reports (more than 50,000 a year) based on Government-sponsored R. & D. and sale of translations of foreign scientific and technical literature.

The availability of new documents is announced in several ways: (a) Via mention and abstracting in *Fast Announcements*, a new release sheet indicating the availability of significant new documents and grouped by subject fields; and (b) via announcement in one of the accepted announcement journals, including *U.S. Government Research Reports*, which list documents generated by agencies other than NASA and AEC; *Nuclear Science Abstracts*, which lists nuclear science documents and publications; *Scientific and Technical Aerospace Reports* (STAR), which lists new reports of the aerospace community; and *Technical Translations*, which lists new translations of important publications originally issued in foreign languages. Recently, the clearinghouse has begun issuing a *Government-Wide Index*, a monthly consolidated index to Government-sponsored R. & D. documented results.

(2) Literature searching services, which have recently been broadened. Clearinghouse collections searched include unclassified and unlimited research reports on defense, atomic energy, space, and other agency projects, as well as technical translations and information on Government-owned patents. The service is operated by the clearinghouse in cooperation with the Department of Agriculture, the Department of Interior, and the Science and Technology Division of the Library of Congress. The clearinghouse reports that steps are being taken to make available the literature resources and specialized information services of other Government agencies as well.

(3) A referral function is also performed by the clearinghouse, which is setting up a master file of information sources in the physical sciences and engineering that include Government-sponsored centers and private industry. The clearinghouse cooperates with the National Referral Center of the Library of Congress in providing the service.

(4) Selective bibliographies are also compiled in many areas of broad interest, such as plastics, welding, transistors, lasers, etc. A free list of these bibliographies can be obtained by writing to the Clearinghouse for Federal Scientific and Technical Information.

(5) Technical information contained in selected Government research reports is examined, reviewed, and "packaged" for industry's use and distributed to such local groups as universities, technical assistance organizations, State and regional economic agencies, professional technical consultants, and others. The packages consist of selected abstracts, indexes, literature reviews, and other information aimed at specific industrial needs, e.g., metal working, textiles, chemical processing.

The clearinghouse now has 4,000 subscribers to its biblographies, with about 80 percent from large companies. Often, one company represents a dozen or more subscribers, and for example, one large Midwestern firm has 119 people subscribing to the bibliographies.

Fast Announcements are presently mailed to 20,000 people. Local groups—State chambers of commerce, manufacturers' associations, consulting engineering groups, and others—cosponsored initial meetings with field offices of the Department of Commerce to explain the program and encourage industry use of it.

State Technical Services Program (Department of Commerce). The newest Federal service in technology transfer is based on legislative authority only 6 months old, and, of course, will likely not reach operational status for some time. This is the State Technical Services Program, to develop institutions in the States to disseminate technical information and otherwise assist local business and industry to obtain and make use of scientific and technical information emanating from federally funded research and development.

The purpose of the program is broadly stated in the enabling legislation as providing "a national program of incentives and support for the several States individually and in cooperation with each other in their establishing and maintaining State and interstate technical service programs designed to achieve the ends" of wider diffusion and more effective application of science and technology in business, commerce, and industry.

The technical services to be provided by the State institutions under the program are classified as (1) preparing and disseminating technical reports, abstracts, computer tapes, microfilm, reviews, and similar scientific or engineering information, including the establishment of State or interstate technical information centers for this purpose; (2) providing a reference service to identify sources of engineering and other scientific expertise; and (3) sponsoring industrial workshops, seminars, training programs, extension courses, demonstrations, and field visits designed to encourage the more effective application of scientific and engineering information.

The initial step under the program is the preparation of a plan and development of a means of implementing it. Specifically, the legislation states:

> The designated agency [organization within each State appointed to administer the program by the governor] shall prepare and submit to the Secretary [of Commerce] in accordance with such regulations as he may publish: (a) A 5-year plan which may be revised annually and which shall: (1) outline the technological and economic conditions of the State, taking into account its region, business, commerce, and its industrial potential and identify the major regional and industrial problems; (2) identify the general approaches and methods to be used in the solution of these problems and outline the means for measuring the impact of such assistance on the State or regional economy; and (3) explain the methods to be used in administering and coordinating the technical services program. (b) An annual technical services program which shall (1) identify specific methods, which may include contracts, for accomplishing particular goals and outline the likely impact of these methods in terms of the 5-year plan; (2) contain a detailed budget, together with procedures for adequate fiscal control, fund accounting, and auditing, to assure proper disbursement for funds paid to the State under this act; and (3) indicate the specific responsibilities assigned to each participating institution in the State.

This program, then, is designed to provide local access to unclassified and unlimited information generated by Federal R. & D. It will not permit special tailoring of the information to the specific needs of the individual user, however, because the law states that no services may be specifically related to a particular company, public work, or other capital project except insofar as the services are of general concern to the industry and commerce of the community, State, or region.

Some Proposed Mechanisms

The application of technology to needs and objectives in the civilian economy can result in important economic, social, and cultural benefits. A huge and rapidly growing inventory of scientific knowledge and technological capability exists in the United States as a result of continuing high public investment in research, development, and engineering. Reliance upon traditional processes for the diffusion of science and technology results in undesirable lags in the application of that knowlege and capability in contexts outside the military/space realm.

