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Annual Report RESEARCH PROGRAM ON THE MANAGEMENT OF SCIENCE AND TECHNOLOGY *1964-1965*

ALFRED P. SLOAN SCHOOL OF MANAGEMENT
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

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INTRODUCTION

IN THE YEARS SINCE WORLD WAR II, research and technology have assumed an increasing importance in industry, universities, and government. Problems of the effective organization and management of technology are widely discussed and debated, but there is a dearth of factual research-based knowledge in this area.

In the spring of 1962 the Alfred P. Sloan School of Management at M.I.T., with the encouragement of James E. Webb and financial support from the National Aeronautics and Space Administration, undertook to develop a program of research and education on the problems of organizing and managing large-scale technology-based enterprises. The studies now in progress and 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 in the general welfare. Statements of the underlying concepts which guide the program appear in talks delivered at the International Conference on Operational Research and the Social Sciences at Cambridge, England, September, 1964; at the 17th Annual Conference on the Administration of Research, September, 1963 (Marquis, 1964),* and at the September, 1963, International Convention of The Institute of Management Sciences (Roberts, 1964b).

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 selected from graduate student candidates for the S.M. or Ph.D. degree, most of whom have bachelor degrees in science or engineering. A list of personnel active during the period of this report is presented in Appendix 1.

The program is administered by a research director and an associate director, guided by a Steering Committee of seven faculty members (Appendix 1). 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 the faculty and student staff and by a number of guests from other M.I.T. schools, from Harvard, 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.

Although the outside support for the program of research studies 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, the Ford Foundation, the Sloan Research Fund of the Sloan School of Management, the M.I.T. Center

* Citations are to reports and publications listed in Appendix 3.

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). Acknowledgement of the particular source is made in the description of each of the research studies.

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.

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, if slowly, from evaluative 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 procedures: 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 all these respects there has been only a beginning, but we expect to continue our efforts, in cooperation with an increasing number of like-minded investigators at other institutions, for many years.

THE R & D PROCESS: PROBLEM SOLVING

The creation of technological innovation involves the transfer of scientific knowledge to potentially useful new processes and products. The activity is essentially one of information processing, though it is labeled in different contexts as decision-making, problem-solving, and research and development. Experimental studies of human thinking processes and field studies of real-life R & D should contribute to each other. The problem solving process can be analyzed into successive, but iterative, stages as follows:

Individual Thinking	Organized R & D
Problem finding	*Recognition of needs*
Analysis of problem	*Technical specifications*
Search for solutions	*Formulation of technical alternatives*
Evaluation of alternatives	*Analysis and test*
Implementation	*Prototype development and production*

Research on problem-solving in R & D laboratories is seriously limited because replication is rare. A project once done is not (deliberately) repeated. In this section we describe research in two kinds of field situations in which comparison is possible and in several experimental laboratory situations which simulate some aspects of R & D.

Problem Solving in Parallel R & D Projects

PARALLEL CONTRACTS AFFORD THE RESEARCHER an opportunity to make direct comparisons of the way different R & D groups perform the same tasks. In this project comparisons are sought between the technical approaches considered, the strategies employed, and the information sources utilized by the competing research groups. The research described here has been directed by Thomas J. Allen, with Maurice P. Andrien, Jr., Richard J. Bjelland, Richard H. Frank, Daniel S. Frischmuth, and William D. Putt as research assistants.*

Sixteen instances of multiple-award contracts have been obtained from major N.A.S.A. and U.S.A.F. centers. Nineteen companies have cooperated in the project. Subsystem lead engineers on each project maintain records of information sources and report their progress

* Supported initially by a grant from the National Aeronautics and Space Administration and currently by a grant from the National Science Foundation.

toward solution on specially designed Solution Development Records. Each project manager is called by telephone once a month and asked to provide orally a resume of activities and technical decisions made during that month.

Preliminary results from an analysis of three parallel pairs indicate that in considering a number of alternative approaches to a technical goal, R & D teams most frequently operate on a two-at-a-time basis. While they may during the total duration of a project look at as many as eight alternatives, at any one time they are trading off between two of them. There is, furthermore, a relation between this phenomenon and the quality of the technical solutions. Groups contributing the poorer of two subsystem designs in parallel projects, on the average, trade off among more alternatives at a given time (Allen, 1965a).

While there is no significant difference between the number of alternatives considered at the onset of a project by groups submitting higher- and lower-rated solutions, there is a significant difference in the total number of alternatives considered. Groups submitting lower-rated designs consider more alternatives over the duration of the project than do their rivals who produced the higher-rated solutions. They generate more alternatives during the course of their study, probably because they encountered difficulty with their initially selected approaches.

When an approach which had been favored is eventually rejected, the length of time required for it to decay from dominant preference to a position of complete rejection is a direct function of the length of time it was in a dominant position.

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 and Andrien, 1965).

Analysis of the sources of technical alternatives to problem solution 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 almost perfectly reversed from 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 is underutilized (Allen, 1965b).

Technical Performance in Proposal Competitions

THE PROPOSAL COMPETITION provides another opportunity for the study of factors influencing success in technical work. It is one of the rare real-life situations (along with multiple-award contracts) in which a number of different firms work on the same task and can therefore be directly compared. Technical evaluations are obtained from the responsible government agency, and questionnaires completed by each firm provide information on the relevant characteristics of the firm and on

the proposal effort. The research study described here was conducted by Thomas J. Allen and Donald G. Marquis, with Maurice P. Andrien, Jr., and Dan I. Abramovitch as research assistants.*

Twenty-two U.S.A.F. and N.A.S.A. competitions were selected, and approximately 200 questionnaires were mailed to the competing firms. Returns were received from about 75 per cent. Analysis of these returns shows that the size of a laboratory's technical work force and the number of engineers and scientists it assigns to the proposal team far outweigh other factors such as company size and technical man-hours of effort in influencing the technical quality of proposals. There is a strong indication that attempts to substitute for in-house competence by use of outside sources of technical information are unsuccessful. The time spent examining literature is not correlated with differences in the quality of the proposal (Allen and Marquis, 1965).

An almost U-shaped relationship is found between the level of effort expended on the proposal and its technical rank. Firms in the upper half of the rankings show a direct relation between man-hours expended and technical ranking; firms in the lower half show an inverse relation. Apparently there exists a "threshold of competence", only above which does it pay to increase one's expenditure of effort. The highest ranked firm, however, expends less effort than the next four ranked competitors, indicating the possible influence of prior experience or other factors on the evaluation.

Neither the mean education level of the proposal team nor the average length of experience of its members, or a combination of the two, is found to be related to technical quality.

Time spent in breadboarding and benchwork is found to be directly related to the proposed cost of the job, suggesting that breadboarding provides information for a more realistic appraisal of the scope of the contemplated effort.

Experimental Studies of Problem Solving

IN THE PROCESS OF RESEARCH AND DEVELOPMENT there is a succession of decisions involving various degrees of uncertainty. To supplement the field studies of decision making, a number of experimental researches are being conducted under the direction of Geoffrey P. E. Clarkson, Donald G. Marquis, William F. Pounds, and O. Peer Soelberg.†

Uncertainty, defined as incomplete information on the probabilities or values of the outcomes of a set of alternatives, has been found to have certain regular effects on decision choices and on strategies for reaching decisions. For example, individuals are found to choose less risky alternatives in the face of uncertainty than in comparable risk

* Supported by a grant from the National Aeronautics and Space Administration.

† Several of these experiments have employed a graduate research assistant on a grant from the National Aeronautics and Space Administration.

problems with greater certainty (Hubbard thesis, 1963).*

When five or six individuals who have already indicated their own decision choices are formed into a group which is instructed to discuss the problems and agree on a unanimous choice, the group decision, unexpectedly, is more risky than the average of the individuals' decisions (Marquis, 1962). This effect is greatest with problems involving uncertainty; there is almost no group effect with problems of pure risk choice (Hinds thesis, 1962).

Preliminary work indicates that there are clear differences among people. Anxious individuals (Alpert-Haber test) show a larger effect of uncertainty, and social-conforming individuals (Marlowe-Crowne test) show a larger shift from individual to group decisions. Continuing experimental work is directed to the study of decision choices among sure wins (all alternatives have positive expected value) compared with choices among sure losses (negative expected value).

Geoffrey P. E. Clarkson is pursuing a different approach to the study of decision making (Clarkson and Pounds, 1963), using a situation devised by William F. Pounds (1963) in which an individual makes a number of monetary bids against a set of unknown competitors whose bids are drawn at random from a distribution unknown to the player. A computer program written in the language of IPL-V grows and collapses discrimination networks in simulation of the subject's decision process (Eglinton thesis, 1965). Work continues on a second computer program to simulate the joint decisions of teams of two individuals.

O. Peer Soelberg has designed a complex, computer-controlled problematical environment which is: (a) sufficiently complex and flexible to provide opportunity for long-term systematic investigations of human thinking processes; (b) sufficiently well specified to permit application of rigorous experimental controls; and (c) sufficiently quantifiable to allow explicit measurement of behavior as well as direct comparison of alternative strategies of problem-solving. Parametric forms of such an experimental environment have been programmed and have been run on both real-time and time-sharing computer systems.

Data have been obtained on the problem solving performance of eighteen men, each working over time periods extending to eight weeks, on a series of four problems in which prior knowledge would be either facilitating, interfering, or neutral for the solution process. Verbal protocols have been analyzed to determine the different types of strategies employed and to construct flow charts of the observed processes. A tentative revision of the theory of problem solving has been formulated to account for the observed diversity of decision behavior and to serve as an organizing framework for the next stage of research. Eventually, a computer may be programmed to simulate a "hairy" research problem.

* Thesis titles and abstracts are listed by author in Appendix 4.

ORGANIZATION AND MANAGEMENT OF LARGE PROJECTS

A project, carried out by a company or university under contract to a government agency, is a suitable unit for research investigation. Such a project has a specified beginning and end, initial cost estimates and technical specifications, and separate and audited accounting. About 40 per cent of all R & D is of this type (N.S.F. data on 1963 expenditures).

The traditional organization of industrial work by functional departments has increasingly been modified to incorporate special task forces with multi-functional membership devoted to a clearly defined objective, such as a new product development or corporate planning. Such groups are integrated into the total organization in various ways; some are strictly "staff" while others approach "line" authority. The R & D project is currently trapped in this ambiguity, and there is much debate and little evidence on the issue. What are the best ways to accomplish the staffing, planning, and control in order to achieve most effective performance?

Case Studies

WORKING WITH EDWARD B. ROBERTS, Archie L. Wood has completed studies of two large-scale R & D programs and performed extensive analysis of a third program. The first is a detailed analysis of Project Mercury, based on extensive public records of estimated and actual costs, schedules, and performance (Wood, 1965). Weakness of spacecraft system engineering appears to have contributed much of the slippage of cost and schedule, but the overall Mercury program is still comparable in performance to other large earlier aerospace projects. The second study involved the collection and analysis of quantitative data on an unmanned instrumented spacecraft program. Results indicate that the large cost and time overruns were caused mainly by underestimates of the technical uncertainty in the development of major subsystems and components and that a strategy taking account of explicit estimates of such uncertainties should improve performance (Wood thesis, 1965).

Dynamic Models of R & D Projects

EDWARD B. ROBERTS' BOOK, *The Dynamics of Research and Development** (1964), is the first application of the principles of feedback systems analysis and industrial dynamics to the problems of R & D. The book includes the exposition of a verbal theory of the causal structure underlying project life cycles, followed by a translation of the theory into mathematical equations. The results of more than one thousand computer simulations are described, indicating the sensitivity of project outcomes to various characteristics of the product, the R & D organization, and its customer. Possible conflicts between industry objectives and government contracting policies are suggested by the computer results.

In an extension of Edward B. Roberts' project model, Joe N. Nay (thesis, 1965) developed a system including up to four projects in parallel. Transition from one project to another was studied, and further conflicts in government-industry contracting relationships were uncovered.

Another industrial dynamics model was developed by Frank S. Holman, Jr. (thesis, 1963) for the design of large weapon systems involving the scheduling of many interrelated functions. Results indicate the beneficial effects of more complex decision rules that take into account the technical interdependencies of the many development tasks.

Planning and Control

THE UBIQUITOUS FACT OF SUBSTANTIAL COST and schedule overruns in large defense systems projects has been well documented by studies at RAND and the Harvard Business School. Further results are presented by Thomas W. Finch (thesis, 1962), who obtained data by interviews and questionnaires at six N.A.S.A. contracting offices on fifty-six ongoing CPFF research and development contracts. The majority were essentially on schedule; the others were from three to six months behind. However, most of the contracts had cost increases averaging about 50 per cent for both small ($100,000 to $1 million) and large (over $1 million) contracts.

