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ALFRED P. SLOAN SCHOOL OF MANAGEMENT

Research Program on the Management of Science and Technology
SECOND REPORT 1965-1967
Donald G. Marquis (Ed.)

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I. INTRODUCTION

In the spring of 1962 the M.I.T. Sloan School of Management, with the encouragement of James E. Webb and substantial financial support from the National Aeronautics and Space Administration, undertook to develop a program of research and education in the area of organization and management of large technology-based enterprises. The studies now completed or in progress or planned for the future are focused on the broad objectives of understanding and improving the effectiveness of R&D activities, and the utilization of science and technology for the general welfare.

The principal researchers are faculty members whose backgrounds are in a variety of disciplines: mathematics, sociology, operations research, psychology, statistics, economics, and engineering. Research assistants are chosen from graduate student candidates for the S.M. or Ph.D. degree, most of whom have bachelor degrees in science or engineering. Fellows in the Sloan Executive Development Program, who are themselves research managers of 10-15 years experience, have been particularly effective investigators. A list of the individuals active during the period of this report is presented in Appendix I.

The program is administered by a research director and an associate director, guided by a Steering Committee of seven faculty members (Appendix I). Coordination is achieved by a weekly research seminar, by many small ad hoc groups, and by numerous informal consultations. The "Friday Seminar" is regularly attended by faculty and student staff and by a number of guests from other M.I.T. schools, from industry, and from government agencies. The seminars serve as a forum for reports of progress and plans, with discussion and debate on questions of research design, methods, and interpretation. Outside guests are frequently invited to present papers growing out of their operating experience or relevant research. A list of topics and speakers is presented in Appendix 2.

The external support of the program was initially by a generous
grant from the National Aeronautics and Space Administration. This
source is now supplemented by grants from the National Science Foundation, Office of Naval Research, Sloan Research Fund of the Sloan
School of Management, M.I.T. Center for Space Research (with funds
granted by N.A.S.A.), and M.I.T. Project MAC (with funds granted by
the Advanced Research Projects Agency). During the past five years
the program has received about $1.4 million from external sources.

At the outset of our efforts we realized that we did not know
how to go about the business of "research on research". There existed
almost nothing in the way of a body of knowledge, a theory, or a set
of methods and procedures. Gradually we have built up a small store
of each, borrowing from the several disciplines underlying general
management research, modifying methods used in studying analogous
areas, and inventing some new research designs and strategies.

The peculiar difficulties of research in this subject, which re-
sult from the uncertainties, the lack of comparable measures of results
when each research task is different, and the long lag in the feedback
loop of results, have been analyzed by Marquis (1966) and Roberts
(1967).

We decided very early that each study would attempt to include or
devise some measure of "results", difficult as this obviously is in
the case of R&D. Measures of results are necessarily different for
studying performance of individual researchers, of teams, of projects,
of laboratories, of commercial firms, of government agencies, and of
industries and nations. We have tried to progress steadily from eval-
uation judgments to more objective quantitative measures. In matters
of research design we have tried to progress from case studies to
large statistical samples and to matched identical cases, in the hope
that we can eventually employ that most elegant of scientific proce-
dures, the experiment. In the realm of theory we try to transform
loosely defined concepts into precise and measurable variables and to
go beyond two variable to multivariable formulations. Several complex
models have already been programmed and run on computers.

In no other field of management is it more essential for indu-
trial, government, and university researchers to carry out systematic
investigations. In no other field, however, is it more difficult.
If one is teaching polymer chemistry or magnetohydrodynamics, there is an established body of knowledge, and one can test whether a student has mastered that body of knowledge. There is nothing comparable to that in R&D management. The body of knowledge in research management accumulated over the past 20 years is pretty thin. It is for the most part derived from four sources:

**Tradition.** The most common source of knowledge is tradition. In the absence of other knowledge, the traditions of research management have come from other management functions, principally from the management of production facilities.

**Revelation.** There are some research managers who operate and who give speeches on research management as if they had gone up to the top of the mountain and received the word directly.

**Experience.** Most R&D managers believe that they have learned from their experience how to improve their management of research. Such a claim is questionable. The reason is that one does not know for a long time the results of his decisions. Whether a manager is planning the allocation of resources, budgeting for his laboratory, selecting projects for approval or termination, he must find it very difficult to operate on the basis of experience. His experience has been in only one or a few laboratories; it has been of a special kind: and (unlike other fields) the results of a managerial action may not appear for 3, 5, 10 or 15 years. Only a little learning can be expected on the basis of experience, because the possibilities for it just do not exist. In the absence of a sound body of knowledge based on experience we see the growth of many fables, myths, and rules of thumb.

We hope that systematic quantitative investigations will provide a more soundly established body of knowledge, on the basis of which research management can progressively become more effective.

This report covers the period of Summer 1965 to Summer 1967, and supplements an earlier report dated July, 1965.
II. TECHNOLOGY TRANSFER AND INNOVATION

The total process of innovation involves many points of transfer of technical knowledge - from science to applied research to design and development to utilization and the diffusion of use. Such transfer may occur within an organization or, more commonly, between separate organizations or subdivisions of an organization. The probability and timing of transfer are dependent on the state of technical advance and on the market or societal demands, but a satisfactory understanding of factors in the process of transfer is far from achieved. The report on Technological Innovation (1967) by the Panel on Invention and Innovation of the Department of Commerce points out that although "this nation spends tens of billions of dollars every year on innovation..., we know very little about the processes of technological change and growth". Growing discussion of problems of "the technology gap", commercial "spinoff" from government R&D, and of region and industry differences in technological development points up the need for increased knowledge of the transfer process.

Conference on Human Factors in the Transfer of Technology

Recognizing that the transfer of technology clearly requires human activity, and that technology tends to be better stored in human experience than in documentation, a conference was arranged to assess the present state of knowledge on human factors in technical transfer and to generate ideas for further research. The M.I.T. Center for Space Research undertook to sponsor and support the Conference, and the involvement of J.V. Harrington, Director of the Center, and Charles F. Kaye, greatly aided the work of William H. Gruber, Planning Coordinator.

The Conference was held at M.I.T.'s Endicott House, May 18-20, 1966, with the following individuals participating:

Professor Thomas J. Allen, Sloan School of Management, M.I.T.
Professor Arnold Amstutz, Sloan School of Management, M.I.T.
Mr. Frank T. Bauchspies, Director, Industrial Liaison Office, M.I.T.
Dr. Guy Black, Council of Economic Advisers, Washington, D.C.
Dr. Richard H. Bolt, Chairman of the Board, Bolt Beranek & Newman, Inc.
Professor Tom Burns, Department of Sociology, University of Edinburgh.
Dr. C.S. Draper, Director, Instrumentation Laboratory, M.I.T.
Professor William H. Gruber, Sloan School of Management, M.I.T.
Mr. John S. Gilmore, Denver Research Institute
Professor E.E. Hagen, Department of Economics, M.I.T.
Mr. Abraham Hyatt, Vice President, North American Aviation, Inc.
Col. Raymond Isenson, Office of the Director, Defense Research and Engineering, U.S. Department of Defense
Mr. Howard Johnson, President, M.I.T.
Professor Elihu Katz, Department of Sociology, University of Chicago
Mr. Charles F. Kaye, Center for Space Research, M.I.T.
Dr. Breene Kerr, Ass't Adm. for Technology Utilization and Policy Analysis, National Aeronautics and Space Administration
Dr. Myer M. Kessler, Associate Director of Libraries, M.I.T.
Professor Donald G. Marquis, Sloan School of Management, M.I.T.
Professor David McClelland, Chairman, Department of Social Relations, Harvard University
Professor Herbert Menzel, Department of Sociology, New York University
Dr. Sumner Myers, National Planning Association, Washington, D.C.
Mr. Franklyn Phillips, Electronic Research Center, National Aeronautics and Space Administration
Professor Derek De Sola Price, Department of History of Science & Med., Yale University
Dr. William F. Pounds, Dean, Sloan School of Management, M.I.T.
Dr. Philburn Ratoosh, Space Sciences Laboratory, University of California, Berkeley
Dr. Howard Reiss, Director, North American Science Center
Professor Edward B. Roberts, Sloan School of Management, M.I.T.
Dr. David Z. Robinson, Office of Science & Technology, Executive Office of the President
Dr. Herman Rochwarg, Project Director, N.E. Economic Research Foundation, Boston
Professor David Sirotta, Sloan School of Management, M.I.T.
Professor Charles H. Savage, Jr., Sloan School of Management, M.I.T.
Dr. Donald A. Schon, Director, Institute of Applied Technology, U.S. Department of Commerce
Mr. Jacques Sevin, Delegation Generale a la Recherche Scientifique et Technique, Paris
Dr. Albert Shapero, Director, Technology Management Program, Stanford Research Institute
Professor Eugene B. Skolnikoff, Department of Political Science, M.I.T.
The conference sessions were informal, and vigorous discussion was stimulated by the presentations prepared by fifteen of the participants. The three days at Endicott House were a period of problem solving and reflection on difficult concepts and questions. Most of the papers were significantly revised by the authors after the conference. They have been assembled in a book edited by W.H. Gruber and D.G. Marquis which will be published in 1968 by the M.I.T. Press. Following is a list of the contributions appearing in the book:

Models, Images and Myths - Tom Burns
Innovation and the Problem of Utilization - Stephen Toulmin
Development and Utilization of Technology in Industry - W.H. Gruber
The Role of Achievement Orientation in the Transfer of Technology - David C. McClelland
Comments on Section I - Donald A. Schon, Herbert Menzel
Structures of Publication in Science & Technology - Derek J. de Sola Price
Human Factors at the Science-Technology Interface - Howard Reiss
Differential Performance of Information Channels in the Transfer of Technology - Thomas J. Allen
Project HINDSIGHT: An Empirical Study of the Sources of Ideas Utilized in Operational Weapon Systems - Raymond S. Iseenson
Effects of Government R&D Contracting on Mobility and Regional Resources - Albert Shapero
The Effects of Government Funding on Commercial R&D - Guy Black
Empirical Studies of Innovation

Although substantial studies of invention, innovation and diffusion have been reported by economists, most of the published literature deals with single case studies. Two recent projects have assembled large collections of data on innovations which meet the test of successful utilization, and Donald Marquis has made arrangements to obtain the original data and carry out further analyses.

Project Hindsight was carried out by the Office of the Director of Defense Research and Engineering (Science, 1967, 23 June, 1571-1577). Expert teams of scientists and engineers traced and identified 710 significant technical advances or inventions which were incorporated in a selected set of 20 recent weapon systems. At our suggestion resume information was also obtained from about 500 of the individuals responsible for the advances.

The other set of data is a study of 567 recent successful commercial innovations nominated by 121 firms in three industries: computers, railways and housing. The data were collected by a National Planning Association project directed by Sumner Myers and funded by the National Science Foundation.
Concern for the effective utilization of scientific and engineering advances has led to a sharpened focus on organizations that have been successful in exploiting rather than merely creating new technologies. In a large corporation such market oriented exploitation often results in new business ventures launched to develop, produce and market a technological advance. Another highly visible form of technological utilization is the new company founded by technically trained entrepreneurs. Both types of technical ventures have been studied over the past years in a research program directed by Edward B. Roberts, with the full-time collaboration of Herbert A. Wainer, aided since 1965 by Eugene F. Briskman, Frederick L. Buddenhanen, Howard A. Cohen, Dean A. Forseth, David R. Hall, Charles W. McLaughlin, Donald H. Peters and Jagdish A. Prasad as research assistants.