It is possible to catalyze the transfer process. Existing experimental programs have been successful in bringing about some transfer and have provided an opportunity for learning. But we still have much more to learn if we are to effectively create a catalytic effect.

Our ability to bring about technical innovation appears to have outrun our capability for social invention, at least momentarily. "It is a fair comment that industrial societies have shown little originality or ingenuity in creating institutions to ensure that all new ideas will be swept into the net and that nothing will be lost." [36]

In recent years, when at last noteworthy scholarly attention has been paid to the question of technology transfer, it has become increasingly apparent that new mechanisms must be devised to perform the transfer or channeling function.

It is now recognized that:

> In a society as complex as ours, it would be sheer coincidence if the producer of new knowledge or ability should meet with the potential user.

> We need intermediaries, variously described as innovators, merchandizers, advocates, couplers, entrepreneurs. No matter what they are called, it is they

[36] *The Sources of Invention, op. cit.*, p. 9.

> who must match the potential of scientific knowledge gained through research, the production capability resulting from engineering development of research results, the physical needs and wants of society as interpreted by marketing research and analysis, and the cultural values of this society as reflected by economic, social, and political attitudes and activities. Without them, there will be haphazard match at best between the means and ends.[37]

What is being demanded are mechanisms that will take the technology to the potential user rather than to hope that the potential user might seek out or stumble across the technology. That implies making available relevant and accurate information to the potential user in a language and form that he understands, at the time when it is useful to him, in an environment conducive to his acceptance of it.

A competitive free enterprise system works in favor of the application of new technology. The pressures of the marketplace spur the innovative process. As one spokesman noted: "In today's economy, if you can't say your product is 'new and improved,' you had better be ready to say '20 percent off.'"[38] But motivation and desire are not sufficient conditions for solution of the problem. The desire to keep from drowning does not always teach a man to swim.

In an earlier time, when the technology was less complex and less voluminous, the technically trained entrepreneur was able to seek out the information he needed. That capability diminishes each day.

The pace of technological change, the volume of new technology being generated, the multidisciplinary impact of technology, and the multiplicity of diverse uses for new knowledge, create a need for social invention. Doing less leaves us in a defensive rather than an offensive posture in relation to change.

The unmet human and community needs with which we are most concerned today have one common element: Their solution, in a technological sense, will be largely dependent on the ability of private companies to muster all of the required technology and apply it in a highly specific fashion.

No one doubts the ability of existing corporations to design systems to solve many of the problems. But these will not be the optimum systems unless all the reasonable alternatives can be examined.

The development of a desirable mass transit system depends, in the end, on an ability to make the best bearings and seals, the best low-cost automatic control systems, the most efficient air-conditioning equipment, the most effective sound and vibration damping, and other related hardware items.

Thus, the channeling of new technologies to technical people in private companies must be the central objective of any effective technology transfer program. As Sumner Myers noted:

> An invention might be conceived in or out of a business firm. It may be perfected in or out of a business firm. But, sooner or later, if it is to be introduced into the economy, this will be done through a business firm.[39]

Perhaps social invention is required on two planes: One, to get new technology to those private companies who can apply it, both as a means of speeding economic growth and as an essential element in the solution of public problems, via a system responsive to the needs of individuals in the technical community; and two, to aid, from a systems viewpoint, in creating the means or an effective market for applying new solutions to our problems.

For example, the many technological inputs useful in the design of better air-pollution control devices need to be channeled to private companies serving that market. Secondly, a means must be devised to bring together all the fragmentary influences which will determine whether new control methods are indeed put to use.

To solve effectively, for example, the air pollution problem in any metropolitan area demands the cooperation of the many municipalities, counties, and other political subdivisions that make up that metropolitan area. In some cases (the New York, Kansas City, and Cincinnati areas, for example), more than one State is involved. Solving the water pollution problem in Lake Erie and making maximum use of that natural resource must involve two countries, eight States, and uncounted local governmental bodies.

The greatest motivation for the use of new technology is the existence of a market to which it can be applied. But how can private industry be expected to make huge investments in the engineering effort required to convert new technological knowledge into practical hardware when there is not the least assurance that the resulting devices can be sold at a profit? Thus, an apparent need arises for social innovation at the market level.

Some entrepreneurial efforts of this type have been accomplished. One good example is the School Construction Systems Development Project in California, where advanced building design concepts are being applied because several school districts indicated a willingness to buy the resulting product. The entrepreneurs involved created a market of sufficient size to justify the investment by several private companies in the engineering of advanced building components and subsystems.

It must be remembered that technology does not

[37] Schrier, *op. cit.*
[38] Gadberry, *op. cit.*

[39] Myers, Sumner, "Attitude and Innovation," *International Science and Technology*, October 1965.

occur in readily usable packages. To solve a specific problem in one context may demand the pulling together of technology developed for a dozen other purposes, its adaptation to the specific situation (at considerable cost), plus, often, the invention of additional technology. Making effective use of new technology often requires more investment and more creative ability than did the creation of that technology in the first place. The competitive market is an exceptionally fine mechanism for bringing about that investment and application of ingenuity. But the marketplace has not been able to function effectively in relation to the pressing urban problems of today. The influences that would create a market are so fragmented that no market has been shaped or defined.

Where a problem exists, there generally is economic opportunity. Where there is economic opportunity, private business should be capable of response. But in the case of most urban problems, there is a missing link—a definable, responsible consumer.