Several small studies relating to project planning and control have been carried out as theses or as parts of other large investigations. Carl E. Kleckner (thesis, 1962) analyzed interview data on the experience with PERT and CPM at eleven military and industrial establishments. Itzhak Jacob (thesis, 1963) explored the possibilities of including performance parameters in the CPM planning of development projects. Marvin Hersh (thesis, 1964) reported interview findings on the major problems encountered in applying PERT in several southern California R & D organizations. Graciano Sa (thesis, 1964) analyzed four methods of solving PERT networks to show how information obtained from a PERT recursion can be improved by increasing the accuracy of

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PERT results and by using more versatile ways of estimating input data. Edward B. Roberts (1963b) discusses the implications of industrial dynamics for the design of management control systems.

It is generally recognized that no elaborate computerized PERT-type system can be any better than the estimates which are the inputs to the system. Sources of inaccuracy and bias in estimating uncertain future values thus becomes a critical area for investigation. Karl A. Miller (thesis, 1963) took advantage of a course in PERT being given in an aerospace firm, to obtain as homework from thirty-seven employees the time estimates for a thirty-two activity network. Total completion times computed for the critical path varied greatly, and a larger optimistic bias was shown by engineering managers, finance personnel, and programmers than by bench engineers. Several studies of the process of estimating probability values are now in progress under the direction of Donald G. Marquis by Richard Bjelland, James R. Miller, and J. Randall Brown.

It is regrettable that there is no published information on the question of whether sophisticated planning and control techniques actually improve performance, but this is the inevitable result of the difficulty of measuring performance. Data on thirty-five large projects indicate some relation between type of control procedure (PERT, bar charts, etc.) and schedule and cost performance but none with evaluations of overall technical success of projects.

Project Organization

A MAJOR EFFORT FOR THREE YEARS has been the collection of comprehensive information on a sample of fifty large R & D projects carried out by industrial laboratories under contract to government agencies. Data are nearly complete on thirty-seven projects, and missing data on the others will be secured during the summer of 1965. The project was designed and directed by Donald G. Marquis with J. Randall Brown, Michael M. Gold, James E. Mahoney, Irwin M. Rubin, and David M. Straight as research assistants during the past year.*

A project was selected in a company or a government agency on two criteria: (1) random or most recently completed, and (2) more than $1 million in size. The thirty-seven projects were contracted by twelve government agencies. The firms are all in the aerospace and electronics industries, and 80 per cent of them are among the 100 largest performers of government-funded R & D. They are located in all parts of the country.

The selection of variables for investigation was initially based on interviews with experienced R & D managers and on published literature. Valuable use was made of a study by James M. Osborne (thesis, 1962) in which he identified critical factors in project success from interviews in industrial and government R & D organizations and from his experience as manager of the Boresight Program for R.C.A.

* Supported by a grant from the National Aeronautics and Space Administration.

Project performance is measured in several ways: (1) objective records of cost, time, and technical accomplishment are compared with the estimates and requirements in the contract; (2) judgments of performance are obtained from the project manager, the laboratory director, and – in the government agency – from the technical monitor and the contract administrator; (3) an account of the critical problems, slippages, and failures in the course of the project, together with the steps taken in response, are obtained from the project manager and the technical monitor.

Information on a number of features of the organization and management of each project is obtained from laboratory records, from the government contracting offices, and by interviews with the project and laboratory manager.

Preliminary analysis of selected portions of the data indicate that the evaluation of successful performance by either company or government personnel is based predominantly on technical performance, with much less weight to schedule and least to cost.

Comparison of project organization with functional organization discloses no consistency in the different patterns of authority exercised by the project manager. No index of project or functional organization based on personnel reporting relationships is found to relate to evaluated successful technical performance, but projects which incorporate administrative personnel in the project team have fewer cost and schedule overruns (Marquis and Straight, 1965).

Project Managers

PROBABLY CRITICAL IN THE SUCCESSFUL PERFORMANCE of a project are the unmeasurable characteristics and competences of the project manager. Laboratory directors have declared that the only way they know how to select a project manager is to observe his performance as a project manager!

Andrew G. Swanson (thesis, 1964) has studied the decision process of choosing project managers by intensive interviews with six executives in a large government research and development laboratory. Using a decision model patterned on Geoffrey P. E. Clarkson's (page 6), he concludes that the process is understandable and describable even though it is carried out in an informal and mostly unconscious way. A set of criteria involving technical and contract administrative experience are matched with characteristics of particular individuals. Ordinarily, one person is tentatively selected at the outset, and his match is compared with that of others who come into consideration.

Another valuable characteristic for a project manager is disclosed by Robert E. Pace (thesis, 1964). In a matrix overlay organization the project manager gets the necessary work done by negotiation with the functional divisions. Questionnaire data on attitudes and orientation of support personnel toward their functional manager and project manager indicate that the effectiveness of the latter depends on how he handles motivating and rewarding forces.

INDIVIDUAL AND INTERPERSONAL FACTORS IN R & D

Research and development activities are performed by people. This truism is nevertheless a source of many of the most vexing problems of management, because scientists and engineers are different from production workers, salesmen, and accountants. By virtue of their choice of occupation, their educational experience, and their orientations and values, they do not respond to traditional supervisory direction as well as they do to certain modified personnel policies and practices.

Questions of motivation, incentives and rewards, group functioning, leadership, and "atmosphere" are questions amenable to study by psychological and sociological research methods, and a number of excellent studies by other researchers have been carried out in this area. Of special interest to us are the long-term considerations involved in technical and research management careers.

Research Ability

A LARGE NUMBER OF INVESTIGATIONS by others have shown that measures of intellectual ability (college grades, intelligence tests) are weak predictors of on-the-job performance of scientists and engineers. The search for a predictive test of creativity has been a special subject of many studies, without any verified usable outcome. A particularly promising new test of creativity, the Remote Associates Test, has been found by others to have high correlations with the evaluated creative contribution of architects and psychologists but zero correlations for scientists and engineers. The latter result was replicated in a typical R & D laboratory by Adolph J. Hansen and Donald G. Marquis (1964) who argue that such laboratories in fact neither stimulate nor reward creative contribution. They then selected for study two small laboratories, staffed largely by Ph.D. scientists engaged in basic research and exploratory development, which were generally reputed to emphasize and to do creative work. A significant positive correlation between test scores and evaluated creative contribution was found in both laboratories, but its magnitude (.40) is not sufficient for use in individual selection.

Motivation: Goal Setting

DURING THE PAST THREE YEARS Andrew C. Stedry, with Michael M. Gold and Dan I. Abramovitch as research assistants,* has conducted a program of studies directed at three questions: (1) In what form can (and should) organization goals be communicated to subordinate levels in the organization? (2) How do these communicated goals interact with goals of the subordinate organization and the individual aspirations of members of the subordinate organization? and (3) How do all of these goals taken together affect the total amount of effort managers will expend in goal attainment and their allocation of effort among the various areas of activity in which goals exist?

Analytic models of multiple goal structures have been formulated in collaboration with Professor Charnes of Northwestern University (Charnes and Stedry 1964a, 1964b). Two field studies in engineering organizations have been completed (Rubin, Stedry, and Willits, 1964; Stedry and Kay, 1964).

Results support the view that goals (or budgets) have a motivating effect on performance. Difficult goals produce better performance than normal goals, unless they are so high that they are rejected as impossible. Thus difficult goals, especially when they are established for more than one area, are associated with either very good or very poor performance.

Motivation: Initial Experience

THERE IS ACCUMULATING EVIDENCE that challenging or demanding tasks during the first job experience have a persisting favorable effect on performance even years later. Barry Graves (thesis, 1962) compared the work experience of two groups of aeronautical research engineers, similar in age, education, and length of work experience but different in that one group was composed of individuals judged to be of outstanding competence. The histories of work assignments over about fourteen years were different only in the first few years: significantly more of the engineers in the superior group worked in applied research rather than basic research or development and test. A possible interpretation is that applied research sets clearer goals than basic research, and that the tasks are more demanding and challenging than those in development and test work.

Fortunately, a more direct test of the hypothesis is furnished by David E. Berlew and Douglas T. Hall (1964, 1965). Sixty-two college graduates newly hired into two operating companies of the Bell Telephone System were carefully followed during their first six years of employment, after which their performance could be gauged by salary level, number of promotions, and judgments of superiors. One major result was that high expectations by the company (more challenging and demanding tasks) were associated with more successful performance, and that the level of company expectations during the first year

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had greater influence on eventual success than expectations during any of the succeeding years. The implication that goal setting and challenging tasks are of critical importance during the first year of work deserves serious attention.

Rewards and Job Satisfaction

BECAUSE THE SUBJECT OF INCENTIVES has received considerable attention from other researchers, no major study has been undertaken. Several theses have dealt with some aspects of the problem. Raymond S. Nelson (thesis, 1962) found no difference in the self-image of engineers in government and industrial laboratories; Eugene J. Eckel (thesis, 1962) found considerable dissatisfaction in two industrial laboratories, accompanied by preoccupation with salary; Charles C. Joyce (thesis, 1963) investigated work experience and other factors in the performance and satisfaction of systems engineers; J. Randall Brown (thesis, 1965) concluded from a factor analysis of questionnaire responses that major sources of satisfaction are the challenge of the work and the belief that rewards in general are dependent on performance.

Technical Obsolescence

THE RAPID EXPANSION OF R & D activities has tended to postpone concern for the inevitable problems of obsolescence in areas of rapidly changing technology. A pioneering exploration of the problem was undertaken by Steve Cenko (thesis, 1964; Cenko and Marquis, 1964), who studied with questionnaire and interview fifty-four electrical and mechanical engineers and twenty-six supervisors in three companies. He found that an index of obsolescence based on both self-report and supervisor evaluation was related to number of years out of school, proficiency in mathematics, and number of advanced courses taken in the past four years.

William M. Evan is undertaking a continuing study of obsolescence for which he has carried out a number of preliminary studies during the past year.* Interviews with engineers, professors, and research executives have underscored the effects of excessive specialization and the difference between growth in general "technical know-how" and specific technical knowledge. He has also related evaluated obsolescence of engineers and scientists in two Navy laboratories with information available in personnel records.

Preliminary analysis of a questionnaire mailed to a number of government, industrial, and academic laboratories has shown some interesting relations between the age distribution of laboratory personnel and the output in terms of papers and patents.

Particularly promising are some experiments relating fear of failure to rate of learning a short programmed course in Boolean algebra.

* Supported in part by a grant for this purpose from the Ford Foundation.

Group Leaders and Group Performance

HENRY B. EYRING HAS MADE A STUDY THIS YEAR of the groups of scientists who plan and carry out experiments on the few high-energy accelerators located at various sites in this country. Special attention is directed to the measurement of group continuity, the openness of groups to new members, and the interrelations of these characteristics with group size and the organizational affiliations of group members. A report is planned for late summer.

Two theses have dealt with special aspects of the supervisor-subordinate relation in R & D laboratories. Jay R. Bonnar (thesis, 1962) found that there is an optimal degree of informality and personal closeness, and William E. N. Doty (thesis, 1963) showed that the amount of influence a supervisor has is a matter of informal authority rather than formal delegation and that "informal vertical status consistency" contributes to the acceptance of influence from the supervisor.

William M. Evan, with John E. Osborne as research assistant, is conducting a major study of conflict and performance in R & D groups.* In the performance of project-oriented research at least four types of conflict may arise: (a) task conflict among peers – disagreement among project members as to how to achieve the objectives of the project; (b) task conflict between one or more project members and the project director; (c) interpersonal conflict among peers – personal dislikes or mutual distrust among project members; (d) interpersonal conflict between one or more project members and the project director.

A questionnaire designed to measure personal, motivational, and organizational factors affecting conflict and performance was pretested and administered to project groups in a government and an industrial laboratory. Preliminary findings provide some confirmation of the hypothesis that technical conflict is positively associated with performance and interpersonal conflict is negatively associated with performance. The evidence is more persuasive for the detrimental effect of interpersonal conflict than for the beneficial effect of technical conflict. The relationship between conflict and performance appears to be partly dependent upon at least two variables: group size and group loyalty. Under a high degree of group loyalty, the negative effect of interpersonal conflict on performance seems to be more pronounced than under a low degree of group loyalty. This is true, however, of the project groups in the governmental laboratory but not in the industrial laboratory. Group size also appears to affect the relationship between conflict and performance. In smaller project groups, at least in the industrial laboratory, technical conflict is more likely to arise and have a positive effect on the performance than in larger project groups where interpersonal conflict is found to have a negative effect on performance.

Russell M. Barnes (thesis, 1964) has explored the use of the

* This project is supported by a grant from the National Aeronautics and Space Administration.

"Semantic Differential Test" as a measure of organizational climate or atmosphere. Responses by 137 engineers in three departments of an aerospace firm indicate a significant relationship between job satisfaction and organizational climate. The measure showed a clear difference between departments.

Career Orientations

A SERIES OF STUDIES by Edgar H. Schein and William W. McKelvey* is developing concepts and research instruments for the study of career patterns of engineers, scientists, and administrators. The broad objective is to facilitate the design of organizational policies and procedures to increase the competence and contribution of researchers throughout their entire careers.

The first phase of the project was an exploratory one, undertaken in the summer of 1962, involving lengthy open-ended interviews with 96 men at the N.A.S.A. Langley and Lewis Research Centers. Results are reported in two papers (Peters, 1963; Schein, McKelvey, Peters, and Thomas, 1965).