New Company Formation and Growth

The most extensive part of the research effort has been a series of coordinated studies of the formation of new companies. Most of these studies have focused on government funded R&D organizations as the potential source of such new companies. The enterprises thus identified as "spinoff" companies are those founded by former employees of the source organizations. Over 200 new companies thus studied are indicated in the table on the next page. The companies range in business activities from service, such as computer software development, to manufacturing, such as special purpose computers and welded modules. The sales of the companies vary from ten thousand to fifty or sixty million dollars per year with most falling in the one to five million dollar bracket. In addition a study of recently incorporated consumer-oriented manufacturers has been conducted to provide a basis for comparison.
Sources of New Technical Enterprises

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<td>Not-for Profit Organization</td>
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<td>MITRE Corporation</td>
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<tr>
<td>Industrial Electronic System Contractor</td>
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Although most of the technical companies studied are relatively young, their ability to survive has been demonstrated repeatedly (Teplitz, thesis 1965; Wainer, thesis 1965; Forseth, thesis 1966; Goldstein, thesis 1967). These new technical enterprises have a failure rate of only 20 percent in their full existence averaging five years. Their survival and growth differ from overall Dun and Bradstreet national statistics for new company failures as well as from the evidence gathered on new consumer-oriented manufacturers (Klahr, thesis 1967), both sources showing an extraordinarily high failure rate.

A number of background characteristics of the entrepreneurs who founded these companies keep reappearing in the various samples. Half of them come from families in which their fathers had been self-employed. Their age at company founding is young (median in the mid-thirties),
and their education is high (master's degree) (Roberts and Wainer, 1966). Evidence suggests that they tend more frequently to come from developmental as contrasted with research oriented organizations and that their work experience has had developmental orientation (Roberts and Wainer, 1967).

A number of factors have been found to be influential on the growth of new technical companies (Linko, thesis 1966). A high degree of technology transfer, moderate entrepreneurial education, and accurate recognition of certain important management considerations including effective personnel and marketing management, have been found to be related to successful enterprise development.

A pilot study of entrepreneurial motivation has produced the suggestion that high achievement drive leads to high corporate performance in the new technically-based organizations (Schrage, 1965; Wainer and Rubin, 1966). Based on these research results a broader study of the psychological characteristics of entrepreneurs has been undertaken and is now nearing completion.

In examining hundreds of new enterprises it has become apparent that many potential companies never get past the idea stage or that they encounter serious difficulties in their initial endeavors as formal organizations. To develop better understanding of such problems further research has been initiated to identify factors that are blocking market utilization of technical ideas of M.I.T. laboratory staff and faculty (Peters and Roberts, 1967). The data reveal a large number of new product ideas that have not yet received serious consideration for exploitation.

The market for venture capital to finance new technical companies has also been studied. Venture capital is found to be plentifully available throughout the United States, although regional differences and potential mismatches between capital availability and entrepreneurial demands are apparent (Rogers, thesis 1966). Even those organizations most oriented to financing new technical firms are biased toward entrepreneurs who are older and more experienced in business than are most of the 200 successful "spinoff" technical entrepreneurs studied (Briskman, thesis 1966). These preferences are quickly learned by the technical entrepreneurs as they organize and build their companies, and many have found financing among their most critical problem sources (Hall, thesis 1967).
Despite these difficulties many new technical companies are founded each year. They produce significant economic and technological benefits, although to some extent at the expense of the entrepreneurs' source organizations. One study indicates that 39 companies formed by ex-employees of a Route 128 industrial firm had 1966 sales totaling $72 million, more than double the sales of their "parent" company (Goldstein, thesis 1967). The potential lost by this major corporation suggests the importance of studying corporate strategy for motivation of technical entrepreneurship within the firm.

New Technical Ventures Within The Corporation

During the past year the first of a planned series of research studies on the internal entrepreneurship process was undertaken by Buddenhagen (thesis 1967). Sixteen new business ventures were investigated in a large ($500 million sales) division of an integrated electronics manufacturer. The men who headed these new technical ventures were quite similar to the new company entrepreneurs described above. In age, education, and work experience, the "internal entrepreneurs" looked much like their "spinoff" counterparts.

A number of the new venture leaders seemed frustrated by their company experiences, several of them indicating they had thought of leaving to form their own companies. One repeatedly encountered reason for this was the corporation's attitude against younger men taking on broad venture responsibility. This attitude showed up in lack of encouragement for the internal entrepreneur, in funding decisions, and in the limited cooperation and independence permitted the entrepreneur.

From these studies of the characteristics and role of the innovative entrepreneur, several changes in organizational form and incentives have been suggested that would help retain and support the entrepreneur in the large corporation (Roberts, 1967). These will be the subject of further research studies during the next few years.
IV. ORGANIZATION AND MANAGEMENT OF PROJECTS

The dictionary defines project as "a planned undertaking: specifically a piece of research". That the word "research" appears in the definition is no accident because a project, as distinguished from a plan or scheme, implies an end product which is innovative. Project management, therefore, can be viewed as the planning, organizing, and controlling of efforts directed toward achieving specified results which are imaginative in scope and vision.

Development Projects

Several years ago an investigation* was initiated to obtain comprehensive data on a sample of 50 large projects carried out by industrial laboratories under contract to government agencies. A project was selected in a company or a government agency on the basis of two criteria: random or most recently completed, and more than $1 million in size (excluding any follow-on production work). Thirty eight firms in the aerospace and electronics industries were involved, 80 percent of which are among the 100 largest performers of government R&D. The projects were funded by 12 government agencies, and ranged in size from $1 million to $40 million with a median of $4 million. All were CPFF contracts. Average project duration was 3.4 years and none lasted more than 6 years. Almost all of the projects required significant advances in the "state of the art" in a wide variety of technological fields, and were more developmental than research in nature. All but one required a prototype or first production item.

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*The research was designed by D.G. Marquis; I.M. Rubin conducted much of the analysis. J. Randall Brown, Michael M. Gold, Arthur J. Hansen, Kenneth R. Hootnick, James E. Mahoney, Robert L. Pearson, Jean-Paul Richard, Irwin M. Rubin, Wyckham Seelig, and David M. Straight served as research assistants during different phases of the investigation.
Information on each project was obtained from five sources: the laboratory manager, the project manager, and the contract administrator in the company and the government technical monitor, and contract administrator. Structured interviews were developed on the basis of published literature and interviews with experienced project managers and were pretested on approximately 20 projects.

Although a total of 50 projects were studied, inevitable difficulties resulted in incomplete records in several cases because interviews could not be obtained with one of the key managers. In 75 percent of the cases the records are complete.

Measures of Performance. Two measures of project performance were obtained. A measure of technical success was derived from the combined judgments of the project manager and the government technical monitor. The ratings were on a scale from 1 to 9 with 1 representing an outstanding success and 9 signifying a failure (in some relative sense, since no project in this study achieved the absolute failure of being canceled before completion). All except one of the ratings fell in the range of 1 to 5, within which there was a symmetrical distribution with the mode at 3.

Information on cost and schedule changes was gathered from the project manager and contract administrator. Careful cross-checking on the reasons for contract changes made it possible to eliminate those caused by the customer's action to modify scope or specifications or by the unavailability of government test equipment or facilities. Thus only those slippages which were directly attributable to the performance of the contractor firm are included. While the data do not include the amount of cost and schedule variance, only those greater than 10 percent are included as overruns.

Cost and schedule performance are correlated 0.82, so the two are combined to form a single performance measure. This performance measure is found to be unrelated to technical performance.*

Initial Decisions. Certain decisions occurring prior to the time that work on the project actually begins are found to influence the overall project performance (Rubin, 1966). Sole source contracts

*Technical performance is not related to the dollar size of the contract, nature of end product, or percent basic, applied or development research necessary to accomplish objectives.
achieve higher levels of technical performance than competitive contracts. This result probably reflects a realistic assessment on the part of the government of contractor capability. The contractor's ability to include a safety factor in his initial cost and schedule estimates is also strongly associated with higher technical performance as well as with fewer cost and schedule overruns.

The amount of work subcontracted is another critical initial decision. The less subcontracted (excluding off-the-shelf hardware), the better is technical performance. Cost and schedule performance is unrelated to the percent of work subcontracted. If, however, an approval from higher management or customer is required on choice of subcontractors, better technical performance results.

The selection of a project manager is obviously an important initial decision. Analyses indicate that the most successful project managers have less total experience (i.e. are younger) and have managed fewer projects than less successful project managers. Technically successful projects were managed by men who were promoted from a smaller project to his present responsibility for a much larger project.

Selection of Program Managers. In a follow-up to the study of the decision process in the selection of program managers at the Marshall Space Flight Center by Swanson (1964), an investigation by Rosenfelder (thesis, 1967) concentrated on the aerospace industry. Questionnaire responses were obtained from 262 project managers in 17 companies. A key executive in each company provided a detailed performance evaluation of his project managers, and in a personal interview described the procedure employed in selecting project managers.

Results indicate that there is no definite profile that can be used to describe the pattern of personality traits and characteristics of a successful program manager. Intolerance of ambiguity, as presently measured, does not appear to be a strong factor in selection. Leadership ability is an essential factor, but there are no simple measures of this characteristic. Potential failures are more accurately predicted than potentially successful candidates. A successful project manager possesses most of the personality traits and characteristics of a good top executive or general manager; a few of these can be measured by psychometric procedures, while others must be
observed in the actual work environment. Therefore, when a candidate has exhibited the essential favorable attributes he may be given the opportunity to demonstrate his performance as manager of a small project, the only criterion of his suitability for greater responsibility in this role.

**Planning and Control Techniques.** There is no published objective evidence on the usefulness of PERT as a method for planning and controlling project work. In our sample, approximately one-half of the projects used some form of PERT; the others used some less sophisticated technique. No difference in technical performance results from the utilization of PERT, but the probability of a cost or schedule overrun is reduced by a factor of two (Rubin and Seelig, 1967)

Some evidence indicates that on projects using PERT, laboratory managers assume greater authority in the areas of changing schedules and initiating work in support areas. The laboratory manager's rating of the project manager's performance is significantly higher if the project manager utilized PERT. The higher rating probably results from improved communication between a project manager and his laboratory manager or from the fact that the project manager (and the project) is more visible when PERT is used. Laboratory managers concern themselves primarily with cost and schedule problems and PERT appears to be useful in dealing with these problems.

Hilton (thesis, 1966) studied the use of PERT in six large industrial organizations primarily in the construction industry. Interviews with executives indicated that PERT is almost always used in the simplest CPM form, with single estimates for activities. As such it is considered valuable, not so much in producing savings in cost or time, but in improving communication and cooperation between groups and with managers involved in a project.

**Authority of the Project Manager.** A measure of the decision-making authority and autonomy of the project manager was constructed on the basis of the number of important types of decisions he made. Neither the total number of areas over which a project manager has control nor his authority to make any subset of decisions was found to be related to performance (Marquis and Straight, 1966).
The role of authority of government program managers was the special subject of study by Field (thesis, 1966), who examined in depth the factors contributing to the effectiveness of the seven program managers responsible for the subsystems of Saturn V at the Marshall Space Flight Center. By intensive interviews with the managers and questionnaires with their associated personnel, he found that in the matrix organization employed at MSFC, the technical problems generally result in more satisfactory outcomes than schedule and cost problems; satisfactory solutions to problems result from use of mutual agreement resolution techniques; and that projects with fewer in-house government personnel working on them have more satisfactory technical problem solutions than projects employing a higher number of government personnel.

Organization Structure. The measure of organization involves the reporting relationships between a project manager and his project personnel. The projects required coordinated activity by scientists and engineers in from three to eight functional departments. An organization is defined as project type when more than 50 percent of the full time technical professionals report to the project manager for work assignments, were physically located near him, and receive merit reviews from him. An organization is defined as functional when more than half of the personnel report to functional department managers (e.g., head of physics department). A similar categorization was made separately for administrative personnel (purchasing, contracts, personnel, etc.).