Perhaps a related reason why these problems have not been solved is that a highly sophisticated systems approach must be employed for factors to be considered are many and in dynamic relationship. The systems capability required exists in few places outside the space/military sphere.

That kind of reasoning stands behind the experimental programs underway in California where large private companies—accustomed to working on space/military problems—have been asked to consider questions like the control of crime and delinquency.

When the State of California decided to sponsor four studies of such earthly problems, more than 50 companies, mostly from aerospace, competed for the four $100,000 contracts. That each winning company has reportedly spent more than twice that amount in consideration of the problem indicates the responsiveness of private industry to the existence of a market.

Our problem, it seems, is that we have not been able to convert our unmet human and community needs into definable markets that would be recognized economic opportunities. Senator Gaylord Nelson has recently proposed studies similar to those in California on a national scale. In introducing the proposed legislation (S. 2662), the Senator noted, in part:

> It would be highly in the national interest to begin devoting a portion of the talents and brains of *our* defense and space industries to other national goals of a great society. This would require no diminution in either our defense or space commitments. We can do both—we can have guns and butter; we can have a moon shot and a national plan for the abatement of pollution; the Polaris project is not incompatible with a new and scientific attack on the terrors of crime. Moreover, the California studies have shown that private firms can help us achieve this objective. . . .
>
> In fact this capability and brain power already available throughout the Nation is . . . a scientific weapon of demonstrated power and a source which represents a high national investment.
>
> Our task is to recognize that we have the scientific know-how, and the men, to solve almost any problem facing society. Once we understand this, I am confident we will choose to use the resource; we will choose to set our highly trained manpower loose not only on space probes but on down-to-earth problems; we will choose to use systems analysis, the computer, and every modern resource available to us in the quest for progress.

A possible means of using those resources and at the same time bringing together the fragmentary influences for the solution of urban problems was suggested at the Engineering Foundation Research Conference on Technology and Its Social Consequences, held at Andover, N.H., July 26–30, 1965.[40]

The suggestion involves local competitions for Government grants to design systems solutions to urban problems. Patterned in part after the AEC's request for proposals on the location of its proposed new linear accelerator, the suggestion would be for the Federal Government to offer a sizable grant—or matching funds—to the winner or winners of a competition for the design of systems for mass transportation, waste disposal, and other urban problems. Proposals would be submitted by and on behalf of entire communities.

The demonstration system that would likely be designed by the winning community with Federal support would be adaptable to the needs of other communities.

The value of this proposed mechanism lies largely in the ability of such a potential award to create a recognizable market—to draw together all the groups within a community who will influence the solutions to the community's problems. Thus it is felt that much will be gained even by communities that do not win awards because many diverse interests will have worked together to design proposals. Such a cooperative effort is seen as a stimulus to further cooperative efforts, and would tend to achieve a degree of cohesiveness and cooperation in many communities that did not exist before. In part, this is using the systems concept in a social and political as well as technological sense.

There is no doubt that a systems approach is required for the solution of most of the pressing problems of our urban communities, and it is frequently suggested that companies now serving the space/military market be encouraged to diversify into areas where the major problems lie. The California experiment tends to reinforce that view.

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[40] Credit for the suggestion must go primarily to Dr. Lyle C. Fitch, president, Institute for Public Administration, and Dr. Arthur Weimer of Indiana University.

Whether such diversification would be the optimum approach to solving the problem is debatable, for the record of successful diversification by defense contractors is meager. Murray Weidenbaum has pointed out:

> Since the end of World War II many major defense contractors have sought to diversify their operations into commercial lines of business . . . . These companies attempted to utilize the technological capabilities developed in the course of their military work to design and produce a great variety of commercial items . . . . With one major exception, these diversification attempts have each been relatively small in comparison with military equipment. The exception, of course, is transport aircraft for the commercial airlines . . . . Other than the few firms selling to the airlines, the large defense suppliers, especially in the aerospace field, have reported commercial sales of 1 or 2 percent, or even less over the years. The list of abandoned commercial ventures is a long and constantly growing one. The surviving efforts continue generally at marginal levels—either actually losing money, barely breaking even, or showing profit results considerably below military levels.[41]

Solo has also explored this question:

> Differences setting the civilian apart from the space/military forms of business organizations also appear to be growing. The two sectors have taken different paths of development. It is entirely natural that this should be so, for those who produce and sell to the civilian market and those who produce weaponry control systems, instruments, and components for the military market operate in quite different environments, and are shaped by quite different forces. Sharp variances between two sectors show up—in the nature of risk, in the appropriate ethics and standards of conduct, in the means of survival and growth, in the emphasis on the costs of production in the one instance and on performance characteristics on the other, in the fabrication of the complex, perpetually changing, prototype in the one and in prerequisite long runs of standardized outputs in the other, in the buyer-seller relationships, and in the nature of organization controls.[42]

The problems of defense contractor diversification into other areas of endeavor are obviously formidable, but considering the capability that exists in such corporations, their ability to contribute to the solution of civilian problems dare not be lightly dismissed.

Another frequently proposed means of bringing the knowledge to the need—or focusing the capability on the problem—is to encourage the mobility of technically trained people. It has often been suggested that sophisticated technologists and experienced systems analysis from military/space organizations be "transplanted" to organizations with marketing know-how in dealing with the civilian sector to raise their level of technical capability.