The second phase consisted of the development of a questionnaire which includes two bipolar scales measuring career styles: active-passive and idealistic-cynical; three scales measuring role skills: task-interpersonal (bipolar), technical (uni-polar), and managerial (uni-polar); and finally two uni-polar scales measuring reference group orientation: institutional and non-institutional. A factor analytic item analysis of pretest data coupled with self-ratings gives evidence of item consistency and concept validity and supports the hypothesis that the four uni-polar scales vary independently of one another.

The third phase of the project involves an extensive questionnaire survey to ascertain the distribution of the various styles, skills, and orientations in government and industrial R & D organizations.

* This project is supported by a grant from the National Aeronautics and Space Administration.

RESEARCH INSTITUTIONS

Perhaps the outstanding development in the conduct of research during this century has been the growth of organized laboratories replacing the individual scientist and inventor. These new laboratories are found in universities, industrial firms, government agencies, and as independent organizations.

Although there is some consensus that university laboratories are optimal for basic research, industrial laboratories for development of new products and processes, and government laboratories for non-commercial missions such as standards, defense, and space, there is considerable overlap in their activities and vigorous debate about optimal organization and management policies for each. This debate will remain fruitless until measures of organization effectiveness for particular purposes can be devised. Recognizing the clear importance of these problems, we can only point to small steps in the indicated direction.

Case Studies

PROVIDING VALUABLE BACKGROUND FOR FURTHER WORK, several students have carried out intensive case studies of different research institutions.

Leo P. Kane (thesis, 1963) studied the M.I.T. Instrumentation Laboratory, a university organization performing research, design, and development on instrumentation and inertial guidance systems for a number of defense and space programs. Attention was directed to the growth and structure of the internal technical effort and the laboratory's liaison with industrial production firms. Regression analyses were performed on staffing ratios, costs, turnover, and other factors as functions of time, laboratory employment, and other variables.

Walter C. Scott (thesis, 1965) studied the Office of Advanced Research and Technology in N.A.S.A. headquarters as an example of a research support program in a mission-oriented agency. Information was obtained by interview and questionnaire on the objectives, the influences on program definition, the utilization of program results, and the relations between headquarters and decentralized research centers.

Paul Flam (thesis, 1965) reports a thorough history of the creation and development of Aerospace Corporation and MITRE Corporation, the two Air Force systems engineering and technical direction nonprofit organizations, and raises questions about their current

function.

Joseph R. Piselli (thesis, 1963) studied by interview and questionnaire an industrial organization performing government R & D. A descriptive model indicates that the three basic functions of research, development, and proposal preparation do not correspond to organization structure and that their differences in professional orientation and job characteristics have important implications for changes in balance and paths for advancement.

Dynamic Models

IN COOPERATION WITH LEO P. KANE'S study of the M.I.T. Instrumentation Laboratory, Gillett Welles, III (thesis, 1963) formulated a conceptual framework for analysis of a R & D organization and constructed an industrial dynamics model. The model divides the organizational work into research, advanced development, and proposal preparation and recognizes the conflicts among these for allocation of priorities and personnel. Variation in technical effectiveness, output rate, and output quality are features of the modeled system. Computer simulations permit study of the effects of policy changes on various aspects of performance and growth of the laboratory.

An industrial dynamics model of the organizational relationships between a central government activity and a remote R D T & E field activity was formulated and tested in 100 computer runs by George R. Wachold (thesis, 1963).

Lawrence E. Kanter (thesis, 1964) describes the growth of a company which leases technology-based equipment. In such an organization there is a divergence in objectives between the R & D activity that produces new technology to replace existing products, and company profitability that is dependent on keeping the leased equipment producing revenue as long as possible. Computer simulations of the dynamic model show the effects of various policies on company growth. These three studies of dynamic models were directed by Edward B. Roberts.

Technical Information Sources

STUDIES OF THE USE AND VALUE of various technical information channels in achieving R & D solutions have been described earlier (page 4).

Analogous study of the information sources for choice and definition of problems (as distinguished from solutions) is reported by William E. Stoney (thesis, 1962) on the basis of questionnaire responses by 157 research professionals in two divisions of the N.A.S.A. Langley Research Center. Each respondent chose up to six ideas which he felt to be among the best in his career and identified the source of each. The most frequently reported source of ideas is the supervisor. The supervisors themselves did not emphasize their own supervisors as much, and this fact indicates that problem ideas originate principally at a low level in the laboratory hierarchy. Work experience and litera-

ture are second in frequency for the total sample, but the two divisions differ markedly. Formal meetings, outside contacts, and education are infrequently reported—a surprising result in view of the emphasis by management on the promotion of these channels of internal and external communication.

These results, together with studies by others, document the necessity for innovation in information systems. The Technical Information Project in the M.I.T. Libraries, directed by Myer M. Kessler, although entirely independent of the research program described in this report, is fortunately located close by, and several cooperative studies are actively under discussion. Dr. Kessler has described his project recently in *Physics Today*, March, 1965.

Space Layout, Communication, and Work

THE RELATIONSHIP BETWEEN WORK and the space in which it is done involves (1) the identification of features of a project's spatial environment and how people feel about them; (2) the relationship of the dispersion of project personnel and their physical travel paths to the project's work-structure; (3) the relation of both (1) and (2) to the project's success or failure; and (4) the development of a system for classifying competences, and a language for describing their interaction, which may be used to construct general models of project structure.

Bernard J. Muller-Thym has directed a study* of these subjects based on interview material gathered at N.A.S.A.'s Goddard Space Flight Center. The analysis indicates that project personnel are far less concerned with environmental conditions such as noise or crowding than with the impact of physical constrictions on the flow of work and communication. Furthermore, problems such as crowding, as perceived by project personnel, bear little relationship to the actual measured conditions. For one project crowding actually led to a beneficial flow of information and a highly integrated work structure.

Evidence also indicates that campus-plan research centers may be detrimental to the performance of project-organized R & D work. It suggests that one or more buildings of such a campus plan be reserved for project work in order to match space structure more effectively with project work structure. Preliminary results are presented in theses by Jerome M. Kaufman (1963) and Robert W. Puffer (1964).

Nicholas Baracos (thesis, 1964) has carried out a comparable study of an automotive engineering office. A detailed analysis of the work flow and communication patterns in seven work centers of the product engineering office, based on questionnaire responses from 162 individuals, provides an accurate tool for observing and measuring the performance of an organization against its task requirements.

* Supported by a grant from the National Aeronautics and Space Administration.

Resource Allocation in R & D Laboratories

THE DIRECTOR OF A LABORATORY participates in a number of critical decisions involving resource allocation: the overall R & D budget, the selection of projects to meet company objectives, the optimal mix of different types of projects, long-range planning of facilities, equipment, personnel, etc.

The new product investment decision is the subject of a case study by John P. Leahy (thesis, 1962) in which he describes a large manufacturer's unsuccessful attempt to enter the market with a novel product. The entire life cycle of the product is traced from its origin in a research discovery, through the many problems of manufacturing and marketing, to its eventual abandonment.

Robert H. Cramer (thesis, 1963) investigated the possibility of applying decision theory to the selection of research projects. He used data from a series of standard gambles administered to several research and manufacturing executives to illustrate a method for incorporating a decision-maker's utility curve into a model for the selection and evaluation of research projects.

Dynamic model studies by Gillett Welles, III, George R. Wachold, and Lawrence E. Kanter (see page 17) are all focused on the allocation of technical resources in R & D organizations among such activities as proposals, research, development, production liaison; among such orientations as output quantity enhancement versus quality improvement; among such product areas as improvement of established products in contrast to creation of wholly new products. In another study George P. Fryling, II (thesis, 1965) has developed a life cycle model of the process of introducing technical products into markets pioneered by a firm's competitors. Stephen I. Dreier (thesis, 1965) furthers this study in a dynamic model of corporate growth that emphasizes the role of financial resource allocation policies.

Recognizing that improved information systems for managerial decisions on project selection will require historical statistical data on the distribution of outcomes for different types of projects, work has been initiated under the direction of Donald G. Marquis to collect such information on a substantial number of projects in a number of commercial R & D organizations.

GOVERNMENT CONTRACTING FOR R&D

Characteristic of the United States more than any other country is the close relationship between government and the private sector in the conduct of research and development. It is typical of most U.S. government agencies that 80 to 90 per cent of their R & D funds are expended by contract with industrial firms and, to a much smaller extent, with universities.

The nature of the contract for such work has evolved from traditional procedures for procurement of other goods and services and reflects the general concern for open bidding and competitive awards, with careful monitoring of quality, and strict accounting controls.

The operation of present research contracting systems, and the possibilities of adaptive improvements, are the subject of several researches here reported.

The Contract Award Process

EDWARD B. ROBERTS AND HIS RESEARCH ASSISTANTS (Laurence B. Berger, Norman Kneissler, Lewis G. Pringle and J. Barry Sloat)* have done several projects whose goal is the design of policies for a more effective government contracting system. The research is divided into three phases: (1) determination of the decision process used for government award of R & D contracts; (2) study of company strategy and decision making aimed at obtaining government contracts; (3) development of new approaches to government contract award process, the design based on the results of the two empirical phases of study.

Work on the first phase of the research program has included interviews and record analysis at three large government centers, one in N.A.S.A. and two in Department of Defense field centers. Project records have been studied in 100 competitive cost-plus R & D contracts which range in size from $100,000 to $40 million. An additional sample has been developed for a study of sole-source R & D awards. Data extracted from agency records and interviews with source evaluation board members, project managers, negotiating officers, and others is producing a view of the actual system underlying contract awards which differs markedly from the formal contracting system (Roberts, 1964a, 1965b).

Most of the contracts are awarded to the same companies that were preferred by the government technical initiators months in ad-

* Supported in part by a grant from the National Aeronautics and Space Administration.

vance of the formal competition. Personal exchanges of information between government and industry technical staff apparently often result in strong convictions by government personnel that are unaffected by the proposal solicitation process. Technical factors rather than cost considerations usually dominate, although there is often correspondence between top technical rank and the low bidder. In the few cases in which cost factors clearly affected the award, later cost-oriented problems showed up more noticeably than in the other projects.

Political pressures were found to be almost nonexistent in the award of these medium-to-large R & D contracts. Despite this the technical initiator and the procurement officer seemed to live in constant fear of the General Accounting Office and Congressional investigators.

Several instances were found in which desired sole source awards were not permitted by the D.O.D. organization. After formal solicitation of proposals from a number of companies, awards were usually made later to the desired companies. In other instances, preferences for two or three firms resulted in solicitation of many more firms, followed usually by award to an initially preferred company.

Company Bidding Strategies

THE SECOND PHASE OF THE RESEARCH PROGRAM involves an extensive program to study corporate strategy and decision-making in R & D marketing activities. Three mail questionnaires were prepared and distributed to the 1,100 winners, losers, and "no-bidders" involved in forty-five R & D awards. Preliminary statistical evaluation of about 400 usable returns have produced numerous significant distinctions between bidders and no-bidders and between winners and losers in these competitions. The dimensions along which the company groups are distinguishable include prior knowledge, past experience, personal contacts with the government agencies, and relative emphasis on proposal formalities (Pringle thesis, 1965; Roberts 1965b).

On almost all potentially meaningful tests no-bidders' responses were significantly different from those of bidders. In general the no-bidders do not know the initiator, have not done prior work for him or his group, have not submitted unsolicited proposals in the area, do not know the funding or the likely competitors, did not anticipate the request for a proposal, etc.

The most important differences between the winners and the losers are: (a) the winners' much higher prior contract work and prior unsolicited proposals; (b) their greater confidence in the importance of the job and their greater "inside" knowledge than their competitors; (c) their proposal strategy reflects responses directed at particular individuals in the government organization and explicit incorporation of technical preferences of the procurement initiator. Finally, less attention is given by winners to the formalities of proposal handling, with only 16 per cent of the winners as opposed to 36 per cent of the losers using technical writers on their proposal teams.

In addition to these large sample statistical studies, intensive investigations of contractor experiences have been continued, completing data-gathering and analysis of the R & D marketing effectiveness of two more firms. Preliminary findings are reported in two theses by Laurence B. Berger (1963, 1965). The interview studies, which have produced results consistent with the other research, have permitted revision of the research methods to lessen the cost and time requirements of additional company studies. The new techniques are now being used in a comparative analysis of proposal strategies and decisions of fifteen northeastern electronics firms. Initial results of this study will be reported by Norman W. Kneissler in August.

New Forms of Contracting

BASED ON THE RESULTS OF HIS STUDIES of the contract award process and company bidding strategy (see pp. 20–21), Edward B. Roberts has proposed a series of changes in R & D procurement practices (Roberts, 1965c). Among them are more flexibility in government gathering of technical information, changes in cost allowances to contractors on proposals and in-house research, and strengthening of technical exchange between government and industry.

Modified forms of contract arrangements are now being used by many government agencies. Charles H. Greer (1964) described and pointed out some of the implications of Cost Plus Incentive Fee (CPIF) contracts. Albert L. Baker (thesis, 1965) analyzed the decision processes used by company project managers to attain their profit goals within the constraints of the CPIF contract. On the basis of interviews with government and industry officials he attempted to ascertain the extent to which the objectives of the government are being met by incentive contracting.

