PROBLEMS IN RESEARCH MANAGEMENT
AFFECTING AN INDUSTRIAL ORGANIZATION

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CHAPTER I

THE PROBLEM AND DEFINITIONS OF TERMS USED

> The organization and management of industrial research constitute an art that can never be encompassed by a book of rules. But there are certain principles and experiences which have repeatedly proved to be applicable and valuable.[1]

I. THE PROBLEM

Statement of the problem. It is the purpose of this study to review certain facts which establish the importance and magnitude of the industrial research effort in the United States and to selectively choose and suggest management practices for its organization and control which have found general acceptance through the test of experience. Indications of current trends have been examined for their possible effect on future corporate planning and management action.

Importance of the study. Research has become a multi-billion-dollar industry in the United States -- the fastest growing and potentially most important fact

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[1] C. C. Furnas (ed.), Research in Industry (New York: D. Van Nostrand Company, Inc., 1948), p. viii.

in our post-war economy.[2] It is currently estimated that $4.2 billion are expended annually and a total of 180,000 to 225,000 professional scientists and engineers are working full time on research and development.[3]

Large businesses have spent and are spending increasingly large amounts for research and research facilities. As early as 1948 the Johns-Manville Corporation spent $2.4 million for research in a twelve-month period. In the same year, IBM reported "development and engineering expenses" of over $3.25 million in their annual report.[4]

The growing interest of management in the administration of effective and profitable research is reflected in the increasing amount of space devoted in annual reports to that subject. Effective research is essential; but without the effective employment of top management in formulating policy and setting sound objectives, it

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[2]David B. Hertz, "Management's Role in Planning Research," Chemical Engineering, Vol. 54, No. 8 (August, 1947), p. 123.

[3]"The New World of Research," Business Week, No. 1343 (May 28, 1955), p. 120.

[4]Hilton D. Shepherd, Vernon A. Musselman, and Eugene H. Hughes, Introduction to Modern Business (New York: Prentice-Hall, Inc., 1950), pp. 364 f.

can be a very expensive luxury.[5]

The writer concurs in the opinion of Philip R. Marvin that research can and must be managed like any other part of a business with finite objectives and on a realistic time schedule. Attainment of profitable results within a reasonable time and at a reasonable cost is a practical management goal.[6]

II. DEFINITIONS OF TERMS USED

Research. When used in this thesis, the term "research" includes basic research, applied research, and technological development. It excludes such effort as may be directed toward economic research, market research, and employee psychology studies.

Basic research. Research activity of a general nature which is carried on with no specific objective beyond the expansion of human knowledge and understanding is termed "basic research." Usually, no schedule for accomplishment is established and the fields of study may be related only remotely to the commercial field of endeavor of the company sponsoring the research.

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[5]Philip R. Marvin, Top-Management and Research (Dayton, Ohio: Research Press, Inc., 1953), p. iii.

[6]Ibid., p. iv.

Applied research. Research effort directed toward a specific objective is termed "applied research." It consists of the application of known scientific laws of engineering, physics, and chemistry to the solution of concrete problems. These problems may concern, for example, the improvement of present products or processes or the finding of new ones. The effort is complete with the manufacture of the prototype article or installation of the pilot line.

Prototype article. The final working model which proves the soundness, reliability, and practicality of the engineering design is called the "prototype article." Usually, it is subject to the re-engineering to improve its producibility and to make it more marketable.

Pilot line. A small-scale process or production line built to prove or test a new method is called a "pilot line." Its purpose is similar to that of a prototype article.

Development. The span of effort expended in the evolution from the prototype to the marketable, commercial, or finished article is termed "development." Its purpose is to test production under simulated manufacturing conditions in order to determine what modifications may be required for full-scale production.

III. ORGANIZATION OF THE REMAINDER OF THE THESIS

Each of the remaining chapters of this study contains a consideration of the background and history of a specific research management area, a presentation of qualified opinions of persons other than the writer, personal conclusions, and a look at the future. Each chapter is concerned with the efforts of top management and the research director in accomplishing effective research programs. The possible effect of research on the parent company is also taken into consideration.

The sequence of the material in these chapters is arranged so that management personnel is led in a logical manner to a better working understanding of the management of a research organization and the problems related to it.

Chapter II contains a review of the history, present status, and predictable future of industrial research in the United States. Its purpose is to acquaint those previously uninformed with the great growth which has taken place in the past fifty years in industrial research and with its current importance to private industry.

Chapters III through IX cover the major problem areas considered to be of the most significance to those directly concerned with and affected by industrial research. The problem areas of Need, Finance, Organization, Controls, Research Director, Personnel, and Government Research are treated.

Chapter X contains the summary and conclusions of the study as well as recommendations to industry and education as to ways of promoting industrial research.

IV. LITERATURE SURVEY

Prior to the preparation of this study, the writer was aware of an apparent lack of information available in research management. A review of college textbooks used for instruction in the management courses over the past ten years confirmed a previously held opinion that little or no useful information specifically directed toward research management problems was contained therein.

Personal inquiries to staff members at the University of California at Los Angeles and the University of Southern California, officers and civilians in the Department of Defense assigned to research work, acquaintances associated with the Stanford Research Institute and the Jet Propulsion Laboratory at Cal Tech, and colleagues in industrial research organizations served to confirm the urgent need for more information on research management problems.

In compiling material for inclusion in this study, the writer reviewed books and current periodical literature on the subjects of research, industrial research, management, business organization, and industrial planning which were available at the principal public, university, and technical libraries in the Los Angeles area. Special reports published by the Government and certain institutions and foundations were also reviewed as source material.

As a result of the literature survey, two conclusions were reached: (1) that comparatively few basic texts have been written which adequately treat the subject of research management, and (2) that the great bulk of useful information is to be found only in special articles and reports published in technical periodicals and by non-profit organizations.

The writer recognizes that basic management principles apply to all areas where management effort is required. However, it is felt by him that the importance of research in modern industry, the growing attention required of management on research problems, and the unique application of techniques often called for in the solution of these problems make profitable a summarization and review of the now disorganized data.

CHAPTER II

INDUSTRIAL RESEARCH -- PAST AND PRESENT

> There is no tribute great enough to express the Nation's obligations to its scientists, engineers, and military personnel for their contributions to our constantly increasing productivity and the strengthening of our national defense.[1]

I. HISTORY

The beginning. Organized research is a product of the 20th Century. It had its beginning in Germany toward the end of the 19th Century, with American effort in the same direction starting shortly after.

The industrial revolution, which was the forerunner of our modern and highly mechanized civilization, did not result from organized research laboratories. The "great inventions" that made the industrial revolution possible sprang from the efforts of individual inventors. To the genius of such men as Crompton, Hargreaves, Arkwright, Watt, Berthollet, Whitney, and Maudslay must go the credit for the great inventions.

Pioneering industrial research in the United States

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[1]United States Congress, Commission on Organization of the Executive Branch of the Government, Research and Development in the Government, 83rd Congress (Washington, D. C.: U. S. Government Printing Press, May, 1955) p. xii.

was the laboratory of Arthur D. Little, organized in 1886. Following in quick succession were the laboratories of Eastman Kodak (1893), B. F. Goodrich (1895), General Electric Company (1900), National Bureau of Standards (1901), and E. E. du Pont (1902).[2] These represented the first organized research laboratories in the United States that were sponsored for the purpose of conducting industrial research programs.

It may be coincidental, but the fact that these companies have enjoyed continued prosperity and are among the "blue ribbon corporations" today can probably be traced to their early sponsoring of research programs and to their continuing support of them.

The growth. In the twenty years immediately following the establishment of organized research in the United States, the original six had increased to 265.[3] In the next twenty years, the most significant factor was the phenomenal growth of research in industry. The fewer than 200 laboratories in 1920 increased to over 2,300 in 1939.

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[2] "The New World of Research," Business Week, No. 1343 (May 28, 1955), p. 115.

[3] David B. Hertz, "Management's Role in Planning Research," Chemical Engineering, Vol. 54, No. 8 (August, 1947), p. 124.

In that year there were over 70,000 research workers and national annual expenditures of approximately $400 million are a matter of statistical record.[4]

In 1952, approximately one-fourth of all our engineering and scientific manpower, or 180,000 engineers and scientists, were engaged in research and development. This search for and application of scientific knowledge required an expenditure of $3,750 million, or over one per cent of our Gross National Product. Of these total dollars, private industry financed 38% for industrial research for its own products and processes.[5]

Today there are 2,845 industrial laboratories, exclusive of 100 non-profit research institutes such as Battle and Mellon and the laboratories of Federal, State and local governments, plus those in the universities and colleges.[6] Expenditures for research and development by private industry in 1956 will be approximately $2.1 billion.[7]

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[4]C. C. Furnas (ed.), Research in Industry (New York: D. Van Nostrand Company, Inc., 1948), p. 500.

[5]United States Department of Defense, The Growth of Scientific Research and Development, Resource Division, Office of Secretary of Defense, Washington, D. C. (July 27, 1953), p. 1.

[6]"The New World of Research," op. cit., p. 120.

[7]United States Congress, op. cit., p. xi.

II. FUTURE

Expenditures for industrial research have grown at a greater rate than those of Gross National Product, capital investment, population, or any other general industrial index. If the present rate of increase were to continue as it has, however, it could hit $7 billion in ten years. Kastens cites predictions of $10 billion by 1963 and of $30 billion in twenty years.[8]

The phenomenal increase in research effort in the past fifty years and the fantastic growth forecast for the future have created many of the problems which are discussed in the succeeding chapters of this study. The problems of meeting forecast requirements for personnel and the financial support of the expanding research efforts are not academic. They are of considerable present concern to the corporate management of American Industry.

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[8]Merritt L. Kastens, "Dollars and Science," Chemical and Engineering News (January 25, 1954), pp. 302-304.

CHAPTER III

THE NEED FOR INDUSTRIAL RESEARCH AND DEVELOPMENT

> Today's research determines tomorrow's profits. Industry's position, profits and research are inseparable in the long-term planning for corporate growth. Constant programming by top management for growth and development is essential to survival in today's industrial environment.[1]

I. A DECISION FOR MANAGEMENT

At some time every industrial organization has faced or will face the problem of the need for or advisability of undertaking a program of research and development. The setting up of a research program is basically a problem of top-management planning in any industrial enterprise.[2]

Many factors have been active in stimulating a company to industrial research activity. If a firm were to review its history, it would probably discover a single factor which brought about such research. This factor, however, would merely indicate the presence of a problem

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[1]Philip Marvin, Top Management and Research (Dayton, Ohio: Research Press, Inc., 1953), p. 1.