Allison has reported on that issue:

> One of the most serious phenomena we are up against is the direction in which "people transfer" goes: For it goes in the wrong direction—from civilian to defense. Donald Fink, ex-head of Philco's research activities, tells how it happens in the electronics fields: "In electronics there are two groups of engineers: Those who are still working on consumer and industrial products and those who have gone on to Government work. These two groups are quite distinct and the path from one type of occupation to the other is strictly a one-way path. They [scientists and engineers] do not go back because Government work allows them to work near the frontier of science and technology; if they are clever and hard-working, they will use the proper engineering solution, and it will be paid for." The result of this, says Fink, is that technological advance in consumer products is at a standstill compared with weapons systems. . . . We are developing scientists and enginers who dc not know the free enterprise system, because they have only lived in the Federal Government environment.[43]

Most of the evidence gathered tends to support the conclusion that there is little movement of personnel between the two sectors. But whether or not such mobility can be brought about seems beside the point. It would certainly not be proper for the Government to attempt to intervene in the process by which people choose where they want to work. Nor does any other means of encouraging such mobility on a large scale seem practical.

While the lack of intersectoral mobility may be viewed as a problem per se, it represents what may be an even more difficult problem in the context of technology transfer, i.e., the difficulty in communicating from one sector to the other.

A message is more likely to gain understanding and response if it fits the pattern of experiences, attitudes, values, and goals of the receiver. True communication is dependent on a number of forces, and the sender of the message can really only control a few of them. He can shape his message, and he can decide when and where to introduce it. He cannot control the environment in which the message is received and in which response takes place. the attitudes and personality state of the receiver, or the receiver's group relationships, standards, objectives, and priorities.

The problem has been eloquently described by Robert A. Solo:

> Rendering articulate the complex and the new is a most difficult task; difficult even when those who would speak together share a common language. And sharing language is far less the usual case than is ordinarily supposed. Such a language is no mere matter of grammar, syntax, and standardized vocabularly. It is also in the habits of thought, in the individual's points of reference, in his philosophy, his values, and his experience, in the form of establish-

[41] Weidenbaum, Murray L., "The Transferability of Defense Industry Resources to Civilian Uses." Reprinted in *Convertibility of Space and Defense Resources to Civilian Needs: A Search for New Employment Potent'als,* Report on selected readings in employment and manpower prepared for the Senate Subcommittee on Employment and Manpower. Washington. D.C.. 1964.

[42] Solo, "Gearing Military Research and Development to Economic Growth." *op. cit.*

[43] Allison. *op. cit.*

ing credibility, and in his manner of ordering the evidence. We speak at each other but we hardly ever converse. And if the one speaks openly and clearly of the significantly new, the other must not merely listen. He must have the capacity to comprehend and assimilate. He must be able to understand. There are two sides always, the speaking and the listening, the giving and the receiving; both require effort and skill. The communication of significantly new insights, invention, thought—even between two individuals face to face—is difficult and rare. But how infinitely more difficult when the communication of invention or discovery is not from man to man but from group to group, from company organization to company organization, from industry to industry, from sector to sector, from nation to nation, from social culture to social culture. Language, interest, outlook, distance, and time—sheath upon sheath—separate the thought and perception of one from the perception and thought of another.[44]

The point is: Any means of channeling new technologies in promising directions eventually boils down to communicating information on new technology from its point of origin to its point of potential use.

Rosenbloom has agreed:

> The transfer of technology—whether it be from person to person, firm to firm, industry to industry, or government to private enterprise—depends primarily on the exchange of information rather than upon the exchange of things. In the long run, therefore, the fullest utilization of the technological by-products of military and space development will flow from a healthy and effective technical information system. This system is not a single monolithic entity, but rather is an amalgum of many loosely interlocking institutions and procedures, serving many publics, concentrating on various aims. Within it, information is exchanged not only by the storage and dissemination of documents, but also by many interactions, formal and informal, between people.[45]

Thus the mechanisms devised to perform the function will center on the gathering, evaluation, packaging, analysis, interpretation, categorizing, extrapolation, assembly, association, handling, and communication of information.

To perform those tasks well, we must learn considerably more about both man and machine. We must develop mechanical and electronic tools, primarily computer systems, to permit us to speed the routine portions of the task. And we must find, educate, and motivate people to perform the more imaginative portions of the work.

As has been reported here, some of the experience and knowledge necessary to build these man-machine systems has already been achieved and more is being accumulated from programs now underway.

An examination of history also shows that we have numerous models we might borrow from and some we might want to deliberately duplicate, experimentally, to learn how to design ultimate systems.

In many instances, there is a real question whether money should be spent to search for a document, to search for knowledge and skills, or to start from scratch. Perhaps one reason that question occurs so frequently is that our models have been less than adequate, and that we have failed to combine elements of several models into one system.

There is increasingly a need to provide a means of taking the technology to the potential user, rather than hoping he will be willing and able to unearth it from its variety of resting places. The transfer of technology depends primarily on the effective communication of information, implying relevance of the information and understanding on the part of the potential user.

Meeting many unmet needs will depend, in large measure, on the ability of innovators in private companies to obtain a wide range of scientific and technical information in a form conducive to their use of it. That means that innovators in private companies must be a focal point in the design of channeling methods.

Thus we must next consider what we have learned and understand in regard to the essential elements of a system that will successfully channel new technologies from their multiple points of origin, in a variety of combinations, to their many potential points of use.