An interesting contrast in the findings is found. When technical personnel are functionally organized, technical performance is improved by a factor of two. On the other hand, the project form of organization of administrative personnel (in most cases this meant having one or more full time administrative persons reporting to the project manager) reduces the frequency of a cost or schedule overrun by a factor of two.

Advanced Research Projects

As an example of advanced research and exploratory development projects, laser research was selected for study. Roberts and Davis (1967), (Davis, thesis 1967) examined management factors in the
evaluated effectiveness of a sample of 30 DOD contract performers representative of the population of dollar size, contracting service and type of performing organization.

Data were collected by semistructured depth interviews with government technical monitors, and by questionnaires filled out by the contractor laboratories. Past performance records of the contractors were obtained from Air Force document files. Findings indicated that:

1. The performance of contractors is lower for laser research than for general research and development. Contractor performance on mission oriented contracts (exploratory development) is higher than for non-oriented contracts (research).

2. The past performance of a contractor in general research and development is not a reliable guide to expected performance in a particular technology such as lasers.

3. In general, universities perform better than companies on research and development contracts, but companies perform better than universities on laser contracts.

4. Experienced government contract monitors are associated with higher technical performance laser contracts than relatively inexperienced monitors. The educational level of contract monitors is negatively related to contractor technical performance.
V. TECHNICAL INFORMATION AND RESEARCH EFFECTIVENESS

Research as an information processing phenomenon is dependent for effectiveness upon the quality of its information inputs. In a program of interrelated projects*, factors influencing the flow of technological and scientific information, and the use by engineers and scientists of specific information channels is related to an independent objective measure of research performance. One major portion of the project makes use of matched sets of "twin" R&D projects to permit direct comparisons of the way different R&D groups perform the same tasks. Comparisons are thus sought between the information gathering strategies employed and the information sources utilized by the competing research groups. The research described here has been directed by Thomas J. Allen with Stephen I. Cohen, William M. Collins, Daniel S. Frischmuth, Peter G. Gerstberger, Arthur Gerstenfeld, Milton L. Lavin and Paul W. O'Gara as research assistants.

Twenty-five instances of multiple award R&D contracts have been obtained from major NASA and USAF centers, and one instance in which seven chemical firms are working in parallel (competitively) to develop a man-made leather, similar to DuPont's CORFAM. More than 30 companies have cooperated in this project. Subsystem lead engineers on each project maintain records of information sources used and report their progress toward solution on specially designed Solution Development Records.

In addition to the study of parallel projects, studies on the flow of information within the laboratory organization have been initiated with investigations of factors influencing the structure of information networks. To date, studies have been completed in three small to medium size laboratories; data are presently being analyzed from a large laboratory (400 professionals) in a major R&D based firm.

*Supported initially by a grant from the National Aeronautics and Space Administration and since November 1963 by grants from the National Science Foundation, Office of Science Information Services.
The functioning of the overall technical information system for research and development differs according to the particular phase of the project which it serves. Depending upon the specific stage in the problem solving process, different channels of the total information system will be called upon (Allen, Andrien and Gerstenfeld, 1966).

Analysis of the sources of technical alternatives to problem solution in nine parallel sets indicates that better-performing R&D groups rely more upon sources within the laboratory than do lower-rated groups. Implicit evaluation of information channels at two levels, by the design engineer and by the customer, indicates a ranking of channels which is unrelated to their ranking on the basis of frequency of use. Vendors are heavily overutilized as an information source, while the laboratory's own technical staff and information from other company research projects are underutilized (Allen, 1966b, 1966c).

The extent to which project team members interact among themselves (both in terms of the number of interactions or their duration) is unrelated to performance. The interaction rate is high and does not differ greatly from one group to another. But the number and extent of interactions with individuals outside of the project team are positively related to performance. It is therefore both diversity and amount of interaction which contribute to better performance (Gerstenfeld, thesis, 1967).

Engineers base their decision to use an information channel almost solely upon the channel's accessibility. Their perception of the technical quality and reliability of the information provided by the channel does not enter into this decision. They compensate for this situation by applying a variable filtering process to the information received. The severity of this filter is determined by the user's perception of technical quality (Gerstberger, thesis, 1967).

Engineers' reluctance to consult with their own internal technical staff is largely attributable to the psychological cost of admitting their lack of competence or expertise on a technical matter. This impedance can be bridged through friendship chains and transfers within the organization (Gerstberger, thesis, 1967).

Communications within the laboratory are influenced by three independent factors: formal organization; informal social patterns; and the

Information flows into the laboratory most readily through technological gatekeepers, engineers who maintain close contact with the scientific and professional engineering literature, or who maintain a greater than normal number of professional contacts outside of the laboratory (Cohen, thesis, 1966; Allen and Cohen, 1966; Allen, 1967b).

A model of the individual technical problem solving process has been developed based on tape-recorded protocols submitted weekly by three engineers, in competing organizations, designing the same subsystem in parallel with one another. This model in the form of a process flow chart details the engineer's interaction with sources of technical information (Frischmuth, thesis, 1966).
During the past several years a number of projects on the R&D contracting process have been carried out by Edward B. Roberts and his associates.* The studies, aimed at the design of policies for a more effective government contracting system, have looked at both the government and the industry sides of R&D contracts.

Contract Award Process

The contract award process studies may be divided into three parts: investigations of competitive R&D awards ranging from $100,000 to a few million dollars; study of larger subcontract awards from an aerospace prime contractor; and examination of all the major contract awards (each >$5 million) by the National Aeronautics and Space Administration. The discussion below treats each of these study areas separately.

Smaller R&D Contract Awards

Research on R&D award decision-making in the size range up to a few million dollars has generated and analyzed data on 90 competitive contracts from two Department of Defense contracting centers. The main findings of the studies have been presented in earlier publications (Roberts, 1964a, 1965b).

Although technical factors far more than cost considerations were found to influence the award of competitive R&D contracts in the size range of up to a few million dollars, the key determinant of the awards is usually the extensive person-to-person contacts between the government technical initiator of a procurement and his technical counterparts in industry. The informal influences are so strong that documents issued by the government technical initiators months in advance of any formal industry solicitation, proposal preparation, or proposal evaluation suggest the eventual contract winner in about 90 percent of the cases studied.

*Research assistants during the period covered were: Paul Bergsteinsson, William H. Dyer, Norman W. Kneissler, and L. Mark Ramsaier.
R&D Subcontract Awards

In an attempt to broaden the classes of R&D business acquisition studied, cooperation was obtained from a prime aerospace contractor to permit study of his decision-making in 32 cases of subcontract awards of more than $500 thousand each (Dyer, thesis, 1967). The average initial subcontract amount in the study was $4 million and the range went as high as $29 million. Subsequent contract growth brought some of these major subcontracts into the $100 million range.

As had been found in the cases of smaller R&D prime contracts, informal discussions between prime contractor technical personnel and their counterparts in the subcontractor organizations were found to be more influential than the formal technical proposals or the bid price. Again most subcontract winners were predictable months in advance of formal solicitation of proposals.

It was further determined that subcontractors who had cooperated in the prime contractor's original proposal were more likely to receive sole-source rather than competitive awards, and also were more likely to get Cost-Plus-Fixed-Fee contracts rather than incentive or fixed price contracts. Thus, the informal contacts between the contract awarding organization and the award recipient not only influence the award event, but also the terms of the contract.

Major Aerospace Contract Awards

The scope of the contract award studies reported thus far has ranged up to several tens of millions of dollars. The final investigations to be reported covered the award of all NASA contracts greater than $5 million, including the several multi-billion dollar manned space contracts. In these studies data were gathered from NASA headquarters and field centers on 72 awards to industry (Fernandez, thesis, 1966). The data were initially analyzed to determine differences in award evaluation patterns by field center, and these differences were associated with characteristics of the Source Evaluation Boards (SEBs) and the processes they utilized.

In a later comprehensive study, Bergsteinsson (thesis, 1967) further examined the determinants of these contract awards. He found that those companies that were highest ranked on overall terms by the SEBs tended to be highly rated primarily in their technical evaluation scores,
with less emphasis given to business evaluation considerations. However, it is critical to note that those firms rated highest by the SEBs were not always the winners of the large NASA awards. In 24 percent of the cases the contract awards by NASA headquarters went to firms other than those which received SEB first-rankings. These contracts accounted for 64 percent of the total funds initially negotiated in all the large contracts studied. The observation that these large contracts do not always follow the award path indicated by the formal evaluators' scorings suggest the multi-influence award process represented in Figure 1. It is worth noting again that the informal route accounts for most of the contract expenditures.

Flow Diagram of the Decision Process for Large NASA Contract Awards

Channel 1  
(formal)

SEB Established

Evaluation Criteria Selected

RFPs Issued

Proposals Received and Evaluated

Findings Presented

Analysis of all Evidence

The Award Decision

Channel 2  
(informal)

Decision Factors

(i) informal discussions and contacts

(ii) considerations of all agency goals (geo-political factors, etc.)

(iii) all other relevant experiences and information
Company Competitive Strategies

The studies described above have focused on the R&D contract awarding organization and the award process. Another series of investigations have probed into company strategy decisions and effectiveness in trying to win these R&D awards. An earlier report (Roberts, 1965) on the analysis of 400 mail questionnaires indicated that bidders differ from no-bidders, and winners differ from losers on relatively similar dimensions. These differences include the extent of prior knowledge, past experience, and personal contacts with the government agencies.

A series of follow-up studies using extensive structured interviews and statistical analyses of the resulting data were carried out with nine electronic systems companies (Kneissler, thesis, 1966; Ramsaier, thesis, 1966). These studies showed that the high performing companies (as measured by competitive capture ratios and by return on proposal investment) are principally differentiated by what they know and what they do prior to receiving formal Requests for Proposals (RFPs). As indicated earlier the data obtained from competitors for major subcontract awards also substantiate the importance of pre-RFP contacts on the fact and conditions of contract award (Dyer, thesis, 1967).

Two recent studies shed further light on the competitive process in R&D. Putt (thesis, 1967) studied the decision to bid by 48 companies competing for two R&D awards, and the proposal preparation process of 21 companies in 6 competitions. Evaluations of each of the 21 proposals were obtained from the relevant government agencies. Companies in general are found to be quite ignorant of their competitive situation. They overestimated the number of companies submitting proposals, the cost optimism of their competitors, and the technical quality of their own proposals. Such misconceptions could result in a loss of effectiveness in the competitive process, and indeed more than 40 percent of the proposals were judged by the government to be technically unacceptable.

Roberts and Dyer (1967) found that companies were also generally unable to predict effectively the amounts of follow-on business that would be obtained. Nevertheless such follow-on opportunities were the principal motivators for many R&D bids and had a serious impact on R&D project performance as well.
The study of the effectiveness of R&D - and of the decisions and procedures which contribute to effectiveness - is difficult for a variety of reasons, and very little knowledge has been accumulated. Objective measures of the economic and social return on R&D are not at hand, and data on R&D expenditures are not generally available in the level of detail which would be necessary for comparison of different organizations, policies and practices.

In a continuing program of studies, William H. Gruber and his associates* are exploring new methods of analyzing some of these important questions. The relation of company growth to investment in R&D was examined in a sample of chemical firms (Perry, thesis, 1965). Since acquisitions were found to be the main factor in growth, it was not possible to demonstrate any clear effect of R&D on subsequent profit after taxes. John M. Petrosky (thesis, 1966) examined R&D expenditure in relation to size of firm and financial performance in the ethical drug industry, finding that medium size firms were able to compete with larger firms in maintaining their share of market.