[2]David B. Hertz, "Management's Role in Planning Research," Chemical Engineering (August, 1947), p. 130.

or a certain emphasis of its management, and would not necessarily prove that other factors were not equally important and had not also contributed to the firm's development.[3]

It is evident from looking at the approximately 3,000 industrial laboratories currently engaged in research that at least this many believe that there is sufficient justification for founding and operating research departments.[4] Before starting a research laboratory, however, management needs to consider very carefully the particular needs and opportunities of its company.

In considering the factors underlying the desirability of establishing a research program within a corporation, the problems involved are not unlike those to be considered in planning for other new facilities. For example, a plant with a limited local market, restricted credit, or a highly specialized product has a very different research problem than a company with a national market, unlimited capital, and a highly diversified product line.[5]

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[3]Marvin, op. cit., p. 29.

[4]"The New World of Research," Business Week, No. 1343 (May 28, 1955), p. 115.

[5]F. Russell Bichowsky, Industrial Research (Brooklyn, New York: Chemical Publishing Company, 1942), p. 23.

II. VALUE OF INDUSTRIAL RESEARCH

Principal aims. Industrial research has been called the "fact-finding agency of scientific management" in industry.[6] Its uses or principal aims are to aid in developing technology through the application of scientific methods and by discovering new materials, new processes and new uses for products. In a recent book on the subject, five research functions are listed: basic research, product research, application advisory research, production process research, and production research.[7]

Advantageous results. Profit is one of the first considerations of management. "Today's profit base must be rebuilt constantly by a steady stream of new products and processes."[8] These new products and processes have resulted from research. In fact, a great portion of the items in common use today originated in an industrial research laboratory in the past twenty-five years. Company after company reports that from 50% to 75% of its sales

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[6] Edward R. Weidlein and William A. Hamor, Glances at Industrial Research (New York: Reinhold Publishing Corporation, 1936), p. 2.

[7] Marvin, op. cit., p. 17.

[8] Ibid.

come from products that did not exist fifteen years ago.[9]

Often overriding the consideration of profit is the problem of survival itself. "The company that lacks an organized program of engineering research on its product eventually finds itself out of business."[10]

In order to safeguard its investment and maintain product leadership, the company that is making and marketing a research product with commercial success keeps on with research in the same field. Industrial research is viewed by many companies not only as a profitable investment, but also as an absolute necessity for continued success.[11] Competition forces every businessman to keep abreast of industrial progress in order to avoid losing out in the competitive struggle.

A businessman at this point is faced with two alternatives. The first choice is to establish a research group in his own organization or to buy research from some other laboratory. The problems accompanying this

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[9]"The New World of Research," _op_. _cit_., p. 108.

[10]George T. Trundle, Jr., _Managerial Control of Business_ (New York: John Wiley and Sons, Inc.; London: Chapman and Hall, Ltd., 1948), p. 42.

[11]Edward R. Weidlein and William A. Hamor, _Science in Action_ (New York and London: McGraw-Hill Book Company, Inc., 1931), p. 48.

choice are discussed in the next several chapters of this study. His other alternative is to let someone else make the discoveries and then adapt them to his own use. This, of course, saves him an initial investment, but can very well put him at a competitive disadvantage by his getting started too late or by increasing his costs through royalty payments.[12]

Expenditures for research and development have had a stabilizing influence on business. The very nature of research tends automatically to resist both upswings and downswings. Rapid increases are most difficult because of the long training period for personnel. A lag of from four to seven years may exist between increases of input and increases of output.

However, an adverse movement or slowing of demand may be stopped or offset by increasing research expenditures. This was particularly true during the last depression when industries who followed an aggressive policy of accelerating their research efforts and expenditures gained positionwise and a result thereof.[13]

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[12] Charles L. Jamison, Business Policy (New York: Prentice-Hall, Inc., 1953), p. 458.

[13] National Bureau of Economic Research, Regularization of Business Investment (New York: Princeton University Press, 1954), pp. 310, 341.

Today's management problems are complex. Scientific management requires and needs the constant and full collaboration of scientific research to keep itself fully informed of the continually changing picture. Sound decisions must be based on fact. "The very rapid progress and present strong position of industrial research are attributable to its economic soundness."[14]

III. RESEARCH IN THE SMALL COMPANY

There are differences of opinion regarding the advisability of a small company doing its own research work. It is generally accepted today that the smaller, newer business probably has the greatest need for research while establishing itself.

In a survey of 1,450 companies conducted by the Harvard Business School, it was found that the smaller the company the more it spent on research. Companies with fewer than five hundred employees spent in excess of four times as much, compared to net sales, as did companies employing 5,000 persons or more.[15]

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[14] Edward R. Weidlein and William A. Hamor, Glances at Industrial Research, op. cit., p. 40.

[15] DeWitt C. Dearborn, Rose W. Kneznek and Robert N. Anthony, Spending for Industrial Research (Boston: Harvard University Press, 1953), p. 29.

Special points for consideration. The objective of a company in setting up a research laboratory is not to support research but to be supported by it. Suggesting that the small business cannot afford research is like suggesting that it cannot afford advertising.

Small businesses can make far more use of a research laboratory, get a bigger percentage of return, and get it sooner than can a big company. In the small company, a research laboratory closely administered by a top executive of that company should return a profit in a relatively short period of time. On the other hand, in the case of a large company, it may be a number of years before research can be considered a financial success.[16] The above statements relative to the importance of research in the small company are concurred in by the American Institute of Management.[17]

There are many problems associated with the establishment of a company-owned laboratory. One of the most

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[16]National Research Council, Profitable Practice in Industrial Research (New York and London: Harper and Brothers Publishers, 1932), pp. 82 f.

[17]American Institute of Management, "The Improvement of Small Business Management," The Corporate Director, (February, 1953), pp. 1-7.

common is that of financing. Costs for research facilities and salaries for qualified personnel make it an expensive undertaking. For that reason, it may not be desirable for a company to set up a research organization of its own unless it can afford to spend $100,000 or more for sponsoring its research and development programs.[18]

Alternatives to company ownership. The small company which has recognized its need for research assistance but is not able to implement its own research department has several alternatives from which to choose. One of the possibilities is for it to avail itself of the services of an association or cooperative laboratory. In certain industries, such as the building trades, this is a common practice.

Where there are problems common to a number of companies, reference to an association eliminates unnecessary duplication, reduces costs, and increases the chances of arriving at a successful solution by combining the knowledge and experience of a number of companies. However, when a number of the member companies organize adequate

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[18] J. F. Downie Smith, "Industrial Exploration and Development," Electrical Engineering (September, 1949), p. 777.

laboratories of their own, the cooperative becomes redundant and its scope of research limited.[19] When the cooperative laboratory is not the answer, another possibility is for a small company to engage the services of an independent industrial laboratory, such as Arthur D. Little, Inc., Evans Research and Development, The Armour Institute, the Carnegie Institution of Washington, or similar private research groups. The facilities of these organizations are among the finest.

Industry, however, has made relatively small use of their services. The 1952 Harvard Survey showed that even in the smallest firms (fewer than 100 employees) more than half of the respondents who spent in excess of $5,000 annually for research had their own organizations. The same survey showed that dollarwise only about three per cent of the more than $600 million spent for research by 191 firms was spent outside the company.[20]

The last alternative to accomplishing its own research is for the small company to make use of the research staffs and laboratories maintained by the universities and

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[19] National Research Council, op. cit., p. 183.

[20] Dearborn, Kneznek, and Anthony, op. cit., p. 7.

colleges. Non-profit institutions have shown the most rapid growth in the actual performance of research. Between 1941 and 1952 their share of the total performance increased from five per cent to 11 per cent.[21]

Not all of the schools, however, will accept outside projects. Of the country's 1,851 schools, 282 will accept or consider research projects from industry or the Government. Acceptance is subject, of course, to the availability of facilities and is governed by institutional policies. In the larger universities, often as much as 85 per cent of their available research effort is taken up by Government projects.[22]

IV. SUMMARY

Many industries, from the very large to the very small, have found it advisable to organize and maintain a research program. Expenditures for such programs have been found effective in increasing profits, solving the problem of survival in a competitive market, stabilizing business and in providing up-to-date facts for use in mak-

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[21] United States Department of Defense, The Growth of Scientific Research and Development, Resource Division, Office of Secretary of Defense, Washington, D. C. (July 27, 1953), p. 7.

[22] "The New World of Research," loc. cit.

ing management decisions.

The small company or industry stands to benefit more proportionately from research than does the large company. The expense of organizing and maintaining such a laboratory is large and may not be within the small company's financial capability. When this is the case, a small company has several alternative sources for research assistance from the outside. These sources, while available, have not been widely used. Regardless of the source, however, small industry does better with a research program than it does without one.

V. FUTURE

It seems likely that industry will find an ever-increasing dependence on the research laboratory in the years that lie ahead. There is no reason to believe that the trend toward the complete mechanization of industry and industrial processing will not continue.

The startling developments in the field of electronics are making possible automation of processes in industry. The harnessing of atomic power to productive purposes is another factor in the present industrial revolution. It seems unreasonable to assume that any segment of American industry will be unaffected by these phenomenal innovations in technology.

The competitive nature of our industrial system will force the businessman to take part in this revolution. He will have to participate and contribute to this advancement or fall by the way. Participation will be by the way of industrial research.

CHAPTER IV

THE FINANCIAL ASPECTS OF RESEARCH AND DEVELOPMENT

> The ready-made formula for the provision of research funds has yet to be devised. Comparisons in other industries, or within companies of the same industry, are of little help.[1]

This writer does not concur with the above-stated opinion of Mr. Voorhies of Standard Oil, believing that an awareness of experienced costs is necessary for a broad understanding of the industrial research problem. There is concurrence, however, that experiences are not directly transferable, and that each company must determine the amount of its expenditure in the light of its own needs and available funds.