The Elements of a Transfer System

> We all take the telephone for granted. When we have to wait more than a few seconds for a dial tone, we grow impatient and frustrated. When we call information—seconds seem like hours. We also take for granted the telephone directory—that innocuous book which methodically lists names and numbers in alphabetical order. Imagine the chaos in the telephone company information centers if one day every other page in everyone's phone books were missing. Imagine your frustration if most telephone numbers were "unlisted"—if a special, prolonged, and elaborate effort was necessary each time you made a call.
>
> Contemplate the chaos in your city if there were hundreds of different phone books—some arranged by people's national origins, others by occupations, by district or by name—yet none of them complete. Each time you needed a phone number you would have to know whether your friend was Irish, or a janitor, or whether he lived in the north side of town. Suppose that in each city the system was different—each used a different terminology or system of spelling—a janitor might be a superintendent or a maintenance engineer.
>
> Suppose each of these phone books, large and small, is only half complete and at least a year old when it arrives. Suppose that phone books were not free but cost so much that only libraries could purchase them. Imagine your frustration if you had to go to the library each time you wanted to make a phone call.

[44] Solo, Robert A., "Studies in the Anatomy of Economic Progress," a working paper.
[45] Rosenbloom, *op. cit.*

Now what has all this to do with the so-called information crisis? The situation I have just hypothecated is a fairly accurate description of scientific communication today. There are some obvious exaggerations. On the other hand, there are even more chaotic aspects difficult to convey by simple analogy. We all use the yellow pages, the classified directory, and frequently find it difficult to locate a number because of peculiarities in our language. Gas stations are listed under service stations and sell gasoline; gas companies may be listed under power companies and sell gas. In science, terminology is constantly changing—faster than the lexicographers or dictionary publishers can cope with. Every scientific dictionary is obsolete long before it is published.

In science communication we not only call local numbers—we are constantly trying to place long-distance transoceanic calls because science is international. Our telephone operators, the information scientists and librarians, must be able to handle dozens of languages including Japanese, Russian, and other exotic tongues.

However, this is only the beginning of the difficulties. After painfully identifying the telephone number of the scientific document he needs, the scientist can't simply dial the number. He must first identify the telephone exchange that handles this number. He may be lucky and find that it is a local exchange. Quite frequently he will find that he must call a Washington exchange or some other remote city. But scientists are stubbornly persevering, and having learned the proper exchange, put through the call only to find that the line is busy. In fact, the average waiting time is a few weeks—and by then—if that hasn't discouraged him—he may find that he called the wrong exchange, the number is out of order, or disconnected, temporarily or permanently. It is not surprising that by the time his call does get through he has sometimes forgotten why he called in the first place.

The working scientist places hundreds and thousands of such calls each year. He would call more often if he did not anticipate, consciously or intuitively, delay and frustration. The net result is that he gives up and only makes a call when he is absolutely desperate.[46]

Dr. Eugene Garfield's analogy points up some of the complexities involved in the design of a national system to channel technology. William T. Knox, formerly manager of corporate planning for Esso Research and Engineering Co. and now in the Office of Science and Technology and chairman of COSATI, served as manager of Esso's Technical Information Division for 5 years. He said:

During that time I changed from a research director ignorant of the enormous problems in the technical information field and skeptical of my interest in it to one who believes that the successful solution of the technical information problem is vital to the continued health of science and technology and demands the very highest skills and capabilities of professionally trained people.[47]

[46] Dr. Eugene Garfield, in testimony before the ad hoc Subcommittee on a National Research Data Processing and Information Retrieval Center, *op. cit.*, p 227.
[47] *Research Management*, July 1964, p. 287.

A similar change of attitude on the part of many highly placed Government officials and top corporation executives will likely be required if effective technology utilization programs are to be developed.

Technology transfer—using new technology for purposes other than the specific one for which it was created—is not now given much emphasis in many Government program offices. Until it is given higher priority, major problems will exist on the input side of the transfer mechanism. For locating the technology which is truly new and significant demands the cooperation of those program offices with the scientific and technical missions, and therefore the R. & D. budgets.

And on the output side of the transfer mechanism, the quality of receivership must improve. The executives and technical professionals in private companies must be exposed to the benefits they can derive from the utilization of Government-generated technology.

Between input and output must be built new bridges—not made exclusively of paper—over which the right information can be successfully conveyed. And the bridges must permit traffic in both directions.

The steps in the transfer process are:

- Finding the technical information.
- Screening out that which has current relevance for possible special emphasis—but not abandoning what remains for it may have unrecognized value.
- Organizing it in a manner that permits its rapid and efficient retrieval for a variety of potential users with different languages, interests, and orientations.
- Bringing relevant parts of it, on a selective basis, to the attention of a variety of potential users.
- Arranging for seemingly unrelated pieces originating in separated areas to be fitted together.
- Encouraging its use on the basis of its value.
- Relating it to ongoing efforts that may enhance its value.
- Organizing it so that it can not only be called out to meet specific defined needs, but also be a source of ideas to the technical man "browzing" through it.
- Permit the full inventory to be examined in a way to allow the discovery of areas of knowledge convergency or potential breakthrough areas and areas of need.
- All this must take place in an economic and social environment conducive to change.

Let us consider the implications at each step in the process.