J. Barry Sloat (thesis, 1964) carried out case studies of five R & D contracts which had been converted from CPFF to newer incentive forms. No obvious positive effects were observed, and there were some dysfunctional consequences of the high motivation to avoid potential losses.

The Department of Defense policies on independent research and development (IR&D) were examined by David H. Oswalt (thesis, 1964). On the basis of questionnaire responses from thirty-four key people in government and industry, he indicates a number of areas of agreement and disagreement on possible changes in policy.

Monitoring Government Contracts

THERE IS GREAT VARIATION in the magnitude and manner of monitoring activity, both between and within contracting agencies, but there is no available information dealing with the effects on contractor performance.

To explore methods for studying this problem, Jean-Paul Richard (thesis, 1963) analyzed a sample of thirty-seven contracts at one agency. Neil A. Holmberg (thesis, 1965) collected questionnaire

data on the monitoring of eleven large N.A.S.A. booster and spacecraft programs. Many particular factors are analyzed, with the overall conclusion that greater monitoring activity is associated with smaller variances in cost and schedule.

SOURCES AND UTILIZATION OF NEW TECHNOLOGY

Although everyone is aware of and properly impressed by the speed with which the transistor, the laser, and the electronic computer have progressed from basic scientific concepts to applied research, development, and practical use, the transfer process has typically been much slower. The average time between invention and first adoption of major technical innovations in various industries has been found to be from ten to fifteen years.

There are a number of interfaces at which the factors influencing transfer can be studied: between science and application in any form, between research and technology within a company, between development and adoption by the first company, between the time of first adoption and subsequent adoption by other companies.

What are the factors – technical, financial or psychological – which facilitate or impede the transfer? What are the channels of transfer which now operate or could be stimulated to operate more effectively? As we face newly recognized problems of urban traffic, water and air pollution, rapid surface transportation, mass education, etc., these questions assume high priority.

Growth of New Technical Enterprises

THE DEVELOPMENT OF NEW BUSINESS ENTERPRISES based on advances in science and technology appears to be an important factor in national economic growth. The environment of a new enterprise tends to permit the earlier introduction of innovative products and processes than would be the case in the well established and usually more conservative large corporation. Current national trends indicate an increasing concentration of sales and productive capacity in a smaller number of our larger corporations. Case studies of new technology-based companies have been written by a number of students in a course on New Enterprises offered by Richard S. Morse.

Peter E. Thurston (thesis, 1964) examined the founding and growth of fifteen new technical enterprises in the post-war period. Public financial data and interviews with company executives identified the key factors in the decision to establish the new enterprise and in the

successful growth of the company.

Julius Mannes (thesis, 1963) concentrated his attention on personnel management as a factor in the growth of three small electronics companies engaged in R & D. Different approaches to the problem of integrating non-professional workers as the companies moved into production activities are evaluated with respect to the maintenance of high performance by the research employees.

Harry Schrage (thesis, 1965) conducted intensive interviews and psychological testing with the presidents of twenty-two young R & D companies in the Greater Boston area. His results demonstrate a significant relationship between profitability and the presidents' veridical perception of customers' and employees' attitudes. Presidents with high achievement motivation (TAT measure) are either very successful or unsuccessful; those with low achievement motivation are near the margin of profitability. Those high on both veridical perception and achievement anxiety (modified Alpert-Haber test) are most likely to have profitable R & D enterprises.

During the past year Richard S. Morse has directed three theses which deal with methods of stimulating and financing new technical enterprises. Wayne F. Aguren (thesis, 1965) studied large nonfinancial corporations as venture capital sources by intensive interviews with thirteen executives of large industrial firms. Such firms seek new technologies and talented technical people as means for sustaining corporate growth or for conversion from defense to commercial business. The average number of ventures per corporation studied is three or four, with an average investment of $750,000 per venture.

Jean C. Lavoie (thesis, 1965) studied the financing of fourteen small technically oriented enterprises in New England, finding that no particular method of financing, providing it is plentiful, is more likely than another to result in success or failure, although each method will have other differential effects on the companies.

Thomas A. Bolles is completing a study of New England development commissions to assess their capabilities in the light of changing technology and changing attitudes of the Federal government toward regional development.

Diffusion of Innovation

THE TRANSFER OF TECHNOLOGY from new ideas (invention or basic research) to useful outcomes (process, product, or service) occurs both within institutions and between institutions. Roger E. Travis (thesis, 1964) has studied the case of the electron beam heating industry. The technology was initially developed to meet a specific need for a joining technique in the atomic energy program. Major technical problems of reproducibility and beam control have been overcome. Current equipment sales, however, are only one-tenth of the estimated potential world market. The author ascribes the present problems to the fact that key manufacturing decisions have been made by men with scientific and engineering background but with little information about the

market place.

William M. Evan and Guy Black are conducting a study of staff proposals for innovations which are submitted for approval and implementation by line management, in order to ascertain what factors affect the success or failure of proposals for innovation. The major exploratory hypothesis is that success of a staff proposal is a function of (a) the characteristics of the proposal itself, (b) the characteristics of the staff specialists involved, (c) the relationship between staff specialists and line managers, and (d) the nature of the organizational structure. Executives and staff specialists in a selected sample of fifty-two organizations were asked to provide data on a pair of proposals, one successful and one unsuccessful. Statistical analysis of the data of this survey is in progress.

The diffusion of manufacturing innovations in the New England shoe industry is the subject of a report by Terry R. Priebe (thesis, 1965). From questionnaire data he analyzed factors in the adoption of three basic process innovations by twenty-one firms. Time of awareness of an innovation is related to several measures of technical competence in a firm, but time of adoption is not related to awareness; it is primarily a function of the size of a firm.

New Company Spinoffs from Government-Funded Laboratories

STILL UNEXPLORED IN THE CONCERN FOR UTILIZATION of government-sponsored technology by the private sector of the economy is the role of new enterprises formed by people who leave government-funded laboratories. Edward B. Roberts has undertaken, with Paul V. Teplitz and Herbert A. Wainer as research assistants, a research program* that is aimed at determining the extent and impact of these spinoff companies, as well as the factors which influence their formation and growth. The results should provide a partial measure of the degree of utilization of government-sponsored technology and might provide suggestions for changes in government R & D policies leading to improved stimulation of effective company spinoffs.

The first nine months of this study have served as an exploratory phase during which research methods have been developed and tested. The research program is dependent upon the cooperation of potential "seedbed" organizations, and this first phase of research has concentrated on university laboratories as spawning grounds. Cooperation has already been secured from two major M.I.T. laboratories which have worked for a number of years on government contract R & D. A search of the personnel records since about 1945 and interviews with key laboratory officials produce a listing of laboratory alumni who left the organization within the past twenty years to participate in the formation of a new enterprise. Additional recorded data and interviews establish further background on each entrepreneur. The new enter-

* This project is supported in part by a grant from the M.I.T. Center for Space Sciences, with funds provided by N.A.S.A.

prises are then studied in detail. Interviews are conducted with the company founders to gather historical information on the firms and motivational, financial, and technical factors important to the new enterprise formations.

The first report of results (Teplitz thesis, 1965) deals with twenty-seven new enterprises started since 1950 by former employees of the M.I.T. Instrumentation Laboratory. Of these technology-based firms all but two are still in existence, several already in the multimillion dollar size category. Almost all of the companies are located around Boston, many within walking distance of their parent laboratory. A noticeable lag of five to ten years exists between the growth of the Instrumentation Laboratory in funding and employment and the growth of the combined spinoff firms. However, the past several years indicate an acceleration in both spinoff sales and in the formation rate of new spinoff companies, and it appears reasonable that the spinoff firms will soon significantly surpass their former organization in sales and employment.

Most of the companies sell most of their product within the aerospace industry, but several firms have branched into such diverse areas as hospital equipment and teaching aids for the blind. The entrepreneurs appear to be prime movers of Instrumentation Laboratory technology into their own firms, drawing heavily on their laboratory experience, mostly in applying their general knowledge of inertial systems to specific applications. About two-thirds of the sales of these companies is to the Federal government or to government contractors, but the nongovernment portion of sales is rising, and 60 per cent of the companies are making efforts to become less dependent on government business.

A second report, covering the Lincoln Laboratory spinoffs, will be completed by Herbert A. Wainer in August. More than fifty companies have been identified as founded by former members of Lincoln Laboratory. In addition, studies are underway of the new enterprises formed by former staff of the M.I.T. Servomechanisms Laboratory (later the Electronic Systems Laboratory), the Digital Computer Laboratory, and the Research Laboratory of Electronics.

Studies have been initiated in the M.I.T. Department of Aeronautics and Astronautics to find the role of the faculty in forming new businesses; and the MITRE Corporation, itself a not-for-profit corporation spun off from Lincoln Laboratory, is cooperating in research on the technology transferred from it via entrepreneurship.

A dynamic history is being written of the evolution of a new technology-based company, formed only six months ago. Through weekly tape-recorded review sessions with the two founders, all major areas of company interests are being recorded. Extension of this "live history" approach is being considered for other new firms.

Further planned research includes study of the spinoff enterprises of other major M.I.T. laboratories and an examination of several government-funded industrial firms in their performance as new company

seedbeds. Extensions of the present studies will go in greater depth into the personality of the entrepreneur and the possible role of existing large firms as sponsors of new R & D based enterprises. Aspects of a generalized dynamic model of the technology development and diffusion process have received preliminary attention by Edward B. Roberts and his advanced class in industrial dynamics.

ECONOMIC AND SOCIAL EFFECTS OF NEW TECHNOLOGY

The developing and changing technology which is so characteristic of the present time has profound implications for the national economy, for the structure and development of various industries, for the profitability and growth of firms in an industry, for education, health, the structure of the labor force, and other important aspects of our society.

Improved understanding of the management of the advancement and diffusion of technology, coupled with knowledge of its effects on our economic and social institutions, will provide a better basis for consideration of public policies on the support of research and technology and its utilization in improving national welfare and international relations.

Effects on the Economy

THE LOCAL IMPACT of new, expanded or curtailed government technical facilities is the subject of three studies. Robert C. Voss (thesis, 1963) analyzed the probable economic impact of the N.A.S.A. Saturn production operation on the Michoud, Louisiana area. On the basis of projected expenditures by N.A.S.A., he estimates that in addition to site employment of 3,000 in 1967 (excluding temporary construction workers), employment created in other industries as a result will peak at 8,700 in 1968. Personal income will increase by about 6.5 per cent, and retail sales by about 4.8 per cent.

Thomas F. Morring (thesis, 1964) describes the impact of space spending on the economy of Huntsville, Alabama. Interviews with fifty civic, government, and business leaders plus questionnaire surveys of local N.A.S.A. and Marshall Space Flight Center officials served as the basis for a statistical analysis of the growth of employment, industry, population, real estate values, banking, and community resources. Joseph D. Mooney (thesis, 1965) has made an intensive study of the background and experience of a sample of engineers and scientists displaced in eight Greater Boston electronics firms as a result of defense contract cancellations and changes.

William H. Gruber, with Leland H. Perry and Albert Teich as

research assistants,* is analyzing the impact of R & D on the U. S. economy in two areas of interest: (1) an examination of the ways in which R & D activity is related to the functioning of the economy during the postwar period; and (2) an attempt to relate changes in the development and utilization of scientists and engineers to the findings in the first area of research.

Because several people have questioned the usefulness of R & D,† this study first compared the functioning of the post-war economy with the pre-war period of 1909–29, when there was relatively little R & D activity. The finding of this phase of the research was that the economy has grown faster, with greater stability and with faster increases in labor productivity, in the post-war period than in the earlier period (Gruber, 1963, 1964). This research was based on aggregate data for the total private economy, and further research will deal with the relationship between R & D activity and increases in output and productivity in particular industries and firms.

Research in the first area indicates marked changes in the labor force (Gruber thesis, 1965). Analysis shows that those sectors of the economy with the faster increases in labor productivity have been those sectors of the economy with smaller increases in employment. Current attention is directed to the development of research methods and of a questionnaire to analyze the impact of increased investment in R & D, and the consequent demand for scientists and engineers, upon their utilization and development.

Effects on Industries and Firms

A QUESTION OF MAJOR CONCERN is how government funding of R & D in industry affects privately financed R & D expenditure. Previous work, using 1952 aggregate industry data, concluded that there was a considerable but uncertain amount of substitution. Guy Black, undertaking an examination of the earlier data and analysis of more recent figures, finds that when the data are structured by industry they reveal a relationship which differs according to industry. There is an apparent positive relationship in those industries in which R & D is supplementary to normal commercial activity but a substitution effect in those industries heavily committed to R & D (Black, 1964).**

The investigation will concentrate next on the following special points: the interaction of privately funded and publicly funded R & D within single industrial laboratories; differences in policy, planning,

* This project was initially supported in part by a grant from the National Aeronautics and Space Administration, and currently by the M.I.T. Center for Space Research, with funds provided by N.A.S.A.