I. COST OF RESEARCH AND DEVELOPMENT

Total cost. In 1954, industry spent about $1.9 billion in support of its own research programs.[2] This amount represented an increase of approximately $500 million over the expenditures of 1952, which were close to

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[1] Darrell H. Voorhies, The Coordination of Motive, Men and Money in Industrial Research, Department on Organization, Standard Oil Company of California, p. 63.

[2] "The New World of Research," Business Week (May 28, 1955), p. 120.

$1.43 billion.[3]

The cost for 1952 averaged about $22,000 for each of the 118,000 scientists and engineers actively engaged in research work. This average cost ranged from $17,000 in the chemical industry to $69,000 in the automobile industry because of a variation in the number of personnel supporting each scientist.[4]

A survey of the same year by the Harvard Business School which considered all persons connected with the research effort (technical and supporting) developed a median of $7,000 per each with a high of $10,000 per person so engaged.[5]

Breakdown of research costs. Many times those experienced with research administration have found that the major item of research expense is that of salaries and wages, which may amount to from two-thirds to three-

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[3]United States Department of Defense, The Growth of Scientific Research and Development, Resources Division, Office of the Secretary of Defense, Washington, D. C. July 27, 1953, p. 1.

[4]Ibid., p. 3.

[5]DeWitt C. Dearborn, Rose W. Kneznek, and Robert N. Anthony, Spending for Industrial Research 1952, 1953 (Boston: Harvard University Press, 1953), p. 38.

quarters of the total expense.[6] A recent article in <u>Business Week</u> cites examples of salaries common today.[7] A director of research commands approximately $25,000 per year. A Ph.D. with no industrial experience will start in research at from $7,000 to $10,000 per year. Skilled technicians and engineers will earn salaries which are slightly higher than salaries paid for similar work in non-research departments. Wage differentials are determined by the needs of the particular program and the technician's experience, training, and specialization.

Costs of research material vary from industry to industry and even between programs in the same laboratory. This variation is caused by differences in the requirements between research programs. For example, an aircraft or guided missile program consumes large amounts of expensive materials, while in a basic physical science research project the cost for material is relatively low.[8]

Wide variations also occur between laboratories in recorded indirect or overhead expenses. The major cause

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[6]C. C. Furnas (ed.), <u>Research in Industry</u> (New York: D. Van Nostrand Company, Inc., 1948), p. 148.

[7]"The New World of Research," <u>op</u>. <u>cit</u>., p. 122.

[8]United States Department of Defense, <u>op</u>. <u>cit</u>., p. 4.

of these variations usually can be found, however, in differences in the accounting system used by the laboratories. Certain expenses may be treated as either direct or indirect costs. Depreciation rates for plant and facilities are not the same in all companies. The examples noted are only two of many areas where difference in accounting treatment will cause wide variance in the overhead rate. Based on the writer's association with research and development organizations, however, a range of from 75 per cent to 135 per cent is common and 100 per cent as the ratio of indirect to direct expense may be considered normal.

Capital investment. The total cost of research and development discussed thus far did not include one very significant item -- capital investment. It included only depreciation charges and cost repair on capital assets. A survey made in 1952 showed this investment in capital assets to be sizable.

A replacement cost of $1.0 billion was estimated for the tangible facilities (land, buildings, and equipment) of 191 companies whose research expenditures amounted to 30 per cent of the industrial total. In addition to this investment, an average annual expenditure of $600 per professional technical person was made for additional laboratory machinery and equipment.[9]

II. FINANCING RESEARCH AND DEVELOPMENT

Determining size of investment. There does not appear to be a ready formula for conveniently determining the amount of money that should be necessary to support a research program. One word of advice has found general acceptance, however, and this is that the research expenditure should be set at a figure which the company can afford to sustain for some years, even under adverse circumstances.[10]

The current practice of determining the amount of funds to be appropriated for research by reference to the ratio which exists between it and current sales is losing favor. While this ratio may be useful for making a quick comparison of one program with that of a competitor, it is dangerous if used as a sole criterion because of the differences in capabilities between companies.[11]

For example, in 1951 company-financed research in

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[9] Dearborn, Kneznek, and Anthony, op. cit., p. 49.

[10] Morrough P. O'Brien, "Research for the Benefit of Industry," Chemical and Engineering News (October 30, 1950), p. 3765.

[11] "The New World of Research," loc. cit.

1,450 companies averaged 0.9 per cent of direct sales. Yet for companies of fewer than 500 employees, the expenditure averaged 1.4 per cent and for those of 5,000 or more, but 0.5 per cent.[12] These ratios have some value because they indicate a certain emphasis on research by smaller organizations, but they would not be valid in establishing the program expenditures for any particular company.

A more realistic approach to be used in fixing the optimum research expenditure consists first in establishing the amount of research which is necessary to achieve the objectives as set by management, and then to adjust these requirements and objectives in light of the resources available for financing a sound program. The appropriation of research funds should be based upon a recognition of the potential gain to be made. This, then, should be tempered by the company's willingness to expand, if necessary, and its ability to finance the program over a relatively indefinite period of time.[13]

Method of financing. One of the most common methods of providing funds for research and development expenses

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[12]Dearborn, Kneznek, and Anthony, op. cit., p. 49.

[13]Philip R. Marvin, Top-Management and Research (Dayton, Ohio: Research Press, Inc., 1953), pp. 32, 48.

is to allocate a fixed portion of the previous year's profits for that purpose. This method, however, has a major disadvantage in that research is likely to become lean in non-prosperous years when the need for research is the most acute.[14]

This particular method requires no actual planning. It may have some value for the firm whose research effort is directed toward providing technical advice to management rather than being intended to accomplish specific results with product or process. Otherwise it has little to recommend it.[15]

Most research directors would rather see the annual expenditures of their laboratories written off as expense than capitalized.[16] A realistic way of doing this is to pay for the cost of the research programs by crediting the research account with the resulting profits of their developments.

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[14] Lawrence L. Bethel, Franklin S. Atwater, George H. E. Smith, Harvey A. Stackman, Jr., Essentials of Industrial Management (New York: McGraw-Hill Book Company, 1954), p. 69.

[15] David B. Hertz, "Management's Role in Planning Research," Chemical Engineering (August, 1947), p. 125.

[16] Furnas, op. cit., p. 155.

One method of doing this is for the research department to put an asking price on its inventions. This charge is then financed in the same manner as the purchase of a new building or equipment. To the amount credited above is added actual charges for special work done at the request of the operating divisions. These credits also are supplemented by outside sources of income, such as royalties from successful patents, and research done for other companies or the Government.

This plan, while rather complicated, has certain advantages, one of the most important being that it keeps clearly in the minds of the directors and investors the real position of research in the industry.[17]

Return on investment. Research programs deal in futures and therefore are replete with unknowns. Many projects are of long duration and can very well end in partial or total failure. The successful programs must pay for those which are unsuccessful.

Research rarely yields quick financial dividends and for that reason it is necessary to judge results over

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[17]F. Russell Bichowsky, Industrial Research (Brooklyn, New York: Chemical Publishing Company, Inc., 1942), p. 114.

a sufficiently long period of time.[18] However, ". . . today's research determines tomorrow's profits,"[19] and the fact that more than 50 per cent of today's sales are of products developed in the past twenty years is proof of that fact.

III. SUMMARY

American industry invested $1.9 billion of its own money for industrial research in 1954. This is important even though the sum amounted to only about 1.0 per cent of net sales for that year. Of much more significance to the company about to organize and maintain a research laboratory is the realization that in terms of engineers and scientists engaged in this effort it amounted to approximately $22,000 per man.

Of equal importance is the fact that American industry has an investment of an additional $21,000 per scientist for land, buildings, and original equipment which was necessary to get started, and that it is adding to this another $600 per researcher each year for new equipment.

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[18]Dudley E. Chambers, "Some Aspects of the Function, Organization and Operation of Industrial Research and Development Laboratories," Journal of the Franklin Institute, No. 249 (April, 1950), p. 291.

[19]Marvin, op. cit., p. 1.

The financing of research and development programs is not handled in the same way in all companies. It is generally agreed, however, that investments in research rarely yield quick financial returns. It is also generally true that those who manage research departments prefer liquidating research costs rather than capitalizing them.

After the objectives of the research effort are defined and the finances approved and made available, a system which provides for the crediting of the research account by direct charges to requesting departments, income from patents and resulting new products, and other income from sources outside the company is to be preferred to less scientific "rule of thumb" techniques.

IV. FUTURE

Research costs are rising. Between 1941 and 1952, while the number of scientists and engineers doubled, the two-fold increase in manpower was accompanied by a four-fold increase in expenditures in the same period.[20] While part of this increase was attributable to the decline in

[20] United States Department of Defense, op. cit., p. 5.

the purchasing power of the dollar, much of the increase was due to higher costs for qualified research personnel resulting from increasing demand and shortening supply.

Added to this has been the skyrocketing cost of equipment, with competition making necessary the very latest and the best. There is no indication that these costs will hot continue to rise and this increasing cost is becoming a matter of growing concern among top company management in this country.[21]

[21]"The New World of Research," op. cit., p. 121.

CHAPTER V

ORGANIZING THE RESEARCH FUNCTION

> Without effective organization and machinery, it is impossible to know what is going forward in a research way, to determine promptly sound executive policies for the laboratory with respect to such matters, and then to make the voice of the directional staff and its influence felt regarding them.[1]

I. CORPORATE STRUCTURE

Frequently a company's industrial research program starts in a backroom laboratory as a fairly minor activity. Its purpose is to provide a service to the manufacturing and engineering departments. From this beginning, however, it eventually grows in stature and in its place on the organization chart. That, briefly, has been the history of research in the most successful companies where currently it is not only responsible for technical matters but for phases of over-all company planning.[2]

Organization plans. In the majority of companies,

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[1]Edward R. Weidlein and William A. Hamor, Science in Action (New York: McGraw-Hill Book Company, Inc., 1931), pp. 270 f.

[2]C. C. Furnas (ed.), Research in Industry (New York: D. Van Nostrand Company, Inc., 1948), p. 13.

one of two organizational patterns is followed in placing the research function in the organizational structure. One of these is to consolidate engineering and research under a single head. The man responsible for engineering and research frequently has control of factory and material processes as well.