Published data on R&D expenditures by industries use a broad (SIC 2 digit) classification. From other sources, Philippe Vuilleumier (thesis, 1967) analyzed data at a finer level (SIC 3 digit) for 600 manufacturing firms. Intercorrelations of 54 variables at three points in time did not reveal any significant relations between R&D intensity and financial performance. Arland L. MacKinney (thesis, 1967) examined the growth of the machine tool industry between the years 1958 and 1965. He failed to find evidence of increased attention to economies of scale and attributes the growth to general economic conditions and to the introduction of numerical control, an innovation originating outside the industry.

In a continuing collaboration with Professor Raymond Vernon, Harvard University, Gruber has examined some of the characteristics of industries and firms that invest heavily in R&D. The effect on world trade is indicated in the following table (Gruber, Mehta and Vernon, 1966)

*Research assistants during the period were Herbert Cremer, Harold Halsend, Leland Perry and John Petrosky

-25-
Research Effort and World Trade Performance
by United States Industries, 1962

<table>
<thead>
<tr>
<th>total R&amp;D expenditures</th>
<th>exports</th>
<th>excess of exports over imports</th>
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<tr>
<td>as % of sales</td>
<td>as % of sales</td>
<td>as % of sales</td>
</tr>
<tr>
<td>$R_1$</td>
<td>$E_1$</td>
<td>$E_2$</td>
</tr>
<tr>
<td>5 industries with highest research effort</td>
<td>6.3</td>
<td>7.2</td>
</tr>
<tr>
<td>14 other industries</td>
<td>0.5</td>
<td>1.8</td>
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</table>

Corporate Integration of R&D

Effective R&D calls for the utilization of specialized expert professionals, not only in R&D but in marketing and production as well. As specialization increases, the need for coordination and integration of specialized functions also increases, but is hindered by differences in interests and difficulties in communication. An exploratory study of 14 petroleum companies by Gordon S. Cochrane (thesis, 1967) demonstrated a strong relationship between ratings of firms on R&D effectiveness, and their reported coordination with executives in marketing, production and general management.

With feasibility demonstrated, Gruber and Otto H. Poensgen are proceeding to distribute a revised questionnaire to executives in the 500 largest R&D performing companies in the United States and a corresponding number in Western Europe and Japan.

Project Selection

Critical in the whole process of research planning for an organization is the procedure for evaluating and selecting projects. David G. Hill (thesis, 1967) studied 14 companies by interviewing managers involved in new product planning. Although they were aware of formal models for quantitative assessment of product compatibility and projected profit, they felt that more informal and intuitive procedures were sufficient.
Dennis Meadows has collected data in several firms to determine the accuracy and bias of initial estimates of cost and probability of technical and commercial success. It appears that the weak relation between initial estimates and outcomes is a serious drawback in the use of formal models for project selection.

The preparation of independent research and development (IR&D) programs was studied by interviews in six aerospace firms by Eugene N. Babb (thesis, 1967). He found no one method used by most companies. The selection of IR&D programs is closely tied to new business planning, and firms use only a few informal criteria to evaluate their programs.

A preliminary study by Kenneth P. Seltzer of 35 projects in a commercial manufacturing firm suggests that R&D projects arising from suggestions by customers and marketing personnel have a higher probability of commercial return.

### Commercial Outcome by Project Source

<table>
<thead>
<tr>
<th>Source of Project Idea</th>
<th>Incremental Sales</th>
<th>Laboratory</th>
<th>Marketing</th>
<th>Customer</th>
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<tr>
<td>None</td>
<td>66%</td>
<td>58%</td>
<td>33%</td>
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<tr>
<td>Small</td>
<td>17</td>
<td>14</td>
<td>33</td>
<td></td>
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<tr>
<td>Medium</td>
<td>17</td>
<td>14</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>Large</td>
<td>0</td>
<td>14</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td><strong>Percent of total budget expended</strong></td>
<td><strong>100%</strong></td>
<td><strong>100%</strong></td>
<td><strong>100%</strong></td>
<td></td>
</tr>
</tbody>
</table>

### Dynamic Models of R&D Organizations

Four Industrial Dynamics simulation models have been created by students working with Edward B. Roberts.

Arthur W. Blackman (thesis, 1966) simulated the growth of a hypothetical industrial research laboratory employing approximately 700 people and operating on an annual budget of approximately 12 million dollars.
Input data for the simulation were obtained from a research laboratory in the aerospace industry.

It was shown that government support plays a dominant role in the growth of the laboratory. Personnel and facilities acquisition policies based on long term growth objectives rather than on short term backlogs appeared to be necessary in order to achieve smooth, nonoscillatory patterns of growth.

Mark Ames (thesis, 1966) constructed a model of a firm committed in its hiring and promotion practices to its original product. The simulations produced by this model show that over-commitment can cause the success of an organization to go through a life cycle similar to the life cycle of its original idea. Only if the organization's commitment is kept at a reasonably low level and a sufficient number of new idea researchers are employed can the organization make a transition from its original product to new products.

The budgeting-hiring system of a typical project organization engaged in engineering research for the U.S. Government was modeled, evaluated and improved by Robert M. Pedraglia (thesis, 1967).

The profit, performance, and dynamic response of the system model to a contract award of a profit-incentive type were observed. Policy changes in the information and budgeting subsystems were defined and evaluated.

Improved stability of the labor force levels and increased profit were realized as a result of 1) the use of updating (or forecasting) in correcting observed labor force data for the effects of reporting and hiring time delays, 2) the use of "damping" in the work force budget adjustment policies implemented by the project manager and 3) the use of a variable budget for the indirect work force.

Lawrence Salba (thesis, 1967) developed and tested an Industrial Dynamics model of the National Aeronautics and Space Administration Electronic Research Center. The model considers the division of effort into in-house and out-of-house work; the effects of various goal-setting policies; and the effects of aging of the staff under a personnel ceiling.
Supervisory management

It is becoming increasingly evident that there is not one recommended style of supervision for all types of R&D groups. Georgio Tesi (thesis, 1966) was able to study seven basic research groups in government installations (Navy department). Questionnaire responses were obtained from most of the scientists, and the research directors were interviewed. The data are now being reanalyzed but it is clear that the most productive scientists and the most productive groups (in terms of papers) felt more freedom to choose their work, were more likely to work beyond regular hours, and felt less influence from the overall laboratory mission.

Ratings of effectiveness of 23 project groups in a large industrial laboratory engaged in government defense R&D were obtained by John M. Thomas (thesis, 1966). A supervisor's flexibility in meeting different needs of his subordinates was not found to be related to group effectiveness, although it elicited satisfaction by subordinates with the direction, freedom and recognition of their work. Amount of technical contact with the supervisor was positively related to group effectiveness, while informal social contact was negatively related.

The career expectations of 121 scientists and engineers in a government R&D laboratory were investigated with questionnaire methods by William W. McKelvey (thesis, 1967). Individuals whose expectations were less adequately fulfilled tended to be cynical about career advancement and also less willing to conform to organizational expectations. It is no surprise, then, that they also received lower promotion eligibility rankings from their supervisors.

Max Goldman (thesis, 1967) obtained questionnaire responses from 45 managers and their superiors and subordinates in a large electronics firm. Testing the idea that better performers differentiate more, i.e. give a greater spread of ratings of others, he found that managers' performance correlated positively with degree of their trust in others and negatively with the amount of their interpersonal differentiation. Managers' performance correlated positively with performance differentiation when coupled with high open communications with subordinates; but managers' performance correlated negatively with performance differentiation when coupled with less open communications with subordinates.
Factors in the relative effectiveness of 8 cross-functional product management teams (44 individuals) were studied by Benjamin P. Colosky (thesis, 1967). Motivation was measured with McClelland's TAT test and showed no relation to team effectiveness. Differences in team climate (responsibility, rewards, clarity and team spirit) and in team leadership were related to effectiveness.
Executive Management in NASA

The National Aeronautics and Space Administration has always made its Center operations openly available for research and has encouraged and contributed to many projects. But a unique opportunity was offered by the invitation from Administrator James E. Webb to study the decision-making and policy-forming activities of himself and associated headquarters staff.

Arrangements were made for a small group to spend six weeks in residence at NASA Headquarters from December 20, 1965 to February 5, 1966. Members were Professor Donald G. Marquis, Professor (now Dean) William F. Pounds, John Eggleston, MIT Sloan Fellow from Manned Spacecraft Center, Joseph Fernandez, MIT Sloan Fellow from NASA Office of Manned Space Flight. Occasional consultation also involved Bernard J. Muller-Thym and Harold A. Wolff. Working directly with the group were Breene Kerr, Assistant Administrator, Irwin Halpern, and Richard L. Lesher. Their wise and generous help contributed greatly to the effective utilization of our limited time.

Pounds and Marquis discussed management policy and procedures with the Administrator, the Associate and Assistant Administrators and many staff members, and attended formal and informal meetings. Eggleston assembled the data on the 600 top executives in NASA which he analysed for his S.M. thesis. Fernandez obtained and coded all the data on the 74 prime contract awards over $5 million in size from 1958 to 1965, including personnel of Source Evaluation Boards, and criteria, weights, and values for each proposing firm in each competition. His thesis traced the origin and change in NASA procurement procedures, and compared the several Centers.

As a special climax to the whole study, a trip to the Goddard Space Flight Center, Marshall Space Flight Center, and the Cape Kennedy Space Center was arranged for eight professors April 27-29. Mr. Webb kindly made available his airplane NASA I for the trip. The guests were Donald
Carroll, Donald Marquis, Henry Mintzberg, Edward B. Roberts, and David Sirota from M.I.T., Vaughn Blankenship from the University of California at Berkeley, and Harold A. Wolff, management consultant.

All the guests felt that they had been offered a unique opportunity to observe the top management of a huge project consisting of over 100,000 activities carried out by 20,000 separately located contractors. Prominent features of the management are the single clear dominating goal, the emphasis on visibility of schedule and budget performance, and the use of PERT-based information displays for control by anticipating exceptions to plans. All the participants found valuable materials and insights to incorporate in their teaching, and several of them have initiated research along lines suggested by their experience.

Academic Teaching

The following subjects are offered regularly in the programs of the Sloan School of Management and the Department of Political Science.

Course 15.384 Research Management. Donald G. Marquis. A semester course with an enrollment each year of about 50 graduate students in management, science or engineering. Small discussion sections are arranged for Sloan Fellows and for experienced research managers.

Course 15.386 Seminar in the Management of Science and Technology. Donald G. Marquis. Offered each semester, the "Friday Seminar" discusses new research results and plans. About half the sessions are presented by professors and managers from other universities or industrial and government organizations. A list of the sessions during 1965-67 is presented in Appendix 2.


Course 15.921 New Enterprises. Richard S. Morse. In this course for prospective entrepreneurs, teams of four students each study in depth a young technical company.

Course 15.582 Industrial Dynamics II. Edward B. Roberts. Application of industrial dynamics to actual company and government problem situations, including the management of technological innovation.

Course 17.42 Government, Politics and Technology. Harvey M. Sapolsky. This course places special emphasis on student projects which explore actual cases of political controversy involving technological change.

Course 17.431 Science and American Foreign Policy. Eugene B. Skolnikoff. This course examines the scientific and technological bases of key issues in foreign policy and the pattern of international scientific collaboration.

Sessions on the Management of Innovation by Allen, Marquis and Roberts are included in the programs for Senior Executives and for Sloan Fellows.

Course for Research and Development Managers

A two-week intensive course on Management of Research and Development is offered each year during the summer. Lecture-discussion sessions each morning present the findings of research studies, and small group sessions each afternoon discuss the implications for organizational and laboratory policies and procedures. About 50 R&D executives can be enrolled each year, and the MIT staff is augmented by invited lecturers.