† Robert Solo, Gearing Military R & D to Economic Growth. *Harvard Business Review*, November-December, 1962; Henry Gemmill, Distorted Destiny? Critics Fear Federal Research Twists Nation's Economy. *Wall Street Journal*, May 6, 1963.

** This project was supported in part by a grant from the National Aeronautics and Space Administration. The follow-up study of individual firms is supported by a grant from the National Science Foundation.

and control that are found in different types of laboratories; the effect of these differences on laboratory performance; and the influence of government funding of R & D on the technological development of the laboratory. During the summer of 1965 inquiries will be conducted in firms in a few selected industries, and the study will be extended subsequently by inclusion of additional industries.

Two special studies of economic aspects of the aerospace industry have been carried out. Kim C. M. Sloat (thesis, 1964) analyzed the individual procurement actions of ten aerospace firms between January, 1961, and March, 1963, showing that they deal primarily (60 per cent) with one government agency; that they depend on just a few projects (the five largest projects in each firm account for 90 per cent of business); and that as production work declined from 90 to 50 per cent of new business, development and engineering work increased while research effort changed little.

Michael Spiro (1965) has just completed a study of the response of the aerospace industry to changes in the level of government orders, using mathematical tools of statistical estimation and computer simulation to demonstrate the effect that the level of orders has on changes in employment. The industry is viewed as an information feedback system in which orders affect unfilled order backlogs and these influence the employment structure of the industry.*

The profitability of R & D for a firm is a question of major importance but one beset by many difficult problems of measurement. Ronald M. Kirshbaum (thesis, 1962) studied the relation between R & D activity and economic results (rate of return on assets, lagged three to six years) in the processed food industry. Although he was able to secure useful data from only seven firms, he found a slight positive correlation.

Jeremii W. Wesolowski (thesis, 1964) obtained information on thirteen firms in the pharmaceutical industry and demonstrated a clear positive correlation between average R & D expenditure over a ten-year period and average profitability for the same period. Size of firm is not the common factor, since both R & D and profit are expressed as per cent of sales. He showed further that the current decline in new drug output is largely attributable to the Food, Drug, and Cosmetic Act Amendment of 1962. The longer and more costly development and test work now required suggests the result of safer drugs, a slower rate of introduction to the market, an increased product life of existing drugs, and increased concentration of drug companies (contrary to goals of the framers of the act).

This general direction of research is being pursued by William H. Gruber, with support from the M.I.T. Center for Space Research. In a recent presentation he analyzed the consequences to management of the shift from variable costs that can be related directly to products to

* This work was supported in part by a grant from the National Aeronautics and Space Administration.

fixed or managed costs that tend to be invariate with sales volume. Standards for the management of fixed costs (such as R & D) do not yet exist, but such costs have now become a larger fraction of business activity, and ways of controlling them and of relating them to the other areas of business activity are becoming increasingly necessary. Future work will link the findings on the relationship between R & D activity and growth in productivity, output, profitability, and exports with the managerial problems of controlling the level of R & D activity.

National Policy Questions

THE FOLLOWING STUDIES are part of a program in the M.I.T. Department of Political Science under the general direction of Professor Robert C. Wood and supported by the M.I.T. Center for Space Research with funds from the National Aeronautics and Space Administration.

The impact of sponsored research activities on universities has been much debated. Robert C. Wood is conducting an examination of research activities at M.I.T. which includes an analysis of the differential bases of research support and the involvement of faculty and students in the various engineering and science departments from 1953 to the present. The study examines the responses of the departments to various bases and magnitudes of support and the resulting impact on the allocation of faculty time between research and teaching. Attention is also given to the pattern of participation of undergraduates and graduates and the conditions of supervision and output. The analysis now suggests that different policies have evolved among the departments in the Schools of Science and of Engineering as to the character of commitment to research projects and their adjustments to other missions and goals. A report of this study is expected to be completed by the end of the summer.

A draft manuscript by Eugene Skolnikoff entitled *Science, Technology, and American Foreign Policy* has been completed for limited distribution and comment prior to revision for final publication. The study comprises four parts: (1) an abstract analysis of the nature of scientific and technological components of foreign policy issues; (2) a policy-oriented analysis that develops in some detail the specifics of the technical considerations associated with central issues of foreign policy; (3) the factors involved in attempting to use science and technology as instruments of foreign policy; and (4) a discussion of the organization of the Federal government to meet the need for necessary technical inputs in foreign policy formulation.

As a comparative analysis of the research process, the organization and activities at CERN have been explored by Daniel Lerner this year. He has formulated a survey instrument and is in the process of conducting a survey among scientists located at that facility in an effort to observe variations in performance among individual scientists and patterns of international collaboration. Comparable work is also underway at EURATOM with the ultimate objective of identifying the different

patterns of organized scientific research in Europe and the United States.

EDUCATIONAL ACTIVITIES

A major responsibility of a university in sponsoring such a research program is the presentation of new research-based knowledge to students, to research managers, to corporate executives, and to public policy officials. Courses, seminars, reports, books, manuals, and lectures are all part of the dissemination process, although the most effective method is probably personal consultation with key individuals.

The country's leading graduate schools of business are now trying out new courses in the management of research and technology and are giving serious consideration to the place of this subject in the present curricula. Some believe that just as the management of production was critically important in the eighteenth century, finance in the nineteenth, and marketing in the twentieth, we are currently in a period when the management of innovation is becoming the critical factor in successful enterprise.

Academic Subjects

THE FOLLOWING SUBJECTS ARE OFFERED REGULARLY in the programs of the Sloan School of Management and the Department of Political Science.

Research Management (15.384) DONALD G. MARQUIS. A series of fourteen weekly lecture-discussion sessions each led by a different faculty member of the research program. Enrolled in 1965 were twelve graduate students in management, eleven members of the Sloan Fellowship Program in executive development, and twenty-four graduate students in engineering and science departments. The topics and leaders for each session are listed in Appendix 2. Each student conducts and writes up a special project.

New Enterprises (15.921) RICHARD S. MORSE. A graduate seminar in which each student writes a thorough case study of a young technology-based company.

American Science and Its Development: Current Issues and Problems (17.442), ROBERT C. WOOD, EUGENE SKOLNIKOFF, THOMAS P. HUGHES, and WILLIAM H. GRUBER. An advanced seminar exploring technology transfer and its implication for national policy.

Sessions on research management have been introduced into the

curriculum of the Program for Senior Executives and the Sloan Fellowship Program. In William H. Gruber's undergraduate subject, Introduction to Industrial Management (15.11), more than twenty students wrote papers on some aspect of the management of science and technology. The advanced subject in industrial dynamics offered by Edward B. Roberts provides an opportunity for graduate students to work on computer simulation models of R & D.

Courses for Research and Development Managers

A TWO-WEEK INTENSIVE COURSE on Management of Research and Development was presented for the first time in August, 1964, under the direction of Edward B. Roberts and Donald G. Marquis. There were over 100 qualified applicants, but space permitted enrollment of only fifty-five research managers of whom thirty-four were from industry, fourteen from government, and seven from universities. The course will be repeated in August, 1965, and the advance applications indicate that it will be even more oversubscribed than last year.

A one-day seminar for 200 industrial research and development executives was presented in Los Angeles on November 5, 1964, under the auspices of the M.I.T. Industrial Liaison Office. Current research findings were described by David E. Berlew, Donald G. Marquis, Bernard J. Muller-Thym, and Edward B. Roberts. In addition, individual staff members have presented numerous invited papers at national and international meetings and have conducted sessions at conferences of R & D managers and in industrial and government laboratories.

Statistical Analysis Routines

IN ORDER TO FACILITATE EFFICIENT ANALYSIS of data by many researchers, a battery of statistical routines is being programmed, debugged, and made available for common use. The programs are of two types: (a) those designed for batch processing of large amounts of data on I.B.M. 7094 computers (J. Randall Brown, research assistant, N.A.S.A. grant); and (b) those designed for prompt man-machine interaction in the testing of hunches and limited hypotheses with moderate amounts of data, using remote consoles connected to the time-sharing computers of Project MAC; data are typed directly into the console according to explicit, sequential formating instructions, analyses are called for, and results are printed out immediately (James R. Miller, Research Assistant, Project MAC).

Most of the routines are oriented toward analyzing typical problems encountered in the social sciences, and, therefore, many of them are nonparametric in nature. These include:

1. Standard two-dimensional contingency analyses (with numerous special-case analyses built in).
2. Special three-dimensional contingency analysis.
3. Rank-order intercorrelation and partial correlation analyses.

4. Binomial tests.
5. Single and multiple percentage difference tests.
6. Homogeneity test on samples classified strictly according to nominal categories.
7. Mann-Whitney U test of the difference between two sample medians.

Several parametric routines have also been written. These include:

1. Linear intercorrelation and partial correlation analyses.
2. Simple and multiple regression analyses.
3. T-test of the difference between two sample means.
4. One-way analysis of variance (fixed effects model).
5. Test for normality of sample data.

Appendix 1: Research Staff

Steering Committee

JAY W. FORRESTER, Professor of Management
HOWARD W. JOHNSON, Dean of the Sloan School of Management
DONALD G. MARQUIS, Professor of Management, *Chairman*
JAMES MC CORMACK, Vice President
MAX F. MILLIKAN, Professor of Economics; Director of the Center for International Studies
EDWARD B. ROBERTS, Assistant Professor of Management
JOHN M. WYNNE, Associate Dean of the 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
PAMELA C. MARSTERS, Secretary
VIRGINIA V. STUPAK, Secretary

Faculty Members of the Sloan School of Management Active in the Research Program

THOMAS J. ALLEN, Research Associate
DAVID E. BERLEW, Assistant Professor of Management
GUY BLACK, Senior Research Associate[1]
GEOFFREY P. E. CLARKSON, Associate Professor of Management
WILLIAM M. EVAN, Associate Professor of Sociology and Management
HENRY B. EYRING, Sloan Faculty Fellow, 1964–65[2]
THEODORE N. FERDINAND, Research Associate, June to September, 1964[3]
WILLIAM H. GRUBER, Assistant Professor of Management
EMANUEL KAY, Lecturer in Management[4]
GEORGE T. KENNEDY, JR., Senior Research Associate, February, 1965–[5]
JAMES E. MAHONEY, Staff Member, Division of Sponsored Research, M.I.T. (to April, 1965)[6]
DONALD G. MARQUIS, Professor of Management
RICHARD S. MORSE, Senior Lecturer in Management[7]
BERNARD J. MULLER-THYM, Senior Lecturer in Management[8]
WILLIAM F. POUNDS, Associate Professor of Management
EDWARD B. ROBERTS, Assistant Professor of Management

[1] Also Executive Secretary, Committee on the Economic Impact of Defense and Disarmament, Council of Economic Advisers, Executive Office of the President

[2] On leave from Stanford University, Assistant Professor of Business

[3] Assistant Professor of Sociology, Northeastern University

[4] Specialist, Personnel Relations, General Electric Company

[5] Associate Professor, Florida State University (Graduate Program in R & D Management, Cape Kennedy)

[6] Now Staff Member (Management Science Grants), Policy Planning Division, Office of the Administrator, National Aeronautics and Space Administration

[7] Chairman of the Board, Cryonetics Corporation

[8] Independent management consultant, New York City

EDGAR H. SCHEIN, Professor of Management
LOUIS A. SELOGIE, Research Affiliate, February to August, 1965[9]
O. PEER SOELBERG, Assistant Professor of Management
MICHAEL SPIRO, Research Associate, February to July, 1965
ANDREW C. STEDRY, Associate Professor of Industrial Management[10]

*Student Research Assistants and Fellows**

DAN I. ABRAMOVITCH (summer, 1964) — *A. C. Stedry*
S.B., Electrical Engineering, McGill University, 1961; S.M., Industrial Management, M.I.T., 1965.

MAURICE P. ANDRIEN, JR. — *T. J. Allen*
S.B., Electrical Engineering, M.I.T., 1963; S.M., Industrial Management, M.I.T., 1965.

LAURENCE B. BERGER — *E. B. Roberts*
S.B., Industrial Management, M.I.T., 1963; S.M., Industrial Management, M.I.T., 1965.

RICHARD J. BJELLAND — *T. J. Allen*
B.A., General Science, Oregon State University, 1962.

J. RANDALL BROWN — *D. G. Marquis*
S.B., Electrical Engineering, M.I.T., 1963; S.M., Industrial Management, M.I.T., 1965.

JAMES F. BURNS (summer, 1964) — *D. G. Marquis*
S.B., Mathematics, University of Michigan, 1961; S.M., Economics, Columbia University, 1963.

PETER C. EGLINGTON — *G. P. E. Clarkson*
S.B., Economics and Accounting, McGill University, 1961; S. M., Industrial Management, M.I.T., 1965.

RICHARD H. FRANK — *T. J. Allen*
S.B., Mechanical Engineering, South Dakota School of Mines and Technology, 1963; S.M., Industrial Management, M.I.T., 1965.

DANIEL S. FRISCHMUTH — *T. J. Allen*
S.B., Electrical Engineering, M.I.T., 1964.