Combining research and engineering has certain advantages when the number of the company's products is not large. When such is the case, it is often possible to cover all the products and provide for engineering development as well. When this can be accomplished, direct control by one head seems to be the more efficient arrangement.

In the second organizational pattern, the research laboratory is independent of the engineering and factory departments. This second plan has the advantage of permitting the research director to take a more detached view and thus gain a better perspective of the major problems of the company.[3]

In very large companies with unrelated and fully decentralized operating divisions, it is sometimes the

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[3]National Research Council, Profitable Practice in Industrial Research. National Research Council, Division of Engineering and Industrial Research (New York and London: Harper and Brothers Publishers, 1932), p. 70.

practice to have separate research groups in each division. When this is done, their activities are coordinated by an executive committee or a corporate director. In some companies, applied research may be done at the division level and basic research at the corporate level. In almost every case, however, the research activity reports and is directly responsible to top management.

Independent research preferred. The most powerful company-financed research organizations, such as those of General Motors, General Electric, and United States Steel, are set up as independent organizations and their directors carry the title of Vice President. In these cases, research is considered an executive function because its activities and policies affect the future position of the company.[4]

Experience has shown that, generally, research does not prosper in an atmosphere of dependency. To be effective, research should be on an equal status with the other operating departments of the corporation in the organizational structure.[5]

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[4]F. Russell Bichowsky, Industrial Research (Brooklyn, New York: Chemical Publishing Company, Inc., 1942), p. 70.

[5]Furnas, op. cit., p. 17.

Preferably, the director of research should report directly to the president, top operating head, or to the same executive to whom the other operating divisions, including production and sales, report. Under any other arrangement, research becomes a service function and not a full operating partner.[6]

Company management must work closely with the research manager to establish and support programs clearly understood and guided ably by top management. The programs must be interpreted in policies known and understood by the research division, with a constant flow of pertinent information to management as well as to the research groups.

> The success of research is an executive problem due to the wisdom and skill of the executives of the corporation directing that research, controlling it and knowing when to say 'no.'[7]

The writer concurs with the logic of the opinions expressed above that research is a top-management responsibility and that organizationally it must be placed there. Frequently, profit objectives of a corporation determine research objectives and thereby research programs. It is

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[6] Ibid.

[7] Philip R. Marvin, Top-Management and Research (Dayton, Ohio: Research Press, Inc., 1953), p. iii.

mandatory that these programs be geared to corporate objectives. The responsibility is that of top management.

II. DEPARTMENTAL STRUCTURE

Director's staff. The most successful research laboratories follow organizational patterns which are very similar. In these, the laboratory is divided into various sections or divisions. Each division is headed by a division chief, who in turn has group leaders reporting to him. Supporting these group leaders are the project engineers responsible for specific assignments.

The division chiefs, plus the heads of the major supporting sections, constitute the director's advisory staff or executive board. At regularly scheduled meetings, the director submits all major technical problems that come before him. It is not the purpose of the director to shift responsibility, but rather to obtain advice of a specialized nature which will enable him to make sound decisions.[8]

Basis for divisional classification. In the majority of research laboratories, problems are assigned to the

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[8] Bichowsky, op. cit., p. 98.

divisions on the basis of a classification of the problem in regard to subject matter. One of the possible research classifications is by function. In an organization of this type, there might be a Division of Fundamental Research, a Division of Development, or a Division of Operating Research. Unfortunately, all research problems can not be so catalogued. It is infrequently found that any given industrial problem is purely fundamental, all developmental, or only operational.[9]

More widely used bases for organization are: by manufacturing departments or plant units, in terms of the technical skill or scientific background required, or in terms of the specific purpose of the research.[10] In the first case, the laboratory would probably be broken to correspond with the various products manufactured. In the second, the organization would parallel the major fields of scientific specialization related to the company's business. In the third instance, there would be one section for new product research, another for product improve-

[9] *Ibid.*, pp. 100 f.

[10] Lawrence L. Bethel, Franklin S. Atwater, George H. E. Smith, Harvey L. Stackman, Jr., *Essentials of Industrial Management* (New York: McGraw-Hill Book Company, 1954), p. 68.

ment, another for packaging, and so on. In the larger companies a combination of all these groupings is used.

The project system. Regardless of the method used to set up the divisions of the laboratory, practically all research organizations use what is known in the research and engineering fields as the "project system." The project is the specific task or job to be done. It is the work unit of the laboratory.

In practice, the projects are assigned to the division heads on the basis of their specialty. The division head assigns the project to a group leader om the basis of task loading and the group leader's familiarity with the subject of the research. The group leader then assigns the task to a project engineer who, with the assistance of assigned scientists and technicians, finds the solution to the problem.

In some of the most modern research organizations of today, the research director and his staff assign a specialized team chosen from the whole laboratory staff for each new project rather than make assignments to a pre-determined group. This team approach cuts across both group and division lines and the team reports directly to a senior staff member.[11]

In all instances, however, the project system is used and its use has many advantages. For one thing, it gives the director a basis for controlling the entire laboratory. For another, its use provides a basis for records and a means of accounting for costs. Lastly, and this is perhaps the most important advantage, the project system makes possible periodic reviews of progress and work accomplishment.[12]

III. SUMMARY

Research activity is most profitable and productive when organizationally responsible to top management. Because of the direct effects that research results have on the future of the company, its proper operation is a management function. The research director should be on the same organizational level as the heads of sales and production, and his department should be a full partner, not a service department. In the largest corporations, the research director carries the title of Vice President.

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[11]Herbert Solow, "Science for Sale -- at a Profit," Fortune (March, 1955), p. 136.

[12]Bichowsky, op. cit., p. 101.

Most research groups are split into divisions, according to the classifications of activities. These divisions may be on a functional basis, by scientific specialty, by plant or department, or research objective. In all laboratories, however, the project system of assignment is used because of the advantages to be gained from better control, more accurate cost accounting, and the ability to make a periodic review of the progress being made in any research project.

IV. FUTURE

Observed trends seem to indicate a decreasing tendency to combine research and engineering under one head, except in those cases where significant economies are gained during the early stages. It is possible that more laboratories will turn to the team approach for research projects. The fresh, unbiased approach made possible by this method may prove a distinct competitive advantage and actually result in a reduction of the number of personnel required in the research laboratory.

CHAPTER VI

CONTROL TECHNIQUES

> With intelligent planning, with a clear vision of both the immediate and the long-range objectives, with proper personnel and direction, research will ultimately bring rich rewards to any industry.[1]

I. PLANNING AND SCHEDULING

Top-management responsibility. The importance of top-management direction in the administration of industrial research was stressed in the last chapter. The management of any enterprise is faced with a most important problem in planning when it has to decide whether to expend funds on a research program. Many executives find it much simpler to plan for plant expansion, a machinery modernization program, or a sales promotion than to choose a satisfactory research program.[2]

There is a strong resistance to the planning and scheduling of research and development programs because of the number of intangibles which make prediction diffi-

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[1]Edward R. Weidlein and William A. Hamor, Science in Action (New York and London: McGraw-Hill Book Company, Inc., 1931), p. 266.

[2]David B. Hertz, "Management's Role in Planning Research," Chemical Engineering, Vol. 54, Number 8 (August, 1947), p. 124.

cult. It should be remembered, however, that even when the plan and schedule are based on sheer guesswork such plans and schedules have value. Forethought is required in their preparation and a guide for measuring progress is provided.[3]

Because the planning of industrial research is difficult, it easily can be by-passed by top management and left to chance. The dollar-and-cents cost of improper planning often cannot be accurately appraised from profit-and-loss statements. While the incurred cost of an unsuccessful research project is tangible, the profit lost from a program never undertaken or unfruitful because of poor planning is much more intangible. This loss can be very large, however, and seriously affect the company's future.[4]

<u>The corporate plan</u>. One of the first considerations of management is to determine the objective at which the research effort is to be aimed. Company policy must provide a guide as to whether new product development is to be the objective, or product improvement, or product

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[3]Philip R. Marvin, <u>Top-Management and Research</u> (Dayton, Ohio: Research Press, Inc., 1953), p. 52.

[4]Hertz, <u>op. cit.</u>, p. 123.

diversification, or a combination of these and others. The amount of effort to be expended, the objective in mind, and the timing make up the corporate plan.

In a survey of 191 selected companies whose net sales amounted to approximately $52 billion in 1951 and whose total employment totaled more than three million, 92 per cent of the research funds were spent for two objectives -- 50 per cent to improve present products and processes and 42 per cent to create new products or processes. The remaining eight per cent was spent to support fundamental research, basic research, and other projects uncommitted to specific problems.[5]

Over one-half of the companies who answered the survey questions reported no expenditures for basic research. Of those companies who did report expenditures for basic research programs, the larger companies spent a proportionally greater amount for that purpose. For companies of fewer than 500 employees, the median amount of expenditure for uncommitted research was zero.

Turning to a consideration of research programs directed at creating new products or processes, it was

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[5]DeWitt C. Dearborn, Rose W. Kneznek, and Robert N. Anthony, Spending for Industrial Research, 1951, 1952, (Boston, Mass.: Harvard University Press, 1953), p. 47.

shown by the survey that companies employing fewer than 2,000 employees spent as much or more for research projects of this kind as they did for projects where the objective was product improvement. On the other hand, companies employing 50,000 or more persons spent twice as much for product and process improvement as they spent for developing new products or processes.[6]

There appears to be a discernible logic in the program planning as evidenced by the results of the survey noted above. The small company is constantly striving to improve its competitive position. It attempts to do this by increasing its market through the introduction of new products while at the same time reducing its costs through increased efficiency.

The operating philosophy of the large company is different. The large company has established itself and its line of products, and therefore, is concerned with maintaining and strengthening its position. It does this by means of product improvement and considers product diversification to be less important. Only the very largest concerns feel the necessity of a major effort in the area of basic research. Other companies consider

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[6]<u>Ibid</u>.

basic research unattractive unless the nature of their product is such as to require it.