Finding the Information. Technology exists in many forms—in documents of many kinds, in not-yet-articulated concepts and understanding, in physical devices and systems. The documents will appear as patents, research reports, unanalyzed data, handbooks, trade press articles, papers in technical journals, proceedings of conferences and seminars, scrawlings in the notebooks of scientists and engineers, and countless other diverse forms.

The chances of finding it will not be good unless at least two conditions are met: (a) Capable people are assigned the task of seeking it out as their primary responsibility; and (b) those who generate it—the practicing innovators and their supervisors—recognize the value of transferring the results of their work and agree to cooperate.[48]

Some pioneering efforts of this type on a formal basis are underway. The Science Information Exchange, for example, has elicited the effective cooperation of most segments of the Government community sponsoring and conducting research in the life sciences which now bring to SIE's attention their current R. & D. activities. SIE has put professional analysts to work documenting those activities, for to be widely communicated, information must be articulated and recorded.

NASA is providing another model. Its technology utilization officers deployed in the various NASA installations have the primary responsibility for seeking out the important results of research and development efforts conducted in NASA centers and by NASA contractors. NASA has put teeth in its philosophy by placing contractual responsibility on its contractors to report new technology resulting from their work under NASA support.

The AEC has been successful in encouraging its scientists and engineers to recognize the importance of civilian applications of the nuclear technology they generate, leading to many economically important activities in civilian industry. Now the AEC is considering giving some emphasis to pinpointing the nonnuclear technical advances made in the course of its nuclear research and development.

The Clearinghouse for Federal Scientific and Technical Information is encouraging other agencies to provide it with copies of their research reports.

The editors of trade, technical, business, and professional publications must also be recognized for their extensive contributions to the location of new technology via continued fieldwork.

The combination of those efforts is beginning to create an environment for the recognition among innovators of the potential secondary importance of their work. But more is required. Perhaps a national policy encouraging the reporting of new unclassified technology generated with Government support would be helpful. There may also be a need to analyze and more specifically define the conditions under which limitations should be placed on the communication of unclassified information.[49] Government agencies should continue to be encouraged to declassify documents at the earliest time consistent with national defense considerations. And limitations on making documents available should be justified against a standard. Ideally, all agencies generating a significant amount of new technology might be encouraged to assign responsibilities for the identification of new technology to qualified and enthusiastic personnel.

Screening the Information. With apologies to Gertrude Stein (and dyed-in-the-wool documentalists), a document is not a document is not a document. The value of one piece of information is not necessarily equivalent to the value of another piece of information.

Because the library has often served as the model for technology transfer mechanisms, in many cases a considerable amount of straw must be waded through in search of the wheat. Too much straw in the diet discourages eating, and also makes for a lot of wasteful mastication. Burning the straw may not be wise since new uses for it may be found in the future. But it should not be served as the main course.

Screening means are required to find information of special significance and relevance and give it special emphasis, perhaps by calling it to the special attention of potential users.

In the process, information should not be discarded solely because it appears to have no practical value at present. It should be retained and categorized so that it can be retrieved at some future date. Some effort is being devoted in Government to this evaluative function.

NASA, for example, employs several private research institutes to evaluate innovations reported by the NASA technology utilization officers. Innovations deemed of special merit are given special emphasis by publication in the form of Tech Briefs and TU Reports.

The clearinghouse, with the aid of the Office of Technical Resources, screens incoming reports to find those of special significance, then calls attention to them via *Fast Announcements*.

The AEC holds conferences and undertakes programs to encourage the use of specially significant items such as its liquid zonal centrifuge.

But only a relatively small portion of the new technology generated through Government R. & D.

[48] The size of this task might be illustrated by the Gemini program. McDonnell Aircraft Corp., prime contractor for the capsule, has 3,196 subcontractors and uncounted suppliers to the subcontractors. Martin Co., responsible for the Titan II launch vehicle, has an estimated 1,500 to 1,800 companies supplying services, parts, and materials. The subcontractors range in size from General Electric Co. to the Blake Rivet Co., a firm with 60 employees that made the special titanium alloy fasteners used in assembling the capsule. The suppliers range in technology base and orientation from IBM to the David Clark Co., a brassiere and girdle manufacturer that made the space suits.

[49] Of the total number of documents announced by the Defense Documentation Center in the 12 months ending July 1965, 47 percent were unclassified but limited; 32 percent were unclassified and unlimited; and 21 percent were classified.

is evaluated for transfer purposes. Certainly, some evaluation occurs outside Government. The trade magazine and the technical journal are screening mechanisms, and individuals who attempt to keep abreast of the unpublished advances in their fields do their own evaluating. But to ask each potential user to evaluate all new technology in his area is to waste a valuable economic resource—skilled manpower.

Other means are necessary. The originator of new knowledge might be encouraged to make a judgment of its utility. Perhaps professional societies and trade associations could assist in performing this function for their memberships. More specialized information centers might be created and, hopefully, paid for, at least in large measure, by the users to perform this task in given areas. Ideally, organizations whose members depend on knowledge of technological advances for their personal and professional well-being could perform the function.

The full burden of screening and evaluation should probably not be the responsibility of the taxpayer at large, since the benefits of the function seem to be spread too unevenly. Some form of cost sharing by the beneficiary is in order, although this does not mean, of course, that he must pay for the service directly. He can pay for it in his purchase of resulting services, such as membership in specialized information centers or regional service centers; by purchase of publications and announcement services resulting from evaluations; by normal support of his professional society or trade association; or via some other means.