MICHAEL M. GOLD — *A. C. Stedry*
S.B., Engineering Management, Boston University, 1962; S.M., Industrial Management, M.I.T., 1964.

DOUGLAS T. HALL — *D. E. Berlew*
S.B., Industrial Administration, Yale University, 1962; S.M., Industrial Management, M.I.T., 1964.

NORMAN W. KNEISSLER — *E. B. Roberts*
S.B., Civil Engineering, M.I.T., 1960.

WILLIAM MC KELVEY — *E. H. Schein*
A.B., Physics and Economics, Monmouth College, 1960; S.M., Industrial Management, M.I.T., 1962.

JAMES R. MILLER — *D. G. Marquis*
A.B., Princeton University, 1959; M.B.A., Harvard University, 1963.

JOHN E. OSBORNE — *W. M. Evan*
A.B., Economics, Bethany College, 1963; S.M., Industrial Management, M.I.T., 1965.

[9] N.A.S.A. Fellow, Graduate School of Business Administration, University of California (Los Angeles)

[10] On leave, 1964–65, at Carnegie Institute of Technology

* The names of faculty research leaders appear in italics.

LELAND H. PERRY — *W. H. Gruber*
S.B., Chemical Engineering, M.I.T., 1963.

LEWIS G. PRINGLE — *E. B. Roberts*
S.B., Chemistry, Harvard University, 1963; S.M., Industrial Management, M.I.T., 1965.

WILLIAM D. PUTT (summer, 1964) — *T. J. Allen, Jr.*
S.B., Industrial Management, M.I.T., 1959; S.M., Industrial Management, M.I.T., 1964.

JAMES H. RANSOM — *W. M. Evan*
S.B., Electrical Engineering, Cornell University, 1963; S.M., Industrial Management, M.I.T., 1965.

IRWIN RUBIN (summer, 1964) — *D. G. Marquis*
S.B., Electrical Engineering, Tufts University, 1961; S.M., Industrial Management, M.I.T., 1964.

J. BARRY SLOAT (summer, 1964) — *E. B. Roberts*
S.B., Engineering, University of California (Los Angeles); S.M., Industrial Management, M.I.T., 1964.

DAVID M. STRAIGHT, JR. — *D. G. Marquis*
S.B., Industrial Management, M.I.T., 1964; S.M., Industrial Management, M.I.T., 1965.

ALBERT TEICH — *W. H. Gruber*
S.B., Physics, M.I.T., 1964.

PAUL V. TEPLITZ — *E. B. Roberts*
S.B., Electrical Engineering, M.I.T., 1962; S.M., Electrical Engineering, Carnegie Institute of Technology, 1963; S. M., Industrial Management, M.I.T., 1965.

JOHN THOMAS — *D. G. Marquis*
S.B., Industrial Administration, Yale University, 1960.

HERBERT A. WAINER — *E. B. Roberts*
S.B., Business Administration, Colby College, 1963.

ARCHIE L. WOOD — *E. B. Roberts*
S.B., Military Engineering, United States Military Academy, 1950; S.M., Aeronautics and Astronautics, M.I.T., 1955; S.M., Industrial Management, M.I.T., 1965.

Appendix 2a: Research Seminars

October 2, 1964
Utilization of Research Results by R & D Managers: What We Learned from the Summer Course
EDWARD B. ROBERTS, Assistant Professor of Managament

October 9, 1964
Management of the Army Electronics Command
GENERAL F. W. MOORMAN, Commanding General, Army Electronics Command, Fort Monmouth, New Jersey

October 23, 1964
The Effects of Company Expectations on Managerial Performance
DAVID E. BERLEW, Assistant Professor of Management, and DOUGLAS T. HALL, Research Assistant

October 30, 1964
Role of Memory and Retrieval Processes in Problem Solving
JOHN R. HAYES, Institute for Cognitive Studies, Harvard University

November 6, 1964
The Utilization of Information Sources during R & D Proposal Preparation
THOMAS J. ALLEN, Research Associate

November 13, 1964
Studies of Large Scale Development Projects
ARCHIE L. WOOD, Sloan School of Management

November 20, 1964
The Award of Government R & D Contracts
EDWARD B. ROBERTS

December 4, 1964
Presentation of thesis plans by graduate students and Sloan Fellows.

December 11, 1964
Some Correlates of Performance in R & D Groups
WILLIAM M. EVAN, Associate Professor of Sociology and Management

January 8, 1965
Continuation of presentation of thesis plans by graduate students and Sloan Fellows.

January 15, 1965
Value Orientations of Corporate Executives, Research Managers and Scientists
RENATO TAGIURI, Professor, Harvard Business School

February 12, 1965
The M.I.T. Technical Information System
MYER M. KESSLER, Associate Director of Libraries, M.I.T.

February 19, 1965
Planning and Control of Large Space Systems
EARL D. HILBURN, Deputy Associate Administrator, National Aeronautics and Space Administration

February 27, 1965
Implications of the Air Force 375 Series for Program and Systems Management
ROBERT W. MILLER, Consultant, Cambridge, Massachusetts

March 12, 1965
Program and Project Management in the Firm
LOUIS A. SELOGIE, N.A.S.A. Fellow, University of California (Los Angeles); and Research Affiliate

March 19, 1965
Some Sources of Uncertainty in Engineering Design
HENRY B. EYRING, Sloan Faculty Fellow

March 26, 1965
Contractor Performance at Cape Kennedy
GEORGE T. KENNEDY, JR., Associate Professor, Florida State University

April 9, 1965
Economic Studies of Innovation and Technological Inputs: A Research Planning Session
WILLIAM H. GRUBER, Assistant Professor of Management, and MICHAEL H. SPIRO, Research Associate

April 16, 1965
Research and Technology Program Management in a Mission-Oriented Government Agency.
WALTER C. SCOTT, Sloan Fellow

April 23, 1965
Innovation in the Regulated Transportation Industries
AARON GELLMAN, Vice President – Research and Planning, North American Car Company

April 30, 1965
Two Views of the Reorganization of the Army Electronics Command
GENERAL PAUL A. FEYEREISEN, Deputy Commanding General, and NORMAN E. LEE, Staff Engineer, Comptroller and Director of Programs Office, U. S. Army Electronics Command, Fort Monmouth, New Jersey

May 7, 1965
System Engineering Non-Profit Corporations in Air Force Research and Development
PAUL FLAM, Sloan Fellow

May 14, 1965
The R & D. Entrepreneur: Personality and Profitability
HARRY SCHRAGE, Sloan Fellow
Technical Liaison of Aerospace R & D Contracts
NEIL A. HOLMBERG, Sloan Fellow

May 21, 1965
Statistical Computer Routines Available for Computer Analysis
J. RANDALL BROWN, Research Assistant, and JAMES R. MILLER, Research Assistant, Project MAC

Appendix 2b: Outline of Topics in Research Management (15.384) Spring Semester, 1965

DONALD G. MARQUIS, *The Changing Nature of R and D*
EDWARD B. ROBERTS, *A Systems View of R and D*
THOMAS J. ALLEN, *The R and D Process: Problem Solving*
ANDREW C. STEDRY, *Motivation and Performance*
DAVID E. BERLEW, *Assessment of Individual Research Ability*
WILLIAM M. EVAN, *Effectiveness of R and D Groups*
WILLIAM MC KELVEY, *Supervisory Management*
JAMES E. MAHONEY, *Project Organization and Management*
BERNARD J. MULLER-THYM, *Space, Communication, and Work*
EDWARD B. ROBERTS, *Government-Industry Contracting Process*
MICHAEL S. BARAM, *Protection of Intellectual Property*
DONALD G. MARQUIS, *Corporate Organization and Policy*
WILLIAM H. GRUBER, *Impact of R and D on the Economy*
ROBERT C. WOOD, *National Policy and Organization*

SINGLE COPIES OF PUBLICATIONS may be requested from the Program office, Sloan School of Management, Room E52–530, Massachusetts Institute of Technology, Cambridge, Massachusetts, 02139.

ALLEN, T. J. *Problem solving strategies in parallel research and development projects.* M.I.T. Sloan School of Management Working Paper No. 126–65, June, 1965a.

ALLEN, T. J., and ANDRIEN, M. P. *Time allocation among three technical information channels by R & D engineers.* M.I.T. Sloan School of Manageagement Working Paper No. 131–65, 1965.

ALLEN, T. J., and MARQUIS, D. G. Positive and negative biasing sets: the effects of prior experience on research performance. *I.E.E.E. Trans. Engng. Mgmt.*, 1964, *EM-11*, No. 4, 158–162.

ALLEN, T. J., and MARQUIS, D. G. *Factors influencing technical quality of R & D proposals.* M.I.T. Sloan School of Management Working Paper No. 68–65, July, 1965.

BERLEW, D. E., and HALL, T. E. *The management of tension in organizations: some preliminary findings.* M.I.T. Sloan School of Management Working Paper No. 100–64, October, 1964.

BERLEW, D. E., and HALL, T. E. *The socialization of managers: the effects of expectations on performance.* M.I.T. Sloan School of Management Working Paper No. 125–65, May, 1965.

BLACK, G. *Substitution of public for private research and development expenditures.* M.I.T. Sloan School of Management Working Paper No. 57–64, April, 1964.

BOK, E. G. *Making American space policy: (1) the establishment of N.A.S.A.* M.I.T. Sloan School of Management Working Paper No. 09–63, January, 1963.

CENKO, S., and MARQUIS, D. G. *Factors in obsolescence of engineering knowledge.* M.I.T. Sloan School of Management Working Paper No. 77–64, 1964.

CHARNES, A., and STEDRY, A. C. Investigations in the theory of multiple budgeted goals. In C. P. Bonini, R. K. Jaedicki, and H. M. Wagner (Eds.) *Management Controls: New Directions in Basic Research.* New York: McGraw-Hill, 1964.

CHARNES, A., and STEDRY, A. C. *The attainment of organization goals through appropriate selection of sub-unit goals.* M.I.T. Sloan School of Management Working Paper No. 86–64, August, 1964.

CLARKSON, G. P. E., and POUNDS, W. F. Theory and methods in the exploration of human decision behavior. *Industr. Mgmt. Rev.*, 1963, *5*, 17–27.

EVAN, W. M. *The engineering technician: dilemmas of a marginal occupation.* M.I.T. Sloan School of Management Working Paper No. 36–63, September, 1963.

EVAN, W. M. Superior-subordinate conflict in research organizations. *Admin. Science Quart.*, 1965, *10*, 52–64.

GREER, C. H. CPIF: The new look in R & D management. *Industr. Mgmt. Rev.*, 1964, *5*, 87–96.

GRUBER, W. H. *What can we expect from our new economy?* M.I.T. Sloan School of Management Working Paper No. 35–63, September, 1963.

GRUBER, W. H. *New standards for the economy of the U. S.* M.I.T. Sloan School of Management Working Paper No. 44–64, January, 1964.

HANSEN, A. J., and MARQUIS, D. G. *Can creativity be predicted in research professionals?* M.I.T. Sloan School of Management Working Paper No. 73–64, August, 1964.

MARQUIS, D. G. Individual responsibility and group decisions involving risk. *Industr. Mgmt. Rev.*, 1962, *3*, 8–23.

MARQUIS, D. G. *Organization and management of R & D.* Proc. 17th Annual Conference on the Administration of Research. Denver: Denver Research Institute, 1964.

MARQUIS, D. G., and STRAIGHT, D. M., JR. *Organizational factors in project performance.* (Proc. Second O.N.R. Conference on Research Program Effectiveness, Washington, D. C., July 25, 1965.) M.I.T. Sloan School of Management Working Paper No. 133–65.

PETERS, D. R. *Notes on career growth in N.A.S.A.: patterning of interview responses.* M.I.T. Sloan School of Management Working Paper 17–63, April, 1963.

POUNDS, W. F. *A study of problem solving control.* M.I.T. Sloan School of Management Working Paper No. 33–63, 1963.

ROBERTS, E. B. *The design of research and development policy.* M.I.T. Sloan School of Management Working Paper No. 08–63, January, 1963a.

ROBERTS, E. B. Industrial dynamics and the design of management control systems. *Mgmt. Techn.*, 1963b, *3*, No. 2, 100–118.

ROBERTS, E. B. *Engineer dynamics and productivity in R & D projects.* M.I.T. Sloan School of Management Working Paper No. 37–63, October, 1963c.

ROBERTS, E. B. *The Dynamics of Research and Development.* New York: Harper and Row, 1964.

ROBERTS, E. B. How the U. S. buys research. *Intern. Science & Tech.*, No. 33, September, 1964a, 70–77.

ROBERTS, E. B. Research on the management of technology-based enterprises. *I.E.E.E. Trans. Engng. Mgmt.*, 1964b, *EM-11*, No. 3, 99–102.

ROBERTS, E. B. *Games and models for training research managers.* M.I.T. Sloan School of Management Working Paper No. 116–65, February, 1965a.