The master schedule. Proper planning of research programs cannot be divorced from the time element. Because the time involved from the start of a research program to its completion will affect both the amount of the expenditure and the areas of attack, it should be carefully considered when the corporate plan is made. Scheduling is an important aspect of top management's responsibility for setting up a sound research program. If done well, it will result in a proper concentration of efforts in accordance with corporate objectives and policies.[7]

Unfortunately, managements have relatively little control over the timing of research developments. Research directors are under constant pressure from their management to set deadlines for the completion of projects. However, while pre-planning and competent technical supervision narrow the range of probable error, predictions of the results of scientific invention are apt to be most erratic.

Capital expenditures for plant expansion and production of new products are frequently either delayed or advanced by not having research pay off on schedule or by

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[7]Hertz, op. cit., pp. 128, 130.

the successful completion of a project sooner than was anticipated. In the building materials industry, research discoveries well ahead of schedule have forced sharp accelerations in capital expenditure programs.[8]

The project plan. When the master plan has become settled and adequate funds made available for support, there still remains the planning and scheduling of each individual project. Project planning should come from the research director and his staff and should not be considered as a problem for top management. The complete planning and scheduling of each project from start to finish should be done, however, from the over-all concept of the planning as established by top management.[9] Research work must be scheduled in order that continuous, uninterrupted attention can be given to it for long periods of time, if that is required.[10]

While there is general agreement among both managers and engineers that some control is necessary in or-

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[8]National Bureau of Economic Research, Regularization of Business Investment (Princeton, New York: Princeton University Press, 1954), p. 125.

[9]Hertz, op. cit., p. 129.

[10]National Research Council, Profitable Practice in Industrial Research (New York and London: Harper and Brothers Publishers, 1932), p. 214.

der to achieve optimum success in any research effort, there is not a general agreement as to how much detail planning is necessary to assure effective control. One expert will advance the opinion that each program "must be broken down into day-by-day work plans and reports of work done."[11] The opposite opinion is expressed by the engineer who is convinced that thinking cannot be scheduled and is apt to look on costs and deadlines with little concern and, perhaps with much disdain.[12]

Somewhere between those two extremes, the laboratory management must find a compromise. The nature of each research project will determine, to a large extent, how much planning is practical. Various factors must be weighed by the research director. Points to be weighed in the consideration include how critical the need is for the sought-for answer, the amount of money available for the project, and how great an advance in the "state of the Arts" is involved. Obviously, a project that reaches far into little-known and relatively unexplored areas of science and engineering cannot be laid out in the same

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[11] C. C. Heritage, "Budgeting Research and Development," The Paper Industry and Paper World (March, 1940), p. 1257.

[12] "The New World of Research," Business Week (May 28, 1955), p. 108.

neat patterns as can a comparatively simple application of common mechanical laws.

On the other hand, when the failure to find a solution to a problem could cause severe financial loss to an organization, or when very limited funds are available to sponsor a critical program, the very best planning and control by all persons concerned is in order. Regardless of how nebulous the research project may be, the application of considered judgment and well-chosen plans of attack will contribute to the successful fruition of the program.

It seems logical that management must exercise sufficient control to assure compliance with the master plan. Management must establish procedures for controlling research departments. This must be achieved, however, without resorting to operating techniques which stifle that type of individual who is most successful in accomplishing industrial research. "Organization and control should not be carried to a degree which smothers imagination."[13]

II. BUDGETARY CONTROLS

An operating project budget should be prepared

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[13] Marvin, *op. cit.*, p. 145.

in the same manner as the project plan and schedule. The preparation of an operating budget for each project is an effective aid in planning the activities of the research department. It provides assistance to the company executives in preparing the company budget and in providing for the continuance of the research effort.[14]

Usually, a preliminary project budget is prepared prior to the initiation of a specific research program. Then, when top management has given its blessing and the project plan has been drawn up, a revised budget is prepared and keyed to both the plan and schedule. Subsequent revisions to the budget must be made to correspond to changes in the program and also to reflect actual costs experienced.

Operating budgets for research projects are subject to the same probabilities of error as are project plans and schedules, and for the same reasons. However, if careful thought is given to their preparation and adequate and parallel accounting records of budgeted and actual expenditures are available for comparison, a valuable control technique is provided for the use of the labora-

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[14] C. C. Furnas, Research in Industry (New York: D. Van Nostrand Company, Inc., 1948), p. 77.

tory director and his management.

III. REPORTS

As in the management of any segment of the industrial organization, certain reports are required. The reports needed by the different levels of supervision are not the same. At the level of the project and group engineer, detail information is needed. Here labor expenditure analyses, material usage, test reports, drawing status and status of prototype manufacture are required on a weekly and sometimes daily basis in order to maintain technical control and supervision.

The research director needs other information in order to direct the activities of the laboratory. In fairly sizable organizations with several active projects, it is impractical for the director to personally review each project frequently. For his purposes, a progress report is prepared by the group project engineers for the assignments under their control to inform the research head of progress being made and of trends resulting from active projects. These reports should be regularly submitted in a standard form for all projects.[15]

[15] *Ibid.*, p. 174.

The progress reports serve to provide a basis for review by the research director and his staff and as a source of data for his use in reporting to corporate management. Significant variations from the project plan, schedule, and budget are highlighted so that necessary revisions in both laboratory operation and corporate planning can be made.

IV. SUMMARY

Planning and scheduling are a necessary and important part of a successful industrial research program. These activities must be carried on at the top levels of the corporation to assure that corporate objectives will be attained and also at the laboratory level to assure adherence to the plan of attack. The great number of intangibles and unknowns in research make scheduling very difficult and accurate predictions unlikely.

Budgetary controls are subject to the same vagaries and errors of forecasting as are research plans and schedules. However, comparisons between the budget and actual cost figures provide management with useful information for administrative purposes.

Operating progress reports, prepared periodically and in a standard form, are necessary at all management levels. The reports should be tailored to meet the needs of the people using them and, when going to top management, should not be so filled with details as to cloud the basic information presented.

In every case, however, the reports, plans, budgets, and schedules should be adequate for control purposes and yet not so confining as to smother the initiative and inspiration of the research scientists. It must be remembered that management people and research scientists have different backgrounds, goals, and ambitions, which fact must be compromised in the control techniques established for the research laboratory.

V. FUTURE

Undoubtedly, with the continued growth of industrial research, many new and specialized management control techniques will be developed that are better adapted to the particular needs of the laboratory. More accurate records of historical information regarding past research projects will make forecasting more dependable.

Only since 1921 has industry as a whole recognized the great importance of planning and control in management.[16] It was much later when the general application of these same principles was made to research management. Modifications being developed now will become the practices of the future.

The great expansion in research activity brought about by both industry and the Government is acquainting both management and science with each other's problems and needs. This interchange of philosophy and ideas can be expected to result in the finding of solutions satisfactory to both.

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[16] Edward R. Weidlein and William A. Hamor, Glances at Industrial Research (New York: Reinhold Publishing Corporation, 1936), p. 147.

CHAPTER VII

THE RESEARCH DIRECTOR

> . . . the research director has a job requiring unusual talents, ranging from executive ability and all that implies to technical training, skill, and experience, and to an unusual understanding of human relations and psychology. He must possess imagination, intuition, enthusiasm, and leadership in the highest form.[1]

I. THE JOB

Adviser to top management. As was pointed out in Chapter V, the research director in many companies is a member of the top-management team with a title of Vice President. As a member of the top team, he is expected to be the one best informed regarding current and potential scientific developments that might affect sales, profits, and the competitive future of the company. By keeping abreast of developments in his company's field and those related to it, the research director can plan and make recommendations for the future progress of the company and his laboratory's part in assuring it.

When formulating research programs, it is equally important to know when to stop or when to make a provision

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[1] C. C. Furnas (ed.), Research in Industry (New York: D. Van Nostrand Company, Inc., 1948), pp. 69 f.

for allocating additional funds. The research director is the one expected to make a definite recommendation at this point. The recommendation should be in such detail as to not require too much effort for management to reach a final decision.[2] Research executives must be present at all top-management meetings to give counsel, to make suggestions, and to point out errors in management thinking in all corporate matters affected by research activities.[3]

Administrator. The direction of the research program should be completely in the hands of the director of research. If he does not have full and absolute authority over the research programs, they will be disrupted by whims and poor judgments not only in the sales and other commercial departments, but in the laboratory itself.[4]

The president of the Bell Telephone Laboratories considers that the problem involves: (1) the selection of competent people, and (2) the most efficient use of

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[2]David B. Hertz, "Management's Role in Planning Research," Chemical Engineering, Volume 54, Number 8 (August, 1947), p. 129.

[3]Philip R. Marvin, Top-Management and Research (Dayton, Ohio: Research Press, Inc., 1953), p. 31.

[4]Furnas, Op. cit., p. 60.

their brains.[5] Four principles for the efficient management of a research laboratory have been set forth as follows:

1. Systematic use of experience, to develop a local science.

2. Scientific selection of research men.

3. Economic control of effort.

4. Promotion of personal efficiency, by education and development of research men and by inducing close, cordial cooperation between the management and the men.[6]

In the administration of a research laboratory, the director who believes in the smoothly operating techniques of scientific management is going to have a better chance to succeed.[7] The different and divergent motivations of people working in and associated with an industrial research laboratory require the utmost in leadership ability from its director. The proper balance and efficient utilization of men, money, and facilities in a constantly chang-

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[5]National Research Council, Profitable Practice in Industrial Research (New York and London: Harper and Brothers Publishers, 1932), p. 18.

[6]Edward R. Weidlein and William A. Hamor, Science in Action (New York and London: McGraw-Hill Book Company, Inc. 1931), p. 271.

[7]Edward R. Weidlein and William A. Hamor, Glances at Industrial Research (New York: Reinhold Publishing Corporation, 1936), p. 134.

ing situation demand the best in administrative ability.

II. THE MAN

The director of the Kodak Research Laboratory expressed the opinion that the success of the research laboratory depends on the men who run it and the willingness of management to utilize the results of their work.[8] In order to be successful in the laboratory and at the same time be effective on the management team, the man with the job of director has to have certain technical qualifications and personal attributes.

One of the qualifications required is leadership ability. This leadership must stem not only from technical knowledge and good business judgment, ability to recognize accomplishments and individual problems, but also from a devotion to the scientific method and a captivating enthusiasm which inspires others. These qualities will foster *esprit-de-corps* in the laboratory which is essential to success.[9]

Industrial research must be as sound economically as from a scientific and engineering standpoint. Many

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[8] National Research Council, *op. cit.*, pp. 80 f.