In addition, members of the staff have presented numerous invited papers at national and international meetings and have conducted sessions for research managers in industrial and government organizations. Donald Marquis served as Visiting Professor at the newly established London Graduate School of Business during the Fall term, 1966.
Appendix I: Research Staff

Steering Committee
Donald G. Marquis, Professor of Organizational Psychology and Management, Chairman
Max F. Millikan, Professor of Economics, Director, Center for International Studies
Richard S. Morse, Senior Lecturer in Management
William F. Pounds, Dean, Sloan School of Management
Edward B. Roberts, Associate Professor of Management
Eugene B. Skolnikoff, Associate Professor, Political Science
John M. Wynne, Associate Dean, Sloan School of Management

Administrative Staff
Donald G. Marquis, Research Director
Edward B. Roberts, Associate Research Director
Betty L. Benedetto, Secretary
Katherine M. Blakeslee, Secretary and Editorial Assistant
Pamela C. Marsters, Secretary and Documents Assistant
Michele A. Parise, Secretary
Virginia V. Stupak, Secretary

Faculty Members of the Sloan School of Management Active in the Research Program
Thomas J. Allen, Assistant Professor of Management
Guy Black, Senior Research Associate; Staff Member, Council of Economic Advisors, Washington, D.C.
William M. Evan, Associate Professor of Sociology and Management; since 1966 Professor of Sociology, Wharton School of Finance, University of Pennsylvania
George F. Farris, Assistant Professor of Management, 1966-67.
William H. Gruber, Assistant Professor of Management
George T. Kennedy, Jr., Senior Research Associate; Associate Professor, Florida State University
Donald G. Marquis, Professor of Organizational Psychology and Management
James R. Miller, Research Associate
Richard S. Morse, Senior Lecturer in Management; Corporate Director, Industrial and Government Consultant
Bernard J. Muller-Thym, Senior Lecturer in Management, 1965-1966; Independent Management Consultant, New York City
L. Mark Ramsaier, Staff Assistant, 1965-66
Edward B. Roberts, Associate Professor of Management
Irwin M. Rubin, Assistant Professor of Management
Edgar H. Schein, Professor of Organizational Psychology and Management
David M. Straight, Jr., Staff Assistant, 1965-66
Herbert A. Wainer, Staff Assistant

Student Research Assistants and Fellows* 1965-67

Mark S. Ames  
B.S., Aeronautical Engineering, R.P.I., 1964

Paul Bergsteinsen  
B.S., Engineering Science, Stanford, 1965

J. Randall Brown  
S.B., Electrical Engineering, M.I.T., 1963  
S.M., Industrial Management, M.I.T., 1965

Frederick Buddenhagen  
B.S., Industrial Administration, Yale, 1965

James F. Burns  
B.S., E. Math. U. Michigan, 1961  
M.S., Columbia, Economics, 1963

Herbert Cremer  
B.S., Economics, Clark University, 1961  
M.B.A., Columbia University, 1963

Howard A. Cohen  
B.S., Economics, M.I.T., 1966

Stephen I. Cohen  
S.B., Chemical Engineering, M.I.T., 1960  
S.M., Industrial Management, M.I.T., 1966

William M. Collins  
B.S., Mechanical Engineering, M.I.T., 1965

William H. Dyer  
B.S., Mechanical Engineering, M.I.T., 1965

Dean A. Forseth  
B.S., Math., N. Dakota State U., 1961  
B.S., Meteorology, University of Washington, 1962  
S.M., Industrial Management, M.I.T. 1966

Daniel S. Frischmuth  
S.B., Electrical Engineering, M.I.T., 1964  
S.M., Industrial Management, M.I.T., 1966

Peter G. Gerstberger  
S.B., Industrial Management, M.I.T., 1965  
S.M., Industrial Management, M.I.T., 1967

*The names of faculty research advisors appear at the right
<table>
<thead>
<tr>
<th>Name</th>
<th>Degree</th>
<th>Institution</th>
<th>Year</th>
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<td>Arthur Gerstenfeld</td>
<td>S.B., Management Engineering</td>
<td>R.P.I., 1950</td>
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<td></td>
<td>S.M., Industrial Management</td>
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<td>Michael M. Gold</td>
<td>S.B., Engineering Management</td>
<td>Boston University, 1962</td>
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<td>Harold J. Halfand</td>
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<td>Norman W. Kneissler</td>
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<td>Milton L. Lavin</td>
<td>B.S., Aeronautical Engineering</td>
<td>M.I.T., 1961</td>
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<td>Maurice E. Maertens</td>
<td>B.S., Economics, St. Mary's (Cal.)</td>
<td>1964</td>
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<td>Dennis L. Meadows</td>
<td>B.S., Chemistry, Carleton</td>
<td>1964</td>
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<td>Eric Morrow</td>
<td>B.S., Economics, M.I.T., 1965</td>
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<td>Khalil E. Nougaim</td>
<td>B.S., Mechanical Engineering</td>
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<td>Paul W. O'Gara</td>
<td>B.S., Industrial Administration</td>
<td>Yale, 1965</td>
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<td>Sharad K. Pathak</td>
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Leland M. Perry
S.B. Chemical Engineering, M.I.T., 1963

Donald H. Peters
B.S. Physics, Rochester, 1962
MBA Pittsburgh, 1963

John M. Petrosky
B.S. Chemistry, University of Akron, 1964

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B.S., Industrial Engineering, Northwestern, 1964
S.M. Industrial Management, M.I.T., 1966

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B.S., Chemistry, Harvard University, 1963
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S.B. Industrial Management, M.I.T., 1959
S.M. Industrial Management, M.I.T., 1964

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B.S. Industrial Administration, Yale, 1964

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S.B., Electrical Engineering, Texas Tech., 1960
S.M., Industrial Management, M.I.T., 1966

Wyckam D. Seelig
S.B., Electrical Engineering, M.I.T., 1965

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S.B., Electrical Engineering, M.I.T., 1965

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S.B., Engineering Science, Antioch, 1959
S.M., Industrial Management, M.I.T., 1961

Albert Teich
B.S., Physics, M.I.T., 1964

James Utterback
B.S., Industrial Engineering, Northwestern University, 1963
M.S., Industrial Engineering, Northwestern University, 1965

William E. Wade Jr.
B.S., Chemical Engineering, University of Tenn., 1965
Appendix 2: Research Seminars

Donald G. Marquis  
Can Research Managers be Trained?  
October 1, 1965

Thomas J. Allen  
Time Allocation Among Three Technical Information Channels by R&D Engineers  
October 8, 1965

A. C. Copisarow, Deputy Controller, Ministry of Technology, United Kingdom  
The Role of Science and Technology in the United Kingdom  
October 15, 1965

David M. Straight, Jr.  
Organizational Factors in Project Performance - An Analysis of 38 Large R&D Projects  
October 22, 1965

Edward B. Roberts  
Herbert A. Wainer  
Gene Briskman, Research Assistant, Sloan School  
Dean Forseth, Research Assistant, Sloan School  
New Enterprises Formed by MIT Laboratory Alumni

Gus Rath, Associate Professor of Industrial Engineering, Northwestern University  
The Information Seeking Behavior of Scientists and Engineers: A Report of Operational Experiments with Medical Researchers and X-ray Crystallographers  
November 5, 1965

Summer Myers, Director of R&D Utilization Project National Planning Association  
Classifying and Tabulating Characteristics of Innovations and Their Technical Information Quanta  
November 12, 1965

William M. Evan  
Conflict and Performance in R&D Organizations  
November 19, 1965

Norman Kaplan, Program of Policy Studies in Science and Technology, George Washington University  
Comments on the Sociology of Science  
December 3, 1965

Zenon Z. Zannetos, Associate Professor, Sloan School of Management  
Toward Intelligent Management Information Systems  
December 10, 1965
Gerald Gordon, University of Chicago, Graduate School of Business

Effectiveness of Research Groups: Report of a Program of Research Studies

Eldon E. Sweezy, Executive Director, Management Council, Bethesda, Maryland

Evaluation of Lab Health: Results of Interview Studies in 64 Labs in the United States and Western Europe

George Farris, University of Michigan

A Causal Analysis of Research Performance

Richard Dunnington and Richard Ritti

IBM Corporate Staff, Armonk, New York

Attitudes and Satisfactions of R&D Personnel

William H. Gruber


Philip Myers, Doctoral Candidate, Harvard Business School

A Comparative Study of Corporate Long Range Practices of Several Large Electronics Companies

S. H. Peres, Behavioral Research Service, General Electric Company

Values and Goals of the Engineer-Scientist as Related to Effectiveness in an R&D Laboratory

J. Randall Brown, Doctoral Candidate, Sloan School of Management

Performance of R&D Project Teams

J. E. Gordon and M. E. Maertens, Research Assistants, Sloan School of Management

Impact of Government R&D Contracts upon Privately Funded R&D Budgets and Management Practices in 67 Industrial R&D Laboratories

C. West Churchman, Professor of Business Administration

Philburn Ratoosh, Management Sciences Center University of California, Berkeley

The Social Sciences Project of the Space Sciences Laboratory, University of California
Colonel Raymond Isenson, Office of Director of Defense Research and Engineering, Department of Defense

Project Hindsight: A DDR&E Project to Trace the Sources of Technological Advances Incorporated in Operational Defense Systems

Irwin M. Rubin
Factors in the Initiation of Development Projects Affecting Performance

April 29, 1966

Alfred J. Kelley, Deputy Director, NASA Electronics Research Center
Management Decision Process in Mission-Oriented Research Organizations

May 6, 1966

Digests of Thesis Research Results

May 13, 1966

John M. Eggleston
Executive Selection and Development in a Large Government Agency

Joseph Fernandez
NASA Source Evaluation Board Process

Georgio Tesi
Managerial Policy and Performance of Basic Research Scientists

S. William Linko
Entrepreneurial Success Factors

William V. Gudaitis
The Controversial Role of the Government Inhouse Labs in System Development

Elmer L. Field
Problem Solving in Government Project Management

Michael W. Hilton
Industrial Use of PERT

May 20, 1966

Henry Mintzberg, Sloan School of Management
Voyage into NASA: Report of a Trip by Seven MIT'ers to Examine the Management Systems Used at Goddard, Marshall and Kennedy

May 27, 1966

Harold A. Wolff, Independent Management Consultant
Problems of Research Design in Studies of Management Uses of Computer-Based Systems

Edward B. Roberts
Progress Report on the Research Program on Science and Technology

September 23, 1966

William H. Gruber
An Overview of the MIT Conference on the Human Factors in Technology Transfer

September 30, 1966

Khalil E. Nougaim, Sloan School of Management
Determining Role Characteristics of R&D Managers

October 7, 1966
Irwin M. Rubin
Wyckham Seelig, Research Assistant, Sloan School Project Management: Some Further Results from the Study of Large-Scale, Government-Sponsored R&D Projects

William A. Barden, Director, Office of Liaison, Defense Documentation Center
Technical Information Transfer and the Defense Documentation Center

George Farris, Sloan School of Management
Leadership and Innovation in Scientific Teams

William H. Gruber
Technical Depth and the Modern Corporation

Peter G. Gerstberger, Research Assistant, Sloan School of Management
Proposed Investigation of the Criteria Used for Information Channel Selection by R&D Engineers

Dennis Meadows, Research Assistant, Sloan School of Management
Estimate Error and Project Selection in the Chemical Industry

Thomas J. Allen
The Flow of Technical Information within an R&D Laboratory

Edward B. Roberts
Discussion of Future Research Program Plans

Donald G. Marquis and Edward B. Roberts
Some Observations on British Technology

Raymond Isenson, Office of the Director of Defense Research and Engineering, Department of Defense
Developments in Technological Forecasting

James R. Miller, III
Experimental Test of a Systematic Procedure for the Assessment of Worth

Richard Rosenbloom, Associate Professor, Harvard Business School
The Flow of Technical Information in Multi-divisional Organizations

Guy Black, Council of Economic Advisors, Washington, D.C.
Research and Development as a Medium for Regional Economic Development
S. H. Peres, Behavioral Research Service, General Electric Company
Factors Which Influence Careers of Engineers in General Electric
March 24, 1967

J. Randall Brown
Staffing Development Projects for Successful Performance
April 7, 1967

Gerald Gordon, Associate Professor, Cornell University
People, Organization and Innovation in Research Laboratories
April 14, 1967

George T. Kennedy, Associate Professor, Florida State University
Theodore J. Eckert, Project Manager, AF Eastern Test Range, Patrick AFB
Management Factors in the Performance of Launch Contractors at Cape Kennedy
April 21, 1967

Sumner Myers, Institute of Public Administration, Washington, D.C.
Technology Transfer and Innovation: Findings of the R&D Utilization Project
April 28, 1967

Max Goldman, Sloan Fellow, Sloan School of Management
Management Effectiveness and Working Relationships
May 5, 1967

Homer Morgan, Sloan Fellow, Sloan School of Management
Attitudes of R&D Engineers Toward Continuing Education

Gerald S. Rosenfelder, Sloan Fellow, Sloan School of Management
Selection Criteria for Program Managers in the Aerospace Industry
May 12, 1967

William Davis, Sloan Fellow, Sloan School of Management
Management of DOD Laser Research Contracts
Appendix 3: Reports and Publications


Appendix 4: Theses, 1965-67

The names of faculty advisers are indicated at the right. Theses may be examined in the Dewey Library at the Massachusetts Institute of Technology. Xerox or microfilm copies may be purchased from the Microreproduction Order Section, Room 14-0551, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139.