Organizing for Retrieval. Few activities that appear so simple to the uninitiated are, in reality, as complex as the problem of arranging information in a manner that permits its easy retrieval for all relevant purposes—and for those purposes only.

Report titles are wholly inadequate as a basis for quick and accurate retrieval, since most titles are as definitive of a report's content as any of the proverbial descriptions the blind men gave after touching the elephant.

For example, consider the report title: Materials Investigation: SNAP/50 Spur Program Mechanical Properties of TZM.

The descriptive terms used to categorize the document for later retrieval were: molybdenum alloys, turbine parts, ductility, titanium alloys, carbon alloys, zirconium alloys, processing, forging, tensile properties, hardness, recrystallization, transition temperature, creep, microstructure, stresses, heat treatment, turbine blades, turbine wheels, gas turbines.

While the descriptors add many dimensions to the ability to retrieve the report, they admittedly exhaust only a small portion of words and phrases that might be used in posing a question for relevant information in the report while a system user involved in turbine design problems would readily retrieve the document from the system, the designer of a propeller shaft, for whom the information might be equally important, would have to phrase his question in terms other than product language. He would have to design a more imaginative search strategy in order to retrieve the document. Although not too much imagination would be required in this case, because the document is indexed under both "stresses" and "forgings," likely areas for the shaft designer to search, the problem is illustrated.

Thus indexing poses a major dilemma: Be conservative in the terms used and the document will not be found in many instances where it might be relevant; be liberal in describing the document and it will show up as an unwanted nuisance far too frequently.

Some solutions exist. One partial answer is the use of hierarchical description methods with considerable cross-referencing. Another is the development of multiple systems with separate sets of descriptors to serve different bodies of users with reasonably homogenous interests and language. The cost of operation of such systems is obviously expensive, but the economic feasibility of moving in that direction should be more fully explored. There are significant tradeoffs between the cost of performing the function and the time savings that would result from reducing the need to examine the abstracts of numerous unwanted documents, plus the advantage of retrieving a greater proportion of relevant information.

The entire question might be better analyzed if more research in the documentation field were performed from a user-oriented rather than source-oriented viewpoint.

The question of abstracting comes up in the same context. With most mechanized systems, and many manual systems, the seeker of information is supplied a set of abstracts as a result of an information search. Seldom would it be practical, under any conditions, to deliver a full set of documents. (The sheer awesomeness that would result from stacking 30 pounds of paper on a man's desk in response to an inquiry would defeat the utility of the system, let alone other obvious problems of logistics and cost.) The information seeker is then in a position of making his own evaluation, determining which documents he wants to examine in full, on the basis of the abstract. The degree to which the abstract mirrors the content of the document then becomes crucial. (Perhaps no one is better equipped to write an abstract than the author of the document, a function that should be and is being encouraged.)

The entire subject of organizing information for better retrieval demands continuing attention by imaginative researchers. Such work should be encouraged by the Government and private groups alike. Contributions to this area are being made from numerous quarters, public and private, including OSIS, AEC, NASA, NIH, and many others. But the problem deserves increased emphasis.

Attention to Significance. Earlier in this paper, the importance of incremental advances in technology was emphasized. The new lubricant formulation, the new circuit design, the new inspection technique, and the improved composite material, while having widespread potential utility, are rarely significant enough to start the technical grapevines buzzing. But incremental advances often deserve special communication, and consideration might be given to means of bringing them to the attention of potential users more rapidly on a selective basis.

Fast Announcements and Tech Briefs are two existing means of doing so. Others might be considered.

Soliciting the cooperation of specialized business publications in performing that function should be encouraged. A more rapid means of communicating such information to the correct audiences would be difficult to devise at low cost.

Knitting the Elements. Frequently, several seemingly unrelated advances that occur at about the same time derive special significance when examined in composite; the addition of a new item of information to a bank of other pieces of information can give the entire resource new significance. Related advances can occur in fields traditionally far removed from one another, such as a medical discipline and a subdiscipline of electronic engineering. This calls for switching mechanisms among information systems. In a few cases, specialized information centers perform such functions today. New methods must be found, including mechanical or electronic aids that will speed the process. Federal Government encouragement of research and exploration in this area is recommended.

Encouraging Use. Many who could benefit from technology transfer have yet to be exposed to the advantages. Many others, discouraged by attempts at earlier times when little could be done to assist them, must again be exposed.

Information is a marketable commodity if it meets certain tests, such as significance, currency, relevancy, ease of availability, and comprehensiveness. But few practitioners in information services or technology transfer programs employ a total marketing approach. Bill Knox has urged:

> Let us look at information services as a business—a business with service as its product—not abstracts, not indexes. not books, but service . . . . Let us concentrate on the marketing side—too long ignored—not on the production side. The major attention and financial support given to hardware and information processing techniques indicates an overemphasis on production variables.
>
> Marketing information services in the way it should be done will probably not be easy. It will require new attitudes, new patterns of thought, new approaches—and new people. The record speaks for itself.[50]

What will be required on technology channeling mechanisms that can generate payment for value received? Several points are obvious:

(1) Information service and technology transfer people must recognize the existence of segmented markets. Tailored services must be proffered to definable groups and subgroups. Selective dissemination services will not be sufficient, though they represent a significant step forward. Needed will be better switching mechanisms, some thoughtful repackaging of information, better categorization at the input side and better "interest profile" building on the output side, better analysis of document content, more emphasis on interpretation of the "why" and "what it means" instead of the mere presentation of "what" and "when."