[9] Marvin, *op. cit.*, p. 37.

scientists are not interested in management work and many others are not qualified because they love science for science's sake and do not care whether there is any usefulness in the discovery.

The director, on the other hand, must never lose sight of the fact that the research is being done with corporate funds and must justify itself economically. To do this requires a sound sense of values and the ability to direct the main lines of research being carried on. When sidelines are discovered, he must help his assistants choose which are likely to yield profitable results and which should be discontinued.[10]

III. THE SALESMAN

In addition to being a qualified scientist, an able administrator firmly grounded in economics, and a well-informed industrial technologist, the research director must be a salesman. His job is not done when the new product has been invented, designed, and proved as a prototype. The new product has to be sold just as though it had originated outside the company.

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[10]National Research Council, op. cit., pp. 52 f.

The selling of an idea, even though a good one, is difficult. The top-management group are apt to be hostile, and naturally so. To the president and each division -- Sales, Engineering, and Production -- a new product or process means new problems. It means new demands on capital, problems of design for engineering, production griefs in the factory, and service problems in the field. To the sales division it means new problems of marketing and distribution. Most important, it can affect profits and corporate earning.[11]

If the director knows his field and his management, has the vision of a prophet, and the enthusiasm of a door-to-door peddler, plus the ability to sell, he will be successful. It is important that he be successful, because only in this way can the results of the laboratory's research programs be turned into the future's profits. It is not without reason that the research director has been called the Vice President in Charge of the Future.

IV. SUMMARY

The position of a research director is a most important one, requiring men of unusual training and ability.

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[11]F. Russell Bichowsky, Industrial Research (Brooklyn, New York: Chemical Publishing Company, 1942), p. 56.

As a member of top management, the director of research has direct responsibility for keeping them informed of important new developments and recommending a course of action as may be required.

The director must be an administrator, an economist, and a practical businessman as well as a scientist. In handling his daily associates he must use the utmost in tact and understanding. He must be able to move comfortably in both the realms of science and industry.

The director of a research laboratory must have outstanding qualities of leadership. Equal to and perhaps even more important than his direction in the laboratory is his leadership in policy formulation and in introducing new products and processes into the factory. Success in salesmanship at this level has a direct bearing on the competitive future and financial position of the corporation.

V. FUTURE

A thoughtful consideration of the responsibilities and qualifications required by an individual suited for successful administration of an industrial research organization will lead to the conclusion that men of this caliber are relatively few. With the increasing importance placed on research by industry and the founding of new laboratories, both within and without the industrial field, the market for highly qualified research managers is not apt to be glutted. The future should provide expanding career opportunities for young men temperamentally suited and properly trained who have a desire to help form the shape of things to come.

CHAPTER VIII

RESEARCH PERSONNEL

> The matter of an adequate supply of properly equipped and trained investigators and directors is absolutely vital to the growth of industrial research.[1]

I. IMPORTANCE OF THE RESEARCH WORKER

It was pointed out in Chapter IV that expenditures for the wages and salaries paid to the scientific and technical personnel employed by the laboratory are frequently the major item of cost. This fact becomes better understood with the realization that the product of a research laboratory is ideas. These ideas result only from the advanced thinking and inventions of the research personnel.

While all jobs require a certain amount of mental effort, the degree of effort necessary varies with the complexity and uniqueness of the task to be performed. In a research laboratory, many of the job classifications and duties are similar or identical to those in the other divisions of the company. For example, the work performed by the clerks, typists, machinists, maintenance men, produc-

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[1]Edward R. Weidlein and William A. Hamor, Science in Action (New York and London: McGraw-Hill Book Company, Inc., 1931), p. 266.

tion control clerks, and planners is much the same throughout all companies. These people accomplish the routine tasks supporting the basic effort of the laboratory, which is research.

This group of laboratory personnel are not to be included as part of the problem group with which this chapter is concerned. It is the scientist and engineer who make up the problem area of this discussion.

II. SELECTION AND PROCUREMENT

It is generally agreed by those engaged in the management of research organizations that the procurement and wise selection of personnel who will be connected with the scientific and technical phase is one of the most important functions in the operation of a successful laboratory. Much of the success of a productive laboratory can be attributed to the wise selection and proper direction of the research workers.[2]

Criteria for selection. The research scientist and technician has to possess a combination of both a formal educational background and certain intangible

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[2] C. C. Furnas (ed.), *Research in Industry* (New York: D. Van Nostrand Company, Inc., 1948), p. 216.

qualities. He ". . . should be a man with a specific area of curiosity, together with a facility in that area."[3]

Academic achievement in a specific scientific field is almost universally mandatory. A large part of the research effort is spent in theoretical analysis. Because of this, educational records play an important part in the selection process. A high scholastic record coupled with an academic degree is considered indicative of ability to think well and logically.

Personal achievement in a technical or scientific sense is another measurement of qualification. This achievement may have been shown in the applicant's having been awarded certain patents, in having had technical articles published, in teaching or academic research, or in successful design work in an engineering department.

The need for a sound engineering or scientific background is readily understood. This background is insufficient, however, without the necessary accompanying personal and psychological characteristics. One of the "musts" is an inquiring mind; another is imagination. To

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[3]Lawrence L. Bethel, Franklin S. Atwater, George H. E. Smith, Harvey A. Stackman, Jr., Essentials of Industrial Management (New York: McGraw-Hill Book Company, 1954), p. 70.

these must be added intellectual honesty and a singleness of purpose which is not sidetracked by an apparent lack of success.

Some scientists are dreamers. Men of this kind are useful and often necessary because they are not tied down by the prosaic and the commonplace. Their influence must be offset in the laboratory, however, by other members of the staff who are of a more practical nature and who can provide a stabilizing effect.[4]

The ability to get along well with people is an asset in all social situations. Many scientists who are most effective in the laboratory, however, are far from gregarious and many are strongly introverted. Because many research assignments are individual, this in itself is not a handicap, provided there is proper supervision and understanding.

The task of measuring intangible qualities is always difficult. This same difficulty occurs in the attempt to properly select personnel for research assignments. While difficult, it is possible to become aware of the presence of these intangible qualities in the ap-

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[4]Furnas, op. cit., p. 239.

plicants through interview and test, and a careful analysis of their background and personal histories. The fact to be remembered is that these intangible qualities weigh heavily in determining those persons most suited to work in the field of research.

<u>Source of procurement</u>. There is no single source for the recruitment of research workers. With the great increase in the national research effort, the shortage of trained research scientists is already a limiting factor in the growth of research and development in the United States.[5] A recent survey of 200 industrial firms was conducted by the Bureau of Labor Statistics for the National Science Foundation.[6] Reports received from the great majority of these firms were to the effect that acute shortages of research and development personnel were handicapping their efforts.

One of the major areas for recruitment is among the graduates of the colleges, universities and scientific schools. The common practice of industry to send interviewing teams to the accredited academic centers is widely

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[5]"The New World of Research," <u>Business Week</u> (May 28, 1955), p. 122.

[6]"Washington Roundup," <u>Aviation Week</u> (August 1, 1955), p. 9.

known. Recently, one company offered to hire the whole graduating class of the Massachusetts Institute of Technology, about 900 students.[7]

The Federal Government is another recruiting area. Scientists working in the many agencies of the Department of Defense frequently are induced to enter private industry for varying reasons. Staff and faculty members of academic institutions are also lured from the educational to the industrial field when granted sufficient incentive.

Industry itself provides still another reservoir to be tapped for the research laboratory. To better qualify its own personnel for research and development work, industry is offering study grants and fellowships for graduate work in the Sciences as an inducement to employment and specialization.

III. JOB INCENTIVES

Salaries. Basic salary schedules for research assignments are set through job evaluation. This evaluation takes into consideration the amount of supervision required

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[7] "The Upcoming Crop of Engineers: They Want Something Different," Business Week (December 18, 1954), p. 152.

for the job, the amount of administrative work expected, scope of experience necessary, and educational achievement. The last factor oftentimes is the deciding factor because it frequently determines the minimum classification that will be offered.

The writer has observed that, generally speaking, the wage and salary schedules for research assignments are comparable from one industry to the next, with certain variations introduced by regional wage patterns. The size of the company will introduce another variable, with the smaller company usually paying a lower rate because of economic necessity.

The shortage of available technical people in a given scientific field will distort wage patterns throughout an industry, a region, or even the nation. It was pointed out in Chapter IV that due to a general shortage of engineering and scientific personnel, the whole salary range of such people has been steadily rising. Bidding by industry for specially trained personnel for research work has forced bulges in the structure in areas where the shortages have reached critical proportions.

Bonuses. It is not an unusual practice to distribute additional bonuses to research workers over and above any general bonus plan for the whole organization. These bonuses are generally of two types, one a specific award, the other a discretionary bonus.

The specific award is made to a few individuals or to a small group whose efforts have resulted in an invention, some product, a process improvement, or some unusually ingenious idea which has resulted in substantial saving or profit to the company. This is in the nature of a special award for outstanding achievement and bears no close relationship to the over-all profit of the enterprise.

The discretionary bonus is more widely distributed and is directly proportionate to profit. In this case, a certain sum is set aside by management and apportioned to those employees who have been most loyal and conscientious in their duties and who have contributed most in a general way to the company's success.

The basic idea of bonuses for research work is sound. Administration of such plans, however, has certain difficulties. One of the most difficult problems is the determination of those eligible for the bonus. The persons excluded are apt to be dissatisfied and feel they have been unjustly treated. Because much of the success in research is the result of the team effort, and because the discretionary bonus is granted more frequently and to more of the people involved in the laboratory, it is probably the better of the two bonus plans except in very special circumstances.[8]

Intangible incentives. It was pointed out earlier that the backgrounds, interests, and professional nature of research scientists and technicians set them apart from the rest of the organization. As a result, they respond to more intangible incentives once the basic financial problem has been solved.

One of these intangible incentives results from proper job assignment. A highly qualified researcher is usually a specialist and, perhaps, even an authority in a certain field of knowledge. It is of great importance to him as an individual, as well as professionally, to be able to continually advance in his chosen field and to keep abreast of the latest developments. Wrong assignments make it difficult or impossible for him to do this.