Allen, Thomas J. PhD., 1966 D.G. Marquis, R.S. Morse, W.F. Pounds
Managing the flow of scientific and technological information.

An investigation of the information flow among scientists and engineers was conducted on 19 parallel R&D projects. Data were gathered by means of time allocation forms, tape recorded progress reports and post project interviews with scientists and engineers. Scientists are found to rely more heavily upon written than oral sources of information; the pattern for technologists is the reverse. For technologists the organization to which they belong imposes severe barriers across which communication is relatively ineffective. The flow of technical information to a member of an industrial organization follows a multi-step pattern with certain individuals serving as key links to the outside world through either the literature or oral contacts outside of their own labs.

Ames, Mark S.M., 1966 E.B. Roberts, A. Amstutz
A model of hiring practices and implementation decisions in a research oriented organization.

An industrial dynamics study investigating the effects on the long run behavior of a technology-based enterprise of organizational commitment to a specific product. Computer simulations suggest that organizations which commit themselves to specific products at the expense of hiring personnel capable of innovative research endure a historical success pattern of growth, maturity and decay similar to the life cycle of the focal product or idea. Corrective policy action can take the form of maintaining commitment at a reasonable level while stimulating new ideas by a consistent policy for hiring more innovative new idea researchers.
The effect of solid state technology on the television service industry.

An analysis of historical quantitative data on component failures in vacuum tube electronics and in solid state circuitry as well as of statistics describing the television repair industry. Based on these data and predictions regarding the rates of transition to transistor and microcircuitry by the black and white and color television manufacturers, the author predicts the impact of solid state technology on the repair industry. The study concludes that the activities of the television repairman will be markedly changed and the total demand for servicemen will be reduced as a result of the adoption of solid state design.

Babb, Eugene N. S.M., 1967 * R.S. Morse, T. J. Allen
Methodology used in the preparation of independent research and development programs within the aerospace industry.

Interviews were conducted with executives of six aerospace industrial organizations to determine an effective approach to be used by aerospace organizations in the preparation of independent research and development (IR&D) programs. It was found that there is no one methodology that can be applied across all aerospace companies; that the selection and preparation of IR&D programs is closely tied with new business planning procedures; and that aerospace organizations have only a few informal criteria with which they evaluate the success or failure of their independent research and development activities. Criteria and procedures for preparing IR&D programs are proposed.

Bergsteinsson, Paul S.M., 1967 E.B. Roberts, I.M. Rubin
The evaluation and selection of sources for major NASA contracts.

The contract award process for seventy-four major NASA procurements between 1958 and 1965 is analyzed with respect to the evaluation of competitors by NASA Source Evaluation Boards (SEB), the selection of award winners by the NASA Administrator, the factors affecting procurement lead time, and the relationship of the award process to eventual contract cost performance. NASA's decision process for large contract awards com-

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bines both the formal evaluation of competitors by SEBs and the selection by the Administrator. In those cases in which the Administrator selected companies not ranked first by the SEB, the rankings were close, and the contract awards were large. Analysis of contract cost performance and its relationship to the award process reveals that the agency environment and objectives may be key determinants of cost performance. The smaller NASA contracts were found to have expanded beyond scope more than larger contracts and early NASA contracts were found to have overrun more than later ones.

The growth dynamics of an industrial laboratory in the aerospace industry.

An industrial dynamics study of the growth of an aerospace research laboratory. Model parameters and initial values are derived from an anonymous research laboratory in the industry. The study concludes that two factors are of primary importance for sustained growth: a long-term commitment by management, and government support. Management must adopt a long-range planning horizon to reduce the tendency for short-range oscillations in acquiring personnel and facilities; government funding assumes a primary role particularly if alternate sources of money are not available. To maintain a level of government interest the laboratory must sustain its facilities and personnel, have a high output rate, and expend effort to attract new government business.

Venture capital: the decision to finance technically based enterprises.

Twenty-four investment decisions by one of the largest small business investment companies are examined in order to determine characteristics differentiating those companies accepted for funding from those rejected. The venture capitalist uses a two step decision process in which a general search is first carried out to determine if the second phase involving an in-depth study is justified. The criteria employed in evaluating new companies are those characteristics generally accepted as indicators of company success: growth potential and profitability. The venture capitalist prefers a group of entrepreneurs rather than an indi-

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ividual, prefers to have some managerial or administrative experience in the new company's management, requires that the product be in production, expects to participate in the equity of the company, and prefers entrepreneurs who consider capital appreciation as the primary criterion of the product's success.

Brush, Edwin, Jr. S.M., 1966

D.G. Marquis, P.L. DeBruyn

Factors in the quality of doctoral theses.

An investigation of the quality of twenty-five doctoral theses in MIT's Metallurgy Department. Quality evaluations of the theses by the department's professors were related to the responses of the students (now alumni) on a questionnaire. A strong correlation is found between high quality doctoral research and the single fact that the student had carried out a Master's thesis in Metallurgy at MIT. In addition, the better theses are written by students who settle early on a thesis topic after exploration of only a few topics, and by those who take doctoral exams earlier and spend fewer years in graduate school. There is no relation between thesis performance and total college grades and only a weak relation with grades in graduate metallurgy courses.

Buddenhagen, Frederick S.M., 1967

E.B. Roberts, R.S. Morse

Internal entrepreneurship as a corporate strategy for new product development.

An investigation of 16 entrepreneurial business ventures in a corporate division of a large electronics manufacturer included examination of the entrepreneur, the project formation and growth, funding, technology, supervision and the impact of the laboratory on the project. The critical variables associated with the process of technical entrepreneurship are identified. Questionnaires were administered and interviews held with company management, the project heads, the supervisors, and other personnel having important bearing on the project. The most important determinant of venture success was found to be the character of the venture's product and its relationship to the company's primary commercial effort. Those ventures whose products had a commercial orientation and were associated with a major company product area were most successful because of the quantity and quality of resources that were avail-
able for the ventures' use. The characteristics of internal entrepreneurs were found to be similar to those of the new company founders studied elsewhere, and there was good evidence that the organization was biased against youthful entrepreneurs.

Burns, James F. PhD., 1967

D.G. Marquis, P. Soelberg

An extremity-variance analysis of group decisions involving risk.

A model was developed for predicting the shift in group decisions from the average of prior individual decisions on case problems involving risk and uncertainty. Tested on 361 group decisions made by male undergraduate students, the model predicted the shift in over half of the decisions. It is suggested that extreme positions are more attractive and forceful since they provide a clearer resolution of the dilemma and a concurrent reduction of uncertainty, and that holders of more extreme positions are confident in their decisions and exercise greater influence in the group discussion. The joint result is that prior extremity and variance are both necessary, but separately insufficient conditions for the occurrence of the observed shifts. The model involves the deviation of initial individual decisions from a neutral mid-point, and their variance.

Clagett, Robert P. S.M., 1967 *

L. Moore, I.M. Rubin

Receptivity to innovation - overcoming NIH.

"Not Invented Here" (NIH) has been used among technical organizations to describe the resistance to adoption of an innovation proposed from a source outside of the organization. Several cases of successful and unsuccessful attempts by an engineering research center to introduce innovations to manufacturing plants were studied to determine causes of NIH. Each case was analyzed by Lewin's force field concept. Analysis of the data indicates that NIH is to a large degree created by those attempting to introduce an innovation. In every unsuccessful case, the plant that was the "client" was excluded from participation in establishing research on the problem from which the innovation was developed or was excluded from the research itself.

* Sloan Fellow

The place of research and development in the corporation: a study of the petroleum industry.

The R&D effort of a number of U.S. petroleum companies was studied by means of questionnaires to determine how well R&D is integrated into the corporate structure. It was found that to be most effective, R&D should be integrated as much as possible into the corporate structure. R&D effort should be directly and specifically related to company goals, there should be effective coordination of the R&D effort with marketing and production functions, and R&D should not have too much influence over its own budget relative to other groups in the company.


Technical information flow within an R&D laboratory.

Analysis by questionnaire of the information-seeking behavior and social structure among 28 researchers in a small scientific laboratory. Information dissemination in the laboratory is found to be a two-step process in which certain key individuals act as mediators to relay information to their colleagues from the technical literature or other external sources. Social structure, as indicated by interpersonal choices for social interaction, strongly affects the person-to-person transfer of information. There were significant differences in attitude and information-gathering behavior between PhDs and non-PhDs. PhDs tended to form a closely knit social and professional group and to hold favorable attitudes toward the laboratory, while the non-PhDs did not tend to group consistently and held less favorable attitudes toward their employer.


Business attitudes among business school students.

An analysis of the role of a business school in determining attitudes among business school students. To determine the progression of attitude formation through business school and into industry. Students from three successive classes of one business school were given questionnaires concerning the company’s overall images. The existence of gaps

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between business school attitude changes and attitude changes after graduation was found in the following areas: the degree of definition of responsibilities in companies, the length of training periods in companies, the value of the education in several departments of business school, the importance of work rules in companies, and the degree of centralization in companies.

Colosky, B. P. S.M., 1967 * D.A. Kolb, M. Haire, R. Beckhard

An experimental study of organization climate and motivation in effective product management teams.

Eight cross-functional product management teams (44 people) in a Massachusetts firm were analyzed in order to relate their motivation and the organization climate to performance. The TAT test was used to measure motivation and climate was determined by the Litwin-Stringer Climate Questionnaire. No relationships were found between team motivation and team effectiveness. However, team effectiveness was related to five climate variables: negatively to conformity, and positively to responsibility, rewards, clarity, and team spirit. Leaders of effective teams were low in affiliation and Team Spirit motivation. Team effectiveness was not related to members' effectiveness, but members judged effective were high in achievement motivation.


Management of Department of Defense laser research contracts.

A sample of 30 completed laser contracts was studied to determine factors in the effectiveness of DOD Research and Exploratory Development. Data were gathered by semi-structured interviews with contract monitors, questionnaires administered to the contractors, and past performance records from Air Force files. It was found that the performance of DOD contractors on oriented projects (Exploratory Development) is higher than on non-oriented projects (Research). Past performance of the firm is not a reliable guide to expected performance in a particular technology such as lasers. Experienced government contract monitors are associated with higher technical performance but also with greater overruns and schedule slippages.

* Sloan Fellow
An investigation of major subcontract procedures in the aerospace industry.