(2) Improved local access will likely enhance the marketability of information on new technology.

(3) Better referral services will be required; successful service organizations seldom tell their customers "no."

(4) More communicators, sociologists, and economists might be needed to add to the engineers, scientists, and documentalists that make up the full complement of know-how in many centers today.

(5) More effort will be expended to determine the real problems and objectives of a potential user of technical information, not just blind faith in what he feels to be his problems. Some imaginative effort to interest the potential user in new technology outside his stated sphere of interest, but within his reasonable sphere when viewed objectively, might also pay handsome dividends.

(6) Certainly we need to learn much more about how new ideas become accepted or rejected within organizations.

Joining Present and Future. The existence of some fragments of technology can and does encourage investment in the development of needed additions. But sometimes, after considerable development cost, it is discovered that someone else got there first. This should be avoided in the broad area of the public domain, if possible.

[50] Knox, William T., "Marketing-Oriented Information Services," Speech at joint dinner meeting of the American Documentation Institute, American Medical Writers Association, Society of Technical Writers and Publishers, and Special Libraries Association. Washington, D.C., Mar. 15, 1965.

Technology transfer implies not only the provision of what now exists but the indication of what factors are sure to bear upon it.

Permission to "Browse." Technology transfer is often looked upon as problem-solving mechanism only. Certainly it is that, but it is also much more. It can be a means of bringing about ideas for the solution of problems not yet recognized and the meeting of objectives not yet defined. Bringing that about requires the development of methods that allow people to browse through the technology available, much as a do-it-yourselfer shops about in a hardware store or a reader scans the contents of a magazine.

Since the volume of information available demands the use of mechanized systems today, allowing for browsing must be brought about mechanically and electronically. A step in that direction will be the use of remote consoles tied to a central information bank on a computer time-sharing basis. Project MAC at MIT is the current pacesetter for systems of this type. NASA's Scientific and Technical Information Division is examining the feasibility of such a system on an experimental basis.

Meeting this requirement, as well as others, demands compatibility among information systems. COSATI should be encouraged to continue to strive for coordination of systems among Federal agencies. Efforts to make Government and private systems compatible must also be promulgated.

The Quality of Receivership. In terms of understanding how to create a climate for innovation, society today is long on theories and short on substantive knowledge. We may also be long on apathy.

But, as has been repeatedly emphasized, new technology seldom occurs in "off-the-shelf packages." Innovations originating in the military/space/nuclear realm generally require adaptation for use in other contexts. Sometimes, a higher order of innovation is required to make successful adaption than was needed to conceive the original advance, and the out-of-pocket costs can be high.

Obviously, there would be a high return on an investment that would in fact define the elements of a "creative climate," that would determine the characteristics that set the innovative person apart from others, or that would bring about an understanding of the essential ingredients of entrepreneurship.

Encouragement of research in the fields of focusing on those questions is recommended. Devising means of overcoming the barriers to technology transfer, and perhaps more importantly, determining how to provide incentives for the utilization of available technology are goals worth pursuing.

Personal Involvement. The written word is essential to technology transfer, but it is insufficient for effective transfer. Required is considerable personal involvement and person-to-person communication.

> The implications of a new technology in a variety of fields cannot be transferred by the written word. Some interplay between individuals is necessary to permit modification of the ideas of both the giver and the receiver in order to have a meshing of the proposals of each. Therefore, to increase the rate of technology utilization, a means must be provided to permit a meeting of qualified individuals. Publication is an important step in this process, but it is only the first step. Its primary purpose is to bring to the attention of the proper individuals the fact that certain information is available and to identify its source, thereby opening the way to subsequent communication between people with mutual interest. It is necessary to set up a system by which this can be accomplished and a special effort should be made to clarify the procedure to be followed.[51]

The Personal Champion. A wealth of experience on a variety of fronts documents the assertion that the odds on a technology being employed are greatly enhanced if it is championed by the inventor, the man who visualizes the application, an intermediary, the management of the firm that might use the concept, or by a person or group responsible for identifying and using new technology.

A company employs purchasing agents to seek out, evaluate, and bring in the optimum materials and supplies. Why not then new technology agents to seek out, evaluate, and bring in the best and most useful new knowledge? These technology agents would be unusual people to whom an air-travel card and a telephone would be far more important than an office and desk. They are generalists with a technical bent, but not necessarily engineers or scientists. They understand the arithmetic of business but are not accountants or mathematicians. They are imaginative and can readily grasp new concepts. They are fully informed on their company's manufacturing capabilities and marketing objectives. They are outstanding communicators, know how to sell ideas, and are capable of dealing effectively at all levels inside and outside the firm. They know how to attach themselves to the industrial, governmental, and professional grapevines that bear the fruits of knowledge most important to their companies. These technology agents are really technoeconomists and sociotechnologists.

Effort should be expended in both the private and public sectors to find men with the required capabilities and interests to perform these functions. Organizations seeking to benefit from the results of Government R. & D. should also determine whether their organizational framework is designed to permit the ready inflow and acceptance of technology generated outside the firm.

[51] *Transference of Non-Nuclear Technology*, etc., *op. cit.*

APPENDIX

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