ROBERTS, E. B. *Marketing and engineering strategies for winning R & D contracts.* M.I.T. Sloan School of Management Working Paper No. 128–65, July, 1965b. (To appear in *Adaptability for Survival in the Defense Industry.* Boston College: Bureau of Business Research, 1965.)

ROBERTS, E. B. Improving R & D procurement. *The Scanner*, Fall 1965c.

RUBIN, I., STEDRY, A. C., and WILLITS, R. D. *Influences related to time allocation of R & D supervisors.* M.I.T. Sloan School of Management Working Paper No. 75–64, July, 1964.

SCHEIN, E. H., MC KELVEY, W., PETERS, D., and THOMAS J. Career orientations and perceptions of rewarded activity in a research organization. *Admin. Science Quart.*, 1965, *9*, No. 4, 333–349.

SWANSON, A. G. *The decision process in project manager selection.* M.I.T. Sloan School of Management Working Paper No. 70–64, 1964.

STEDRY, A. C. Aspiration levels, attitudes, and performance in a goal-oriented situation. *Industr. Mgmt. Rev.*, 1962, *3*, 60–76.

STEDRY, A. C., and KAY, E. *The effect of goal difficulty on performance: a field experiment.* M.I.T. Sloan School of Management Working Paper No. 106–64, November, 1964.

WOOD, A. L. *The analysis of large-scale R &D programs: a case study of Project Mercury.* M.I.T. Sloan School of Management Working Paper No. 115–65, February, 1965.

Appendix 4: Theses, 1962–65

THE THESES LISTED HERE were all, except when noted, written for the Master's degree in management. As such they represent only a fraction of one year's work by a student, and therefore they tend to be exploratory investigations rather than complete definitive studies. The more substantial researches will be incorporated in working papers and published articles. The names of faculty advisers are indicated in italics.

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.

1965

ANDRIEN, MAURICE P., JR. *D. G. Marquis, T. J. Allen*
The utilization of technical information in parallel R & D Projects.
Time allocation to various information sources by engineers and scientists in four government-funded parallel R & D projects is more stable over the duration of the project for higher rated teams as compared with less successful teams.

BAKER, ALBERT L., JR.* *J. D. Nyhart, R. Evans, Jr.*
A study of the managerial decision process under multi-incentive government contracts.
Interviews with D.O.D., N.A.S.A., and industry officials were conducted to determine what decision processes are used by project managers to attain their profit goals within the constraints of the CPIF contract and to ascertain whether the objectives of the government are being met through incentive contracting.

BERGER, LAURENCE B. *E. B. Roberts, T. J. Allen*
Comparative analysis of R & D marketing strategy.
The competitive proposal activities of two companies were studied to explore the hypothesis that firms behave as if past performance, personal relations, and the perceived capabilities of the companies, rather than the technical content of their proposals, are the dominant factors in the award of government-funded R & D contracts.

BROWN, J. RANDALL *D. G. Marquis, T. J. Allen*
Job satisfaction of R & D engineers.
Factor analysis of data from a survey of 112 engineers engaged in nine large development projects under government contract indicates that job satisfaction is strongly related to the reported dependence of rewards on performance and to the reported degree of challenge in their work.

DREIER, STEPHEN I. *E. B. Roberts, A. E. Amstutz*
Financial growth of a company.
A general model of a young growing company is developed using the industrial dynamics approach, emphasizing the determinants and effects of budgeting behavior. Product development and promotional responses are two of the main areas of policy studied by use of computer simulations.

EGLINGTON, PETER C. *G. P. E. Clarkson, D. G. Marquis*
B.M., the bid maker, an information processing model.
A computer program was written in IPL-V language to simulate the development of discrimination nets in subjects who participated in a simple sequential decision making experiment and successfully predicted the individual subjects' decisions in later stages of the experiment.

* Sloan Fellow

FLAM, PAUL* *D. G. Marquis, C. L. Wilson*
The role of Aerospace and MITRE *Corporations in Air Force research and development.*
Analysis of the conditions and events leading to the creation, growth, and present function of the two AF systems engineering and technical direction nonprofits is based on documents and interviews with key executives in defense, industry, and the two corporations.

GRUBER, WILLIAM H. (Ph.D. Econ.) *R. Evans, Jr., D. V. Brown, C. A. Myers*
Productivity, education, and changes in the labor force.
Examination of the statistical evidence that productivity increases during the post-war period have shifted the occupational structure of the labor force away from blue collar employment toward the white collar occupations that tend to require higher educational attainment. Those sectors of the economy with faster increases in productivity tended to be those sectors of the economy with smaller increases in employment. This resulted in a shift in employment toward the non-goods sectors.

HOLMBERG, NEIL A.* *D. G. Marquis, A. Hyatt*
Technical liaison of aero-space R & D contracts.
Regression analysis of 25 liaison parameters in a questionnaire survey of 11 N.A.S.A. technical program managers contracting R & D to other organizations indicated that an increase in liaison activity is associated with reduction in cost and schedule variances.

NAY, JOE N. (S.M., Electrical Engineering) *E. B. Roberts, W. W. Seifert*
Choice and allocation in multiple markets; an R & D systems analysis
A multiple project model of an R & D organization is developed and tested using industrial dynamics methods. Transition problems in shifting engineers among projects are studied, and it is concluded that the build-up and decline structure of projects forces instability upon the organization. Conflicts are found between company and customer goals, leading to suggestions for new combined policies to smooth transitions.

PRIEBE, TERRY R. *L. B. Moore, D. G. Marquis*
An analysis of diffusion in manufacturing innovations in the New England shoe industry.
Factors in the adoption of three basic process innovations by twenty-one firms were analyzed from questionnaire data. Time of awareness of an innovation is related to several measures of technical competence in the firm, but time of adoption is not related to awareness but primarily to size of firm.

PRINGLE, LEWIS G. *E. B. Roberts, T. J. Allen*
An investigation of R & D marketing strategy.
A questionnaire survey of 408 industrial firms that participated in the competitions for forty-six government contract awards indicates that bidders have significantly more prior information than non-bidders and that winners as compared with losers in the bid competition are more familiar with government technical preferences, have done more previous work with the technical initiator, and regard their contracts as more important to the customer.

SCHRAGE, HARRY* *D. E. Berlew, D. G. Marquis*
The R & D entrepreneur: personality and profitability.
Interviews and psychological tests of twenty-two presidents of young R & D firms indicate that the more successful R & D entrepreneurs perceive significant areas of their business environment more realistically than the less successful ones and that achievement motivation and other aspects of the entrepreneurial personality are also related to profitability of the enterprise. (*Harvard Business Review*, to appear in 1965)

* Sloan Fellow

SCOTT, WALTER C.* *D. G. Marquis, A. Hyatt*
Research and technology program management in a mission-oriented agency.
A questionnaire and interview survey of fifty-seven managerial representatives involved in the advanced research and technology program management for N.A.S.A. explores the broad objectives, program planning, allocation of resources, and dissemination of results in the programs.

STRAIGHT, DAVID M., JR. *D. G. Marquis, L. B. Moore*
Project vs. functional organization in the R & D industry.
Analysis of thirty-seven industrial R & D projects under government contract showed very little correspondence among several indexes of degree of project organization, and no clear relation to successful performance.

TEPLITZ, PAUL S. *E. B. Roberts, R. S. Morse*
Spinoff enterprises from a large government sponsored laboratory.
Questionnaire study of twenty-seven new firms started by former employees of the M.I.T. Instrumentation Laboratory shows the pattern of technological transfer, and some of the factors in successful growth.

WOOD, ARCHIE L. *E. B. Roberts, D. G. Marquis*
An analysis of a large-scale development project.
Analysis of documents and a questionnaire survey of key personnel involved in the development of a complex spacecraft indicated that the large time and cost overruns resulted from underestimates of the technical uncertainty in the development of major subsystems and components, and that a strategy taking account of explicit estimates of such uncertainties could improve performance.

1964

BARACOS, NICHOLAS* *B. J. Muller-Thym, E. B. Roberts*
The dynamic behavior of an automotive engineering organization.
A detailed analysis of the work flow and communication patterns in seven work centers of the product engineering office, based on questionnaire responses from 162 individuals, provides an accurate tool for observing and measuring the performance of an organization against its task requirements.

BARNES, RUSSELL M.* *E. H. Schein, W. F. Pounds*
Organizational climate: A case study.
Administration of the *Semantic Differential Test* to measure nine dimensions of the organization climate perceived by 137 engineers in three departments of an aerospace firm indicates a significant relationship between job satisfaction and the type of climate perceived.

CENKO, STEVE* *E. H. Schein, W. F. Pounds*
Factors in obsolence of engineering knowledge.
A questionnaire and interview survey of fifty-four electrical and mechanical engineers and twenty-six supervisors in three companies indicates that engineer obsolescence is related to the number of years out of school, mathematics proficiency, and the number of advanced courses taken.

FRYLING, GEORGE P., II.* *E. B. Roberts, W. F. Pounds*
The dynamic problems of introducing a competitive product to the market.
The thesis uses the industrial dynamics approach to study a company whose product development and marketing strategy is technical followership. Emphasis is placed upon the problems of timeliness of the company's entry into the market, the amount of initial capacity purchased, and the basis for adding further capacity.

* Sloan Fellow

HANSEN, ADOLPH J. *D. G. Marquis, D. E. Berlew.*
Predicting creativity in the research professional.
Scores on the *Remote Associates Test*, a new approach to the assessment of creative potential, were found to yield a low positive correlation with supervisors' evaluations of their creative contribution in two labs which emphasize creative research, in contrast to zero correlations in typical industrial labs.

HERSH, MARVIN *R. B. Maffei, B. Smith*
Investigation into PERT, *a new management technique for R & D programs.*
Individuals responsible for the implementation of PERT in several southern California R & D organizations were interviewed to determine what major problems they had encountered in its application.

KANTER, LAWRENCE E.* *E. B. Roberts, B. Smith*
An investigation of the interaction between the depth and breadth of R & D endeavor and the growth of the company.
The dynamic aspects of R & D in a company which primarily leases its output are studied. Computer simulations suggest the effects of various policies on the growth rate of the firm.

MORRING, THOMAS F.* *A. J. Siegel, R. Evans, Jr.*
The impact of space age spending on the economy of Huntsville, Alabama.
Interviews with fifty Huntsville civic, government, and business leaders plus questionnaire surveys of local N.A.S.A. and Marshall Space Flight Center officials were used to obtain the economic statistics necessary for describing the impact of space spending on the area.

OSWALT, DAVID H. *D. G. Marquis, B. J. Muller-Thym*
Analysis of Department of Defense policies toward independent research and development.
Questionnaire responses from thirty-four key people in government and industry indicate a number of areas of agreement and disagreement on possible changes in policy.

PACE, ROBERT E., JR.* *D. G. Marquis, D. E. Berlew*
A study of the project manager's influence on technical support groups in a project overlay organization.
Analysis of attitudes and sources of satisfaction of 107 individuals in thirty groups supporting thirteen projects at MSFC indicates that a project manager in a technical organization can be a direct source of motivational influence for the line division personnel supporting his project.

PUFFER, ROBERT W., III *B. J. Muller-Thym, E. B. Roberts*
Work, space and communication: A study of research and development.
Study of six R & D projects at Goddard SFC indicates that researchers are less influenced by physical environment (noise, lighting, etc.) than by differences in the degree of face-to-face communication depending on distance between R & D personnel. To help in planning a project's working space, a methodology is formulated which permits visualization of the interaction between skills required for the project.

PUTT, WILLIAM D. *D. G. Marquis, A. C. Stedry*
Manager reactions to reductions in resources in research and development.
A behavioral model of the project manager, analysis of DOD incentive and control policy, and a case study all suggest that reduction in program support leads to increased project risk as test effort is reduced without changing the performance goals.

* Sloan Fellow

RICHARD, J. JEAN-PAUL — *D. G. Marquis, R. B. Maffei*

Technical monitoring of research and development contracts by a government agency.

Thirty-seven Air Force study and hardware contracts were studied in order to describe the monitoring process and to measure effectiveness of the effort as a function of number of reports required, number of concurrent monitoring assignments, and other factors.

SA, GRACIANO — *J. D. C. Little, W. F. Pounds*

A study on the solutions to PERT networks.

Four methods of solving PERT networks are discussed to show how information obtained from a PERT recursion can be improved by increasing the accuracy of the PERT results, and by using more versatile ways of estimating input data.

SLOAT, J. BARRY — *E. B. Roberts, T. J. Allen*

Incentive contracts for the procurement of research and development: A study of several cases.

Interviews with the government and contractor personnel associated with five R & D contracts which had been converted from a cost reimbursement basis to an incentive form of cost sharing indicated several fundamental difficulties inherent in the contract change process and in the use of profit incentives.

SLOAT, KIM C. M. (S.B., Management) — *E. B. Roberts*

The contracting structure of the aero-space industry.

Study of the individual procurement actions of ten aerospace firms between January, 1961, and March, 1963, indicated that they deal primarily (60 per cent) with one agency; that they depend on just a few projects (five largest projects account for 90 per cent of their business); and that as production work declined from 90 to 50 per cent of new business, development and engineering rose correspondingly while study and research changed little.