Another incentive to accept a specific job or assignment is the opportunity to pursue advanced study. This may be accomplished by the company's allowing him to work toward advanced degrees at company expense or on

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[8]Furnas, op. cit., pp. 272 f.

company time. The company can further this by encouraging his attendance at technical seminars held by professional, educational, or industrial organizations in his field.

Other prime incentives to the research worker are professional or public recognition through publication of achievements. The company can allow the scientist time to write for technical journals or give his name to products or processes for which he is responsible. Another incentive is provided by the company's filing for and issuing patents in the name of the discoverer, keeping, of course, a royalty-free license thereto.[9]

Other intangible incentives, such as assigned parking place, freedom of movement in and out of the plant, flexible hours of work, and working conditions physically conducive to uninterrupted thought, are of unusual importance because they reflect the professional status of the individual.

IV. SUMMARY

The research worker is the most important and the

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[9] Bethel, Atwater, Smith, and Stackman, Jr., op. cit. p. 70.

most expensive factor in a research laboratory. The most elaborate plant and advanced computer will not accomplish any research project without the scientist and trained technician. The laboratory's product is ideas.

Because of his important place in the laboratory, the proper selection of the research worker is equally important. Academic and personal achievement rank high in the selection process. This achievement can be weighed through an analysis of the individual's formal education and professional achievement. Certain intangible qualities, such as imagination, initiative, curiosity, and intellectual honesty, weigh heavily in suiting an individual for research work.

All likely sources must be surveyed for the recruitment of possible research engineers. Not only the graduating classes of educational and scientific schools must be combed for recruits, but government agencies, faculty members and industry itself must be considered.

Basic wage and salary schedules for common research assignments are fairly standard but are subject to regional variations and inflation in cases of critical shortages. Incentive bonuses are often added to basic pay scales. These can either be specifically granted to individuals as special awards or be in the form of discretionary bonuses which are based on company profits and distributed to a broader group.

Intangible incentives play an important part because the research worker is a well educated man. Because of the professional status connected with the job, factors affecting prestige carry unusual weight. Proper job assignment and opportunity for technical advancement through various channels are necessary parts of the employment agreement.

V. FUTURE

With the forecast rate of growth of both industrial and government research programs, the present shortage of adequately trained persons will grow more acute. The rising cost for such personnel is only one of the critical problems faced by the research director and his management. The inability to do the required job because of a lack of trained personnel is perhaps even more critical. Every technical and trade journal points up the ever-increasing rate at which science and technology are advancing toward an era of scientific innovation which will require the services of scientists and engineers for work which may be even more important than research and development.

The solution to this problem certainly does not lie in more fanciful recruitment programs, but rather in doing something about the source of the problem. One point of attack is at the educational level. Inquiry has shown that the inspiration toward scientific inquiry starts in the grade school and is fanned into flame during high school. If discouraged there, a potential scientist is lost by college time. Concrete steps must be taken in the formative years to assure that the budding scientist will continue to make science or engineering his life's work.[10]

The other point of attack is in industry itself. Here, the strongest of efforts will have to be made to do more research with fewer people. Possible approaches to this problem lie in freeing the scientist from routine work so that he can spend more time in creative endeavors and in using the research worker in assignments calling forth his maximum talent. Shifting assignments can often rekindle a researcher who has gone stale through too much specialization.

Too little is known about the processes of creative thinking, but one of the joint laboratory and management research projects will continue to be increasing the efficiency and output of the creative thinker.

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[10] "The New World of Research," Business Week (May 28, 1955), p. 126.

CHAPTER IX

GOVERNMENT RESEARCH IN INDUSTRY

> The Federal Government through 29 different agencies conducts programs of research and development. On the basis of the budget proposals for appropriations for the fiscal year of 1956, the total expenditures of the Government for that year will be about $2,400,000,000, of which about $2,050,000,000 is in the Department of Defense and $350,000,000 by the civilian agencies.[1]

I. GROWTH OF GOVERNMENT RESEARCH AND DEVELOPMENT

Between 1941 and 1952, research expenditures by the Federal Government have surpassed those of private industry. While industry provided 57 per cent of the total research expenditure and the Government only 41 per cent in 1941, the Government contributed 60 per cent and industry but 38 per cent in 1952.[2] This constituted an almost complete reversal in their relative positions in twelve years.

In this same twelve-year period, the number of re-

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[1]United States Congress, Commission on Organization of the Executive Branch of the Government, Research and Development in the Government, 83rd Congress, May, 1955, p. xi.

[2]United States Department of Defense, The Growth of Scientific Research and Development. Washington, D. C. Resources Division, Office of the Secretary of Defense (July 27, 1953), p. 10.

search scientists and engineers employed by the Government increased from 17,000 to 33,000. Those employed by private industry, however, increased from 62,000 to 118,000 in the same period of time.[3]

One of the reasons for this large increase of scientists associated with research in industry was the shifting by the Government of its research assignments to private industry. Industry, while furnishing 38 per cent of all research funds, actually performed 68 per cent of the work.[4] Because of the magnitude and importance of this work, a consideration of problems associated with the performance by industry of research projects for the Government is a matter of general management interest.

II. SOURCES AND METHODS OF PROCUREMENT

Sources. It was noted earlier in this chapter that the Department of Defense administers the great bulk of the Government's research dollars. Each of the Military Departments operates its own research and development program. Under Presidential Reorganization Plan No. 6 of 1953, two Assistant Secretaries for Defense and an Assist-

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[3] Ibid., p. 12.

[4] Ibid., p. 3.

ant for Atomic Energy were created to coordinate the Government's research effort.[5]

Each of the services (Army, Air Force, Navy, and AEC) have various agencies which distribute bid proposals and negotiate contracts for research projects with industry. In the Air Force, the major sources are the Air Materiel Command and Wright Air Development Center in Dayton, Ohio, and the Air Research and Development Center in Baltimore, Maryland.

Major Navy procurement sources are the Bureau of Aeronautics and Naval Ordnance Laboratory in Washington, D. C., the Bureau of Ships, also in Washington, and the Naval Ordnance Test Station at Inyokern, China Lake, California.

For the Army, major ordnance research and development programs are placed by Picatinney Arsenal in New Jersey, Redstone Arsenal in Alabama, the Detroit Tank Arsenal and the nine Ordnance Districts in the United States. In addition, the other Army corps, such as the Corps of Engineers at Fort Belvoir, Virginia, award special research contracts.

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[5]United States Congress, op. cit., p. 5.

The Atomic Energy Commission acts directly and also through such agencies as the Sandia Corporation and the White Sands Proving Ground in New Mexico, the UCLA Medical Center in Los Angeles, and others.

Type of research projects. The Government's projects in research run the full gamut from the realm of abstract science to complete weapons systems ready for field use in combat. In the civilian agencies, the programs range from crop and animal research, conservation, geology and paleontology, to medical research and meteorology.

Methods of procurement.[6] In placing contracts with industry for research and development, the Government agencies follow two basic methods: formal advertising and negotiation. When formal advertising is used, invitations for bids are conspicuously posted at the procurement offices and mailed to a mailing list of interested bidders. This method is used when the award is determined principally on price, provided the low bidder is competent to perform. It is unusual, however, when research contracts are procured in this manner because of security aspects

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[6] Information for this and the following section has been taken from Armed Services Regulation, Sections I, II, III, VII, and XVI. 1955 Edition, Department of Defense, Washington, 25, D. C.

and the degree of specialization required.

The method of contract placement most generally used by the services for research contracts is negotiation. This method involves the careful selection by the procuring agency of a limited number of bidders who are felt to be especially well qualified for the specific project. Each bidder is requested to outline in considerable detail his scientific approach to the problem, state his special qualifications in respect to trained scientists and available facilities, cite his past experience in handling related projects, and give a detailed cost breakdown of his quoted price.

When all the proposals have been received by the procuring agency, a comparative analysis will be made. The contractor's engineering approach, current capability, past performance, and proposed costs will be weighed. From an analysis of all bids, one or two companies will be selected, after which negotiations establishing the price and contract terms will be held between the Government and the contractor. These negotiations usually result in the awarding of a contract to one or possibly two successful bidders. The Government reserves the right to reject all bids and request new ones if not completely satisfied.

Type of contract. Because of the number of intangible elements attending any research program, Government agencies negotiate a "cost-type contract" with successful bidders. The form most generally used is a CPFF (Cost Plus Fixed Fee) contract.

The distinguishing feature of such a contract lies in its provision for reimbursing the contractor for "allowable" costs incurred in the performance of the contract, plus a fixed fee or profit. This fee is established prior to the award of contract during the negotiation period, and a maximum allowable cost is established as the basis for the fee payment. Excess costs incurred by the contractor are not subject to reimbursement by the Government without the negotiation of a supplemental agreement by the contractor and the Government.

While it is not the intent of this section to attempt a full treatment of the law and theory behind this method of contracting, an enumeration of certain standard provisions of these contracts is necessary in order to understand their effect on an industrial research organization. The provisions noted are mandatory for CPFF contracts.

As to the method of reimbursement for actual incurred cost, the contractor is permitted to submit invoices for payment on a monthly basis, or more frequently if so authorized. These costs must be a matter of record and are subject to audit by a Government agency where items questionable in the eyes of that agency are disallowed or suspended pending clarification by the contractor and specific approval by the contracting officer who acts as the agent of the procuring agency.

Because the Government reimburses the contractor for allowable incurred costs, it reserves the right to approve certain of the expense before the expense is incurred. For example, wages and salaries, whether direct or indirect, if paid in part by the contract must be reviewed and approved. The contractor's accounting method, as well as the individual items of indirect expense, is subject to review and approval. Any travel necessary in the performance of the contract must have prior approval before the cost is allowable. Sub-contracts in excess of five per cent of the contract amount, or $25,000, must be approved by the contracting officer in writing before being placed by the contractor.

The Government withholds up to $5,000 upon completion of the contract, pending a disclosure by the contractor of any new inventions developed in the performance of the research project. The Government reserves an exclusive, royalty-free license to use these items. It also withholds 10 per cent of the total contract amount, pending a release of the Government by the contractor of any future claim.

The contractor must afford free access to accredited representatives of the Government who will review his compliance with security regulations, his performance under the contract, his quality control, and his books. All records of the contractor concerned with the contract must be kept for seven years after the contract is completed or terminated.