A comprehensive qualitative model of the subcontracting process is presented. About 30 subcontracts were studied by means of interviews and questionnaires administered to both the vendor and customer. Analysis of the data showed that: 1) the technical approach bias obtained from vendor contracts prior to preparation of the work statement is very important in determining the eventual subcontract winners; 2) a free flow of information between the prime contractor and the vendors is possible because public pressure is absent and the company is able to limit the bidder's list; and 3) winners had more experience in the relevant technical area and were willing to spend more time and money in proposal preparation than were the losers.

Executive selection and development in a large government agency (NASA).

The study examines both the present structure of NASA management and the methods being used by that agency to develop management personnel. It describes the 621 top NASA Executives (GS16 and above) by their educational backgrounds, years of experience, location prior to joining NASA, age, and years with NASA. It pinpoints the relatively small interagency mobility over the seven years history of NASA by identifying management moves made over that period. Participation in management development seminars both within and outside NASA is surveyed. Finally the thesis describes current NASA objectives and policy on management development, selection and recruitment.

The origin, evolution and operation of the NASA contractor source evaluation board process.

A description, history, and statistical analysis of NASA's use of Source Evaluation Boards in awarding large R&D contracts, based on interviews with the NASA Administrator, headquarters and field personnel and on historical data from NASA files. The study finds that significant

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differences exist between the use of the Source Evaluation Board process by different NASA centers, but that there are no significant relationships between such descriptive factors as board size, length of review, and the prior experience of board members.

Field, Elmer, Jr. S.M., 1966 * D.G. Marquis, R.L. Kahn
Problem solving in government project management.

An analysis by questionnaire of the interactions and methods employed by project managers in a large government agency. Fifty-six problems were identified, and the project manager and those associates with whom he must solve the problems, the techniques of solution, and the evaluation of the outcome. The study concludes that technical problems generally result in more satisfactory outcomes than program (cost and schedule) problems and are viewed by the project manager as less demanding; satisfactory solutions are associated with those methods of resolving problems which involve mutual agreement; and projects with fewer in-house government personnel working on them have more satisfactory technical problem solution than projects employing a larger number.

Fitzgerald, Charles T., Jr. S.M., 1966 R.C. Casselman, R.S. Morse
Organizing for new product evolution in small, technically-based, manufacturing companies.

Fifteen small technically-based companies with annual sales of $12 - 120 million were studied by means of interviews to determine: 1) the essential elements of the process of new product development, 2) the organizational patterns which appear to be most useful in implementing these tasks, and 3) the nature of the changes in these key elements inherent in the growth of the company. Factors crucial to the overall process of new product development were found to be: 1) definition of overall product policy, 2) evaluation and selection of specific proposals, 3) the need for product champions, and 4) the control of development projects. It was shown that the organizational pattern for the new products task can be expected to change as the firm diversified into substantially different fields.

* Sloan Fellow
Forseth, Dean A. S.M., 1966          E.B. Roberts, R.S. Morse
The role of government-sponsored research laboratories in the generation of new enterprises -- a comparative analysis.

A study of the twenty-four new enterprises which were established by individuals formerly employed by MIT's Electronic Systems Laboratory or the Research Laboratory of Electronics. Questionnaire and interview data led to the findings that: entrepreneurship relates to family background; direct transfer of technology from the former place of employment is associated with success and with an early reliance on sales to the federal government; and the number of founders of the new firm is related to its subsequent success. The report also summarizes the work of earlier theses, providing a total sample of 119 "spin-off" companies.

Frischmuth, Daniel S. S.M., 1966          T.J. Allen, D. Siroti
A model for the description and evaluation of technical problem solving.

A model of the technical problem solving process in the form of a process flow chart detailing the engineer's interaction with sources of technical information was developed on the basis of tape-recorded problem solving protocols obtained from three engineers working on the same technical problems involved in a three-company parallel contract. The model indicates that the problem solver should not view the process as only finding the best solution for a given problem, but that he should search for the best solution and the best problem criteria.

Gerstberger, Peter G. S.M., 1967          T.J. Allen, I.M. Rubin
An investigation of the criteria used in information channel selection by R&D engineers.

The criteria generated and employed by engineers for selecting information channels in problem-solving were investigated by means of questionnaires and interviews with 19 engineers in 2 divisions of an industrial electronics firm. A direct relationship is found between perceived accessibility of information channels and several objective measures of utilization, but those channels highest in technical quality are not found to be the most frequently utilized. The relevance of informal relationships in the laboratory to the transfer of technical information and interpersonal communication is recognized and discussed.

A comparison between group and individual problem solving by R&D engineers.

In two laboratories conducting identical projects under parallel government contracts data were collected by questionnaire and interview from project personnel, and success ratings were obtained from the government technical monitor. The results suggest that there is no clear superiority of group methods over individual methods of resolving problems or vice versa; group methods were superior in only one of the two laboratories. Group problem solving resulted in higher evaluated solution quality when the group spent less conference time in giving opinions and more time in asking for opinions and showing a moderate degree of disagreement. The nature of prior experience markedly affects the openness to alternatives with which the group approaches a problem.


Interaction study in parallel R&D projects.

Three parallel projects in the aerospace industry were studied to determine the relationship between interaction, performance, space and technical discussion choices. Data were obtained weekly over several months on sixteen subproblems. Interaction was found to be positively related to performance when the interaction was with colleagues outside of the immediate group, confirming earlier studies on the importance of in-house sources of information. Sociometric questionnaires completed by 70 researchers in one laboratory and 44 in a parallel laboratory demonstrated a strong positive relationship between physical proximity and choices for technical discussion.


Management effectiveness and working relationships.

Questionnaire responses were obtained from 41 managers and from their subordinates and superiors in a division of a large electronics firm. The relationships between the managers’ rated effectiveness and certain characteristics of his managerial style were examined. A high degree of trust in others, the ability to differentiate between others in regard to job performance, and the setting up of good channels of communication with

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subordinates were found to be important factors in effective management. No evidence was found to support the hypothesis that managers' performance is related to their ability to differentiate among others in regard to interpersonal factors.

Goldstein, Jerome S.M., 1967 E.B. Roberts, I.M. Rubin
The spin-off of new enterprises from a large government funded industrial laboratory.

Thirty-nine new enterprises founded by individuals who had previously been employed by a large government funded industrial laboratory were studied to determine relationships between the performance of the new enterprise and the characteristics of the entrepreneur and the enterprise. A comparison was also made between these industrial spin-offs and prior studies on academic spin-offs. It was found that the entrepreneurs studied were generally highly educated, and that nearly half of them had fathers who were self-employed. The more successful entrepreneurs had been in supervisory positions. Companies founded initially by more than one individual, with greater initial capital financing, and with a greater emphasis on marketing, were generally more successful.

Gordon, John E. S.M., 1966 D.G. Marquis, G. Black
The effects of government sponsored R&D upon the management of private R&D.

A questionnaire-interview study of 67 industrial laboratories in three industries related government activity in support of research and development with management practices in company funded R&D. Significant differences in the effect of government support are found among types of laboratories and different industries. The importance of government activity is apparent in the management of private R&D particularly in those areas where management procedures and techniques are undergoing change in general. There was a tendency for laboratories to broaden and deepen their own technological areas in response to interests of the federal government.
Use of in-house R&D laboratories by department of defense project managers.

A study of the relationship between government laboratories with the project offices of the three services who monitor overall weapon system development programs. Interviews were conducted with thirty-three such project managers to determine preferences for in-house versus contracted R&D. The study concludes that the past experience of the government laboratory is the essential determinant of its participation. The thesis describes and suggests reasons for differences in the level of utilization of the in-house laboratories by the three services and in the criteria on which project managers base their evaluations of government laboratories.

A study of the capital seeking process of the technical entrepreneur.

Interviews were conducted with the founders of 21 new, technically-based enterprises, all of whom had, at some time, sought capital from a venture capitalist. The two most important sources of initial capital were the founders themselves and private investors. The companies initially financed by the founders were found to be more successful. While banks and private investors were seen as helpful, SBICs were generally not thought to be very useful in the founding stage of the company, but were important considerations in mergers.

*Sloan Fellow
Engineers and engineering students’ attitudes on various sectors of
the engineering profession.

Questionnaires were administered to about 300 practicing engineers
in one company and to Senior engineering students at the University of
Idaho to explore the different images of the four engineering sectors:
Design and Development, Field Service, Production, and Research. It
was found that the images of Production Engineers and Field Service
Engineers were less attractive than Research and Design and Development
Engineers. They were perceived as less scientific, less competent,
less satisfied and with less prestige. The students concurred in this
differentiation but to a lesser degree.

An examination of the initial evaluation process for new product ideas.

An examination of the initial evaluation process for new product ideas was made by means of interviews in 14 companies to determine: 1)
the extent to which formal and informal procedures for new product
planning are used, 2) the extent to which mathematical models for
aiding in the new product decision process are being used, or might
possibly be used, and 3) whether there is any apparent pattern of
success of firms which can be determined from company characteristics.
More formal organizational structures and more formal methods of analysis tended to occur in companies that were rated more successful in
terms of certain scales developed for this purpose. The extent of
change in products and the rate of change in product lines do not as
such have a demonstrable effect on success; the particular change it-
self must be considered.

The use of PERT in industry.

Interviews were held with both government project managers and
with managers in six large industrial organizations. The interviews
identified utilizations and interpretations of the effectiveness of PERT
techniques; an analysis was made of related performance. The thesis
concludes that PERT has proven to be a valuable scheduling tool in its

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applications and was instrumental in effecting improved cooperation and communications among the groups undertaking a project.

Klahr, Michael W. S.M., 1967  E.B. Roberts, P. Casselman
A study of new enterprises producing consumer products.

Twelve entrepreneurs and the companies which they founded in 1961 were studied by means of interviews and questionnaires to determine what factors might be related to the success or failure of the firm. Of the 12 individuals interviewed only 4 were still in business after 6 years. Of the 75 initially identified, 82 percent had failed. Thus the individuals studied were generally unsuccessful. Their average age was 45, they were all married and most had only a high school diploma.

An investigation of marketing strategies in the government R&D industry.

An attempt is made to classify companies in the government R&D business as "proposal oriented" or "contact oriented" based on their emphasis either on established procedure or on informal relationships as the primary tools for winning contract awards. A sample of eight firms was studied in an attempt to relate these orientations to the probability of winning awards. The results indicate that it is extremely difficult to categorically define a firm's attitudes. Firms behave as if both informal contact and procedural process were important; however, some firms place relatively more weight on one type of strategy than on the other.

Development of electrical technology in Japan.

The information gathering patterns of Japanese electrical engineers were studied by means of an analysis of references in two Japanese electrical engineering journals to determine how specific technologies develop over time in a country in which they are introduced from abroad. The hypothesis that older technologies, having had sufficient time to
build up and reach the critical level of self-sustaining growth depend more on domestic information that newer technologies, was established and tested. The results of Chi-square tests quite conclusively supported this hypothesis when several technological fields were grouped together.

Entrepreneurial success factors.

Questionnaire data on eighteen new technical enterprises in the Boston area were analyzed to determine factors contributing to sales growth. The significant factors clustered in four areas: perception of the needs of the external markets, corporate capacity to satisfy these needs, method and rate of new product generation, and understanding of the firms' own internal requirements. The statistical relations of these factors become nonsignificant in ranges of extremely high rates of growth (greater than $120,000 a year), suggesting that a different managerial style is required at these levels.

Research and development effects in the machine tool industry.

An examination of the effects which research and development and innovation have had on machine tool industry was made by means of industry data and interviews with executives. The condition of the industry was analyzed in 1958 and 1965 and the determinants of industry behavior at each of these two points in time were compared. It was found that the major new force, in addition to general economic growth, acting to increase industry growth was numerical control, an innovation which originated outside of the industry.