SWANSON, ANDREW G.* — *D. G. Marquis, W. F. Pounds*

Selection of project managers in a government research laboratory: A study of the decision process.

Information from intensive interviews with six officials responsible for selecting project managers at a government R & D laboratory was used to formulate a model of the process.

THURSTON, PETER E. — *R. Robinson, R. S. Morse*

The founding and growth of new technical enterprise.

Study of the experience of fifteen new technical enterprises developed in the post-war period isolated the key factors in the founding and the growth processes of the firms and indicates the chief problems encountered in their development.

TRAVIS, ROGER E. — *P. Pigors, C. M. Adams, Jr.*

Electron beam heating industry: from laboratory model to production unit.

This case study of the inception, growth, and future of the electron beam heating industry provides information on the problem of transferring new technology to commercial products and processes.

WESOLOWSKI, JEREMII W. — *E. B. Roberts, D. G. Marquis*

The impact of the 1962 new drug regulations on pharmaceutical research and development.

A questionnaire survey of forty-seven top pharmaceutical firms indicates that the current decline in new drug output is largely attributable to the Food, Drug and Cosmetic Act amendment of 1962. The longer development work now required will result in safer drugs, a slower rate of introduction to the market, and an increased product life of existing drugs.

* Sloan Fellow

1963

ALLEN, THOMAS J. — *D. G. Marquis, B. J. Muller-Thym*
Problem solving by research groups: A study of factors influencing technical quality in the preparation of proposals for government contract.
Three Air Force contract competitions were studied to find the correlation of various factors in the proposal preparation process with the technical ratings of the proposals.

BERGER, LAURENCE R. (S.B., Management) — *E. B. Roberts*
A study of company strategy toward research and development proposals.
Interviews and a company file search relative to the proposal activities of a specific company indicate the criteria used by the firm in making its bid-no bid decisions, and the bidding strategy elements it employs to obtain R & D contracts.

COLEAL, ERNEST* — *T. M. Alfred, E. H. Schein*
A study of the internal staffing system for Air Force laboratories.
A survey of the experiences and attitudes of 230 scientists and engineers in three Air Force laboratories and interviews with members of top and middle management investigated the effectiveness of Air Force procedures for finding eligible job candidates from within and for accommodating the individuals' preferences.

CRAMER, ROBERT H.* — *B. Smith, W. F. Pounds*
An application of decision theory to the selection of research projects.
Data from a series of standard gambles administered to four research and four manufacturing executives in a complex technology-based corporation are used to illustrate a general operational method for incorporating a decision-maker's utility curve into a model for the selection and evaluation of research projects.

DOTY, WILLIAM E. N.* — *T. M. Alfred, D. E. Berlew*
A study of supervisor-subordinate relationships in a research and development organization.
A theoretical rationale of supervisor-subordinate influence in technical organizations where formal authority is deliberately deemphasized is formulated and tested by a survey of 188 research personnel.

HOLMAN, FRANK S.* — *E. B. Roberts, D. G. Marquis*
A dynamic analysis of a large system development.
The applicability of industrial dynamics to a system study using the functional analysis technique to schedule many interrelated functions is demonstrated, and computer simulations are used to indicate the effects of changes in the available manpower on the project completion time.

HUBBARD, JOHN H. — *D. G. Marquis, W. F. Pounds*
Individual and group decisions involving risk and uncertainty.
Experimental studies of simple gambling choices by student subjects showed that group decisions were more risky than individual decisions only when there was some uncertainty in the choice situations.

JACOB, ITZHAK — *D. C. Carroll, G. M. Kaufman*
Network planning for time, cost, and performance.
A procedure for explicitly treating performance variables, in addition to time and cost, in the CPM analysis of a project in an early state of development is formulated and demonstrated.

* Sloan Fellow

JOYCE, CHARLES C., JR. *D. G. Marquis, E. H. Schein*

Career plans of systems engineers.

Questionnaire study of eighty-nine systems engineers in a large technical organization investigates what kinds of educational experience and continuing professional development result in the highest performance, and what job characteristics affect performance and satisfaction.

KANE, LEO P. *E. B. Roberts, D. G. Marquis*

A model-oriented approach to studying the structure and performance of a research and development organization.

A study of the M.I.T. Instrumentation Laboratory was made to validate an industrial dynamics model of the organization and to gain understanding of decision making in the areas of the laboratory's marketing, internal technical effort, liaison activities, and personnel policies.

KAUFMAN, JEROME M. *B. J. Muller-Thym, E. B. Roberts*

Language for competence mobilization in two research and development projects.

Interviews with key personnel in two Goddard Space Flight Center projects led to the formulation of a method for visualization of the four elements of work, communication, activity, time, and space and demonstrate the relation between distance and frequency of contacts.

MANNES, JULIUS *P. Pigors, H. W. Johnson*

Personnel management in small but expanding enterprises engaged in research and development.

Interviews with personnel managers and staff in three growing research-intensive organizations were used to appraise the effectiveness of different approaches in personnel management to integrating non-professional production workers into the informal organization which is essential to high performance of the professional employees.

MILLER, HOWARD F. *E. H. Schein, D. G. Marquis*

The relationship between the relative importance of first job assignments and later productivity for research and development workers.

In a study of forty-six R & D personnel on their first assignment a relation was found between the importance assigned by researchers to various aspects of their job and superiors' assessment of their productivity.

MILLER, KARL A. *D. G. Marquis, R. B. Maffei*

An empirical assessment of certain influences on the temporal activity estimates in a network describing uncertainty.

Thirty-seven employees in an aerospace firm were asked to estimate the thirty-two activity times for a PERT network describing a jet engine improvement project. Variability was great, and more optimistic bias was shown by managers and finance personnel than by engineers.

PISELLI, JOSEPH R.* *B. J. Muller-Thym, E. B. Roberts*

The design of an R & D engineering organization.

A descriptive model of an industrial organization performing government R & D was checked by questionnaire study and indicates that the three basic functions of research, development, and proposal preparation do not correspond to organization structure and that their differences in professional orientation and job characteristics have important implications for changes in "balance" and paths for advancement.

* Sloan Fellow

RUBIN, IRWIN M. *A. C. Stedry, O. P. Soelberg*

An investigation of the factors affecting how an engineering supervisor allocates his time.

To gain a better understanding of the pressures on engineers making the transition into management, a questionnaire survey of ninety-four professionals from three levels of management in an electronics laboratory was made to determine what factors influence the allocation of time at the first level of engineering supervision.

SEIBEL, MELVIN C.* *E. H. Bowman, L. B. Moore*

A study of the factors influencing make-or-buy decisions of large manufacturers selling to the U. S. Air Force.

Literature search, a detailed case study of one large defense contractor's make-or-buy operations, interviews with key industrial and Air Force officials, and a review of the report of a recent Air Force study group were used to determine whether the controls applied by the Air Force to the defense contractors' make-or-buy decisions are commensurate with the problems they were designed to alleviate.

THORPE, THOMAS J. V. *J. C. Emery, D. C. Carroll*

Management information systems for procurement of electronic defense systems.

A review of Air Force histories, regulations, and manuals traces the development of Air Force policy in its acquisition of complex electronic defense systems from 1947 to the present and shows that centralization of the weapons acquisition process was the logical development of the system and that the innovations of computer technology and scientific management foster centralization.

VOSS, ROBERT G.* *R. Evans, Jr., R. C. Wood*

Impact of the National Aeronautics and Space Administration on the economy of New Orleans.

Economic statistics and predictions from published reports and from interviews with New Orleans' civic and business leaders were assembled to predict the impact of N.A.S.A.'s Saturn production facilities at Michoud on the area's economy.

WACHOLD, GEORGE R.* *E. B. Roberts, A. C. Stedry*

An investigation of the technical effectiveness of a government research, development, test, and evaluation organization.

Computer simulations with a dynamic model of the organizational relationships between a government agency and a remote R D T & E field activity are used to test the effects of various agency policies on the technical effectiveness of the activity.

WELLES, GILLETT, III *E. B. Roberts, D. G. Marquis*

An analysis of the dynamic behavior of a research and development organization.

A conceptual framework for representing the dynamic process of R & D is formulated and used in computer simulations of the various effort and information flows of the M.I.T. Instrumentation Laboratory to determine the effects of various policies on the performance and growth of the laboratory.

* Sloan Fellow

1962

BONNAR, JAY R. — *D. G. Marquis, T. M. Lodahl*

R & D project management: a study of supervisor-subordinate interpersonal relations.

Results of a social-distance questionnaire administered to 107 development engineers in four industrial organizations indicate that although individuals differ in the degree of informality or closeness they prefer with their superior, there are a number of supervisory behaviors supported by a sufficient percentage of subordinates to make them useful guides for management.

ECKEL, EUGENE J.* — *T. M. Lodahl, D. G. Marquis*

Motivational rewards for engineers in industry.

An interview and questionnaire survey of twenty-eight engineers and first-level engineering supervisors in two industrial firms explored the reward structure and the sources of engineer satisfaction and indicated a general lack of challenge and involvement, with a concomitant emphasis on salary.

FINCH, THOMAS W.* — *E. B. Roberts, B. J. Muller-Thym*

Factors that influence changes in cost and time schedules of research and development contracts.

Interviews and questionnaire survey of N.A.S.A. contracting officers in six offices indicated that of fifty-six CPFF R & D contracts, the majority were on schedule but had cost increases averaging about 50 per cent which were attributed to specification changes and definitization.

GRAVES, G. BARRY, JR.* — *D. G. Marquis, T. M. Lodahl*

Influence of work history on the development of effective researchers.

The histories of work assignments over about fourteen years of two groups of twelve aeronautical research engineers, similar except that one group was chosen to contain engineers of outstanding competence, indicated that the principal differences were found in the nature of the work performed in the earlier years.

HINDS, WALTER C., JR. — *D. G. Marquis, T. M. Lodahl*

Individual and group decisions in gambling situations.

In a laboratory betting situation to test recent research indicating that decisions on case problems made by the group tend to be more risky than those made by the members alone, it was found that there was almost no difference when choices among simple money bets were discussed by groups.

KIRSCHBAUM, RONALD M. — *D. G. Marquis, M. J. Gordon*

A study of research and development in the processed food industry.

Regression analysis of time series data for seven food processing firms, 1945–1960, indicated a small positive correlation between R & D effort and economic results (rate of return on assets lagged three to six years).

KLECKNER, CARL E.* — *C. J. Haberstroh, D. C. Carroll*

New techniques for project planning and control.

Information from interviews at eleven military and industrial establishments using PERT and CPM is used to analyze their experience in applying the new technique.

LEAHY, JOHN P. — *M. J. Gordon, H. J. Claycamp*

The new product investment decision: a case study.

This case study of a large manufacturer's unsuccessful attempt to enter the market with a novel new product analyses the entire life cycle of the product from its origin in a research discovery through the many problems of manufacturing and marketing to its eventual abandonment.

* Sloan Fellow

MULLEN, HUGH F. *B. E. Goetz, E. J. Baghdady*
A cost comparison between harmonic and pseudo-random signaling methods in high-accuracy satellite tracking systems.
A cost analysis procedure for projects which have not yet been fully developed is formulated and its application attempted in a specific project.

NELSON, RAYMOND S., JR.* *T. M. Lodahl, G. Smith*
A study of the engineering image in government and industry.
A questionnaire survey of 306 industrial and government engineers supports the conclusion from past work that the government engineer has an unfavorable image relative to the industrial but found that the self image of individuals in the two groups was not different.

OSBORNE, JAMES M.* *D. G. Marquis, E. P. Brooks*
Factors in project success.
Key personnel in five major industrial firms and in three large government organizations were interviewed to identify those factors in the management of major weapons system projects which are influential in the initiation, conduct, and evaluated performance of such projects.

ROBERTS, EDWARD B. (Ph.D.) *F. M. Fisher, J. W. Forrester, D. G. Marquis*
The dynamics of research and development.
A general systems theory is developed for explaining the time behavior and overall results of R & D projects. Using the techniques of industrial dynamics, a mathematical model is constructed of that verbal systems theory, and more than 1000 computer-simulated project life cycles are created. Sensitivity analyses are performed on the effects on project outcomes of changes in the characteristics of the project, the R & D organization, and its customers.

SCHULTZ, RAYMOND J.* *T. M. Alfred, C. A. Myers*
Successful career patterns – automotive engineers.
The employment histories of 310 automotive engineers and engineering managers were studied to determine how the career patterns of successful (i.e., highly paid) engineers differed from those of the less successful.

STONEY, WILLIAM E., JR.* *D. G. Marquis, T. M. Lodahl*
Environmental factors influencing idea production in a research laboratory.
A survey of 157 research professionals at N.A.S.A.'s Langley Research Center investigated in quantitative form the environmental factors in their laboratories which had proved most effective in stimulating the production of ideas.

VAN DEUN, JULES J.* *A. J. Siegel, D. V. Brown*
Labor relations in engineering organizations.
Twenty-five men with extensive experience in supervising technical personnel were interviewed concerning the effects that the unionization of professional employees might have on their relations with their employers and on their working environment.

* Sloan Fellow