Maertens, Maurice E. S.M., 1966 D.G. Marquis, G. Black
Government-funded R&D: substitution or pump priming?

R&D administrators of 67 firms in three industries were interviewed to determine the extent to which government funding stimulates or substitutes for private investment in research. An R&D multiplier is determined for each industry measuring the relationship of private to public funding. Among the relationships discovered are: there

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appears to be a priming effect in the machinery and scientific instruments industries, but substitution in electronics; a strong substitution effect is observed for "single" laboratories performing all of the research for a company; there is essentially no relationship in corporate central laboratories.

McKelvey, William W. Ph.D., 1967  
E.H. Schein, D.G. Marquis

Expectational noncomplementarity and deviant adaptation in a research organization.

The career expectations and adaptations of 121 scientists and engineers in two divisions of a government aerospace laboratory were measured on 11 attitude scales. Results indicate that those whose career expectations were not fulfilled expressed attitudes of cynicism (perceived lack of control over career advancement) and unwillingness to conform to organizational expectations. This group received the lowest promotion eligibility rankings from their supervisors.

Miller, James R. Ph.D., 1966  
D.G. Marquis, H. Weingartner  
G. Kaufman

The assessment of worth: a systematic procedure and its experimental validation.

A methodology was designed for evaluating the worth of an alternative (defined essentially as the degree to which the alternative results in the realization of a specified set of objectives). Programmed for computer use, the procedure was evaluated experimentally by following the sequential decision process on a standard problem by 48 managers. The study concludes that attempts at quantifying the elements critical to the decision affects the decision-making process positively and that the procedures were regarded favorably by the decision makers studied.

Morgan, Homer G. S.M., 1967  
I.M. Rubin, D. Montgomery

Attitudes of research and development engineers towards continuing education.

A projective (semantic differential) instrument designed to measure attitudes toward continuing education was given to 312 engineers in a government R&D laboratory. The instrument describes a

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hypothetical R&D engineer as having (a) obtained an M.S. degree, or (b) completed seven courses, or (c) completed only one course since receiving his B.S., and asks the respondent to rate the applicability of a number of adjectives. Research and development engineers did not perceive any significant difference between obtaining a degree or completing seven courses in a continuing education program. Both, however, were seen as having more positive attributes than taking only one course. Advanced education was perceived as being associated with high management potential, high ambition, greater professionalism, and as keeping an engineer more up to date.


A dynamic model of the budgeting-hiring system of a typical R&D organization.

A model of the budgeting-hiring system of a typical project organization engaged in engineering research for the government was constructed, evaluated and improved. The profit, performance, and dynamic response of the system model to a profit-incentive type of contract award was observed. Policy changes in the information and budgeting subsystems were defined and evaluated. Improved stability of the labor force levels and increased profit were realized as a result of (1) the use of updating in correcting observed and labor force level data for the effects of data collection, reporting and hiring time delays, (2) the use of "damping" in the work force budget adjustment policies and (3) the use of a variable budget for the indirect work force.


Corporate R&D in the U.S. chemical industry.

The research and development efforts of firms in the chemical industry are analyzed statistically in an attempt to relate these innovative factors with measures of corporate success. The results indicate that there is a strong relationship of R&D expenditures and personnel to company size, but that acquisition, rather than R&D expenditures, is the major factor in growth in the period studied. While a few significant relationships are found, the difficulty imposed by the use of published data leads to the recommendation that subsequent

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studies be made on less heterogeneous samples in order to control non-

essential factors.

Petrosky, John M. S.M., 1966 W.A. Gruber, A. Amstutz

The role of research and development and other selected variables in

the performance of firms in the pharmaceutical industry.

An economic argument is presented that promotion, finance, ac-

quisition-merger, diversification, and foreign penetration contribute
to corporate performance in increasing economies to scale, while dis-
economies to scale exist in research and development. Analysis of the
ethical drug industry indicate that concentration is increasing in the
industry, with larger firms replacing smaller firms in various product
lines. Methods were devised and tested for examining the relationships
among product sales and investment in R&D and promotion.

Poust, Roy N. S.M., 1966 D.G. Marquis, I.M. Rubin

An analysis of problems encountered in R&D project management.

Thirty-two large government development contracts were studied
to determine the relationships between problem importance, frequency,
and solution time for managers of R&D projects. Questionnaire data
were obtained in interviews with the relevant project manager, labor-
atory manager, and government technical monitor. Project managers
and technical monitors indicate that technical problems are most fre-
quent and most time consuming, while laboratory managers most often
encounter cost problems. Rankings of problem importance are found to
be inversely correlated with rankings of problem frequency.


The preparation and pricing of research and development proposals

A study of the decision to bid in 48 companies competing in 2
government R&D competitions, and of the proposal preparation process
of 21 companies in 6 competitions was made. Evaluations of each of the
21 proposals were obtained from the relevant government agencies and
used as criteria of effectiveness. Widespread ignorance of the market
by the companies was discovered. Several pricing and costing strate-
gies were identified and their effectiveness evaluated. A detailed
model of the decision to bid and the pricing decision was built. It
is suggested that increased feedback from government to all companies about their relative performance at the conclusion of each competition would improve the efficiency of competitive procurements.

Ramsaier, L. Mark S.M., 1966

Performance measures and marketing strategies in research and development.

Twenty-two proposal bids by seven companies were analyzed by comparing potential strategy factors of "high" and "low" performance companies. Prior to the receipt of the Request for Proposal (RFP) the more successful firms are more apt to acquire information about the technical initiator's identity and interests, interact with him, and undertake technical work specifically along directions related to the contract. Post RFP activities are helpful to companies which are less well known initially to the customer.

Radomsky, John S.M., 1967 *

The problem of choosing a problem.

The process and information used by managers to choose the next activity in which to invest their time is described and related to concepts of psychology, decision making, scheduling and organization theory. The respondents were three managers of a large successful manufacturing firm who were asked to verbalize their task selection decisions for a full day during which video tape recording was employed. The process was found to be goal oriented, dynamic, intentionally rational, satisficing and heuristic. The general hierarchy of values assigned to tasks during work hours was: 1) expedite the functioning of the organization, 2) solve already identified tasks in manager's own inventory, 3) search for new tasks and 4) engage in model building, self-development, etc.

Rogers, Claude E. S.M., 1966

The availability of venture capital for new, technically-based enterprises.

Sources for venture capital and its availability to technically-oriented entrepreneurs were analyzed on the basis of questionnaires.

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returned from 37 sources. The most recent investment and the most recent rejection were studied and compared. Important factors influencing this decision are the evaluation of the entrepreneur and management team, and the growth potential of the market. The frequency of referrals from various sources was compared for Boston, New York, and other regions.

Rosenfelder, Gerald S. S.M., 1967

Selection criteria for program managers in the aerospace industry.

Two hundred and sixty-two program managers from 17 aerospace companies completed a general background questionnaire combined with Gough's Adjective Check List, Ghiselli's Self Description Inventory, and an ambiguity tolerance test. Key executives from the companies were asked to provide performance evaluations of the managers and information on the company's program manager selection method. All the variables were compared with the Overall Performance ratings to determine the best selection method. No definite profile was found for the successful program manager. Intolerance of ambiguity does not appear to be a strong factor in the selection of a program manager, but leadership ability is found to be an essential factor in considering a candidate for a program management job. The only ultimate test of a candidate's suitability for this job is his performance on a previous program management assignment.

Salba, Lawrence S.M., 1967

A planning model for the NASA electronics research center.

An Industrial Dynamics model of NASA's Electronic Research Center considers the division of effort into in-house and out-of-house work, the effects of various goal-setting policies, and the effects of the aging of the staff. It was concluded on the basis of the results of experimental runs with simulated data that better techniques of setting, communicating, and understanding the effects of goals are needed, and that any ceiling on the number of personnel in a research organization tends to lead to stagnation and reduced productivity.

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Management factors in launch performance.

Sixteen organizations engaged in servicing and testing missile subsystems prior to launch at Cape Kennedy were studied. Objective performance measures were based on holds, excess time and scrubs during 408 launches in nine missile programs. Significant variance in company performance is found after allowance for different programs and different subsystems, and is related to company management practices.

Smylie, Robert M. S.M., 1967 W.B. Crowston, J.F. Pierce
The application of decision CPM to incentive contracts.

An investigation was made of the applicability of integer programming for selecting the optimum combination of jobs, when alternatives are available, in order to maximize fee under incentive contracts, where the contractor's fee is dependent on meeting or improving contract costs, schedule, and problems. An example CPM network, including alternative jobs, an incentive structure, and a fee structure based in part on an existing contract was developed. The necessary integer program equations were written for the example problem and were solved using the stopped simplex algorithm. The technique requires that a number of computer runs be made covering the span of possible program costs and that an auxiliary calculation using the contract incentive structure be used to compute the fee position and thus determine the optimum solution.

Stoner, James Ph.D., 1967 D.G. Marquis, G.C. Hoyt
The effect of general values on cautious and risky shifts in group decisions.

An investigation with student subjects of factors in individual and group decisions on life situation items involving risk. Initial individual decisions on the items are found to be consistent with widely held values as assessed on a separate instrument. Significant differences between individuals' perceptions of their own riskiness relative to "other people like them" are also found. For life situation items on which the widely held values favored the risky alternative and on

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which subjects considered themselves relatively risky, unanimous group decisions were more risky than the average of the initial individual decisions. The group decisions tended to be more cautious on items for which widely held values favored the cautious alternative and on which subjects considered themselves relatively cautious.

Tesi, Georgio S.M., 1966 * D.G. Marquis, R.L. Kahn
Managerial policy and performance of basic research scientists.

Seven government basic research laboratories were compared on the basis of questionnaire replies by the professional scientific personnel and of interviews with the laboratory directors. A measure of involvement is derived from the percentage of respondents working extra time without compensation. A measure of productivity of each laboratory was calculated on the basis of papers published or presented to scientific meetings. Factors influencing the productivity of PhD and non-PhD members of the sample differ significantly. PhD performance is little affected by laboratory policy and environment, and appears to be derived from the profession rather than the employing organization. Non-PhDs' productivity is strongly influenced by managerial policy and environment, and by the degree of commitment of their PhD colleagues.

The concept of supervisory flexibility in an industrial research laboratory.

Measures of the effectiveness of 23 small project groups engaged in government defense research in a large industrial laboratory were related to various aspects of the supervisor-subordinate relationships. Two overall conclusions are drawn: (1) a supervisor's belief in the importance of understanding differential needs of his subordinates, together with some skill in acting according to these differences is more important for project effectiveness than his accuracy in perceiving the needs of his subordinates; and (2) a project supervisor's flexibility has more positive impact on the satisfaction of research professionals with the manner in which they are supervised and the extent of their freedom and recognition than on their performance as a group.

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Research on the usefulness of R&D and the characteristics of R&D intensive industries.

Characteristics of R&D intensive industries were determined using the financial data over time for about 500 companies from a Compustat Tape from Standard and Poor's. The industries have been defined wherever possible at the SIC 3-digit level. The work has contributed to the development of a method for grouping companies into industries at a finer level of activity then was heretofore possible with data available from government publications.

The spin-off of technology from government-sponsored research laboratories: Lincoln Laboratory.

This study investigated fifty technically-based enterprises founded by former employees of MIT's Lincoln Laboratory with particular emphasis on the transfer of Lincoln-developed technologies. Data were collected by interview with the founders of the new enterprises and their former supervisors and colleagues, and from the Massachusetts State Corporate Records Department. Several factors were found to relate to the success of the spin-offs, including a high degree of technological transfer from the parent laboratory and the existence of a specific business and marketing function within the firm. A high proportion of founders had fathers who were self-employed, and differences in age and education level were observed between the sample entrepreneurs and the general population.