III. SPECIAL PROBLEMS FOR INDUSTRY

Effect on profit. Government research projects awarded to industry are not, usually, a profitable venture within themselves. In fact, it is not infrequent for a contractor to complete a contract with no net profit, or even to suffer a loss. There are several reasons why this is true.

One of the basic causes is the amount of fixed fee allowed. While the procurement regulations make provision for a maximum fee of 13 per cent of estimated cost, the great bulk of the research contracts are negotiated for a fee of seven per cent or less.

Another reason for small or no profit, one closely related to the fee problem, is the fact that all costs incurred by the contractor are not reimburseable as allowance costs by the Government. Examples of such non-reimburseable costs are: entertainment, interest, certain profit-sharing plans, product advertising, certain depreciation expenses, insurance (except Workman's Compensation), selling expenses, and many others. Because these costs are normally incurred in a business enterprise, they become part of the cost of sales and effectively reduce the seven per cent fee to four per cent or less before taxes, and a net of less than three per cent after taxes.

Effect on organization. Because the procuring agencies have formalized and made mandatory procedures, the contractor must of necessity conform and establish special procedures for materials handling, reporting, quality control, purchasing, accounting, and contract administration, with special Government forms and methods in every department. These forms and procedures may be very different from the industry's normal way of doing business.

Because of the special handling required, the contractor is forced to duplicate and separate his military and commercial business. The volume of his Government work will determine whether a company goes to separate plants, separate departments, or separate sections within departments in order to solve the problem of handling two systems. The problems of the contractor are increased by each new agency of the Government dealt with because each has variations of operation within a general framework.

Benefits derived. In spite of the problems and difficulties encountered in doing business with the Government, and ignoring for a moment the part industry must play in the nation's defense, an industrial organization does benefit by doing research for the Government.

Many of the research programs progress from research through development to full-scale production. Production contracts are usually let on a fixed price or profit-sharing basis and offer good profit potentials to the businessman. Competitively, the company performing the research and development should have an edge when the production item comes up for bid.

The sponsoring by the Government of advanced research programs in the fields of electronics, aviation, communications, packaging and preservation, medicine, and many others, has enabled private industry to accomplish research programs which in many instances it could not have sponsored out of its own funds. This research has resulted in new inventions and new products for civilian consumption, accelerated improvements in the standard of living, and resulted in increases in the Gross National Product.

A third benefit from participating in research for the Government results from the ability of the company to maintain specialized personnel on a full-time basis that it might not be able to afford otherwise. Many times special facilities for research can be financed by participation in Government programs. Sometimes these facilities are paid for entirely by the Government. At other times an approved program of accelerated amortization of depreciation results in sufficient tax benefits to enable the contractor to finance his own program.

IV. SUMMARY

Since 1941, the Government has financed and sponsored an ever-increasing amount of the national research effort. Industry, however, performs the bulk of the work and employs over two-thirds of the scientists and technicians actively engaged in research work.

Over 85 per cent of the research money made available by the Government will be handled by the Department of Defense in 1956. Private industry will be asked to perform at least half of this work under contract to the Army, Navy, Air Force and Atomic Energy Commission.

Through the media of formal advertising and negotiation, industry will accept contracts to accomplish specific projects ranging from the most abstract basic research to more mundane problems of soil conservation and animal husbandry. Acceptance of these research contracts, frequently ensnares the contractor in red tape, audits and endless negotiations and gives him a relatively small net profit.

However, as a result of his efforts in the past, new commercial products and processes were developed and profitable results were obtained from the resulting production of both military end items and allied commercial products. Participation in the Government's research programs has enabled private industry to afford better facilities and more specialized personnel than it probably could have financed through its own facilities.

V. FUTURE

There is no indication that the Government will not continue its research effort; in fact, the opposite is true. The policy of the present administration in respect to fostering private enterprise seems to insure that private industry will continue to do the major part of the work.

There is a trend, officially established but not widely publicized, which will progressively diminish the amount of Government-furnished facilities. Present planning within the Department of Defense calls for the placement of new contracts with those companies who already have the required facilities available, or who will furnish them at their own expense.

This policy, if increasingly pursued, may result in a growing disinterest on the part of industry to participate in Government projects, particularly in view of already low profit margins on Government research contracts. Continual pressure on the Government for a more realistic approach to and realization of industry's problems -- red tape, unilateral contract terms, lack of long-range planning, and small profits -- seems to be bearing some fruit. However, the marginal gains in these areas could well be totally offset by an unrealistic approach to capital expenditures for special facilities.

CHAPTER X

SUMMARY, RECOMMENDATION AND CONCLUSION

The history, growth, present importance, and predictable future of industrial research and development in the United States have been reviewed in the preceding chapters. Major problem areas in the management of research and development within an industrial organization have been examined. An attempt was made to define those problem areas for both corporate management and for those directly responsible for the research group itself. The mutual but separate responsibilities of each management group have been defined.

No attempt has been made to outline a set of pat solutions to the problems of research management. However, certain techniques and practices which appear to have had general acceptance were outlined. In other cases, opinions of well-qualified people in the field were cited.

I. SUMMARY

Today, the management of research and development operations is far from being an exact science. However, it is rapidly gaining recognition as a separate field in industry which offers career opportunities of professional status.

The place of Science in industry has been established and research is now passing through the growing stage of being a popular fad. This, however, is only a phase in its rapid growth. Its importance to industry and its problems for management have been the subject of this paper.

Since 1886 industrial research has grown from the one laboratory of Arthur D. Little to over 3,000 laboratories today, with expenditures of over $2 billion annually. One-fourth of our technical and scientific personnel in the United States are actively engaged in this research effort. Unfortunately, comparatively few basic texts have been written which adequately treat the subject of research management. The great bulk of useful information in this field is to be found only in technical journals and publications of non-profit organizations. In this form, it is not readily available or known to management personnel.

Industrial research has been found profitable for both the large and the small company. Expenditures for research have been effective in increasing profits, in solving the problem of survival in a competitive market, and in helping management in long-range planning. The very small company may find it outside of its financial capability to finance its own laboratory. For those who find themselves in that position, outside assistance is available.

The costs involved in supporting an industrial laboratory are significant. For this reason, some feasible method of financing this expenditure is necessary. At the present time, the method which provides for the liquidation of research costs annually has wider acceptance than a system in which those costs are capitalized. Returns on research investments are generally slow. Because of this slow return, funding must be provided on a long-term basis.

The place of the research function within the corporate structure is most important to its success. The research director should be on the same organizational level as the head of the major operating divisions. The function and its director should be directly responsible to top management. This close relation of the research effort with top management is most understandable in view of the effect that research has on the corporate future.

Planning and scheduling have an important effect on successful research management. Planning and scheduling research, however, is difficult because of the large number of intangibles involved. Proper planning at both the corporate and laboratory levels is necessary for proper control and the attainment of research objectives. Proper budgetary controls and timely reports are important control tools.

The research director is a key man for both the corporation and the laboratory. As a member of the top-management team he is expected to serve as a consultant in matters of policy regarding new products and future planning. In the laboratory, his qualities of leadership and administrative ability are vital to smooth operation. The special background required, the training and experience necessary, and the unusual responsibilities of the assignment have opened up a new career field of opportunity in this management area.

The problems associated with the procurement, selection, training, and satisfaction of the scientist and technician working in the laboratory are different and generally more difficult than those encountered in other personnel areas. The research worker is a scarce commodity on today's labor mart. He has different motivations and therefore responds to a different set of incentives. Because of the professional status associated with research work, personnel factors affecting prestige must be given special emphasis. The proper handling of these problems is mandatory because the researcher is the most important factor in the laboratory.

The Federal Government has turned to industry for most of its research work. The acceptance of the research effort by industry has resulted in many problems for industry and some benefits. On the plus side, by participating in Government research projects, industry has gained a competitive advantage on production, has been able to afford better research facilities, and to justify maintaining specialized personnel on its payroll. On the other hand, as a result of research contracts, industry has been ensnared in red tape with little or no net profit from the effort. Procurement policy within the Government can be greatly improved to the benefit of both industry and the procuring agency.

A review of forecasts of the probable research effort in the future showed that its unprecedented past growth will likely continue. With the increasing demands on research by both industry and Government, the present problems associated with the scarcity of manpower and rising costs will be multiplied. Management techniques which are scarcely adequate to cope with today's research problems must make rapid improvements to properly handle tomorrow's problems.

II. RECOMMENDATION

Industry for many years has considered the university as part of the team in the industrial community. There is a continual and active interchange of information between the two. In the field of industrial training for both supervision and the shop, it is common practice for industry to sponsor special courses at their own expense with instructors furnished from the university.

The universities, on the other hand, maintain active liaison with industry through business school associations, field trips, research projects, and the use of industrial personnel on their teaching staffs. A constant effort is made by them to improve the preparation of its graduates for their place in society after college life.

Both industry and the university, however, have been slow to recognize the need for additional educational work in the management of industrial research. The only program of this type of which the writer is aware is given by the Harvard Business School for selected Air Force officers who are actively engaged in the supervision of research and development contracts. It is the opinion of the writer that a course generally conforming to the one outlined in the following Appendix would be most beneficial.

<u>Recommended program</u>. The recommended course of instruction should be made available to four groups of students. The course should first be made available in the evening or in extension courses and directed toward the top and middle management personnel of local industries. These people have the most immediate need for help. If given proper advance notice, an evening class would be assured full attendance.

The second group of students should be made up of those who are majoring in Science and Engineering. For them the course should be mandatory. They are the ones who most probably will be associated in some way with the national research effort. These are the students who, because of their specialization, go into industry with little or no understanding of the full value of their work as viewed through the eyes of their management. A course of this kind might well increase the now small number of science and engineering graduates who develop into sound administrators.

The third group of students who should have this course as part of their curriculum is the group majoring in the field of Business. For these the course should be offered in the sophomore year so that all Business School students might have a fuller understanding of the part

Science plays in modern industry.

The fourth group should be those who are doing graduate work in the Management field. This group has an immediate need for a fuller understanding of the industrial research management problem. They can be expected to have a more active association with industrial research in the next ten years and therefore should be made aware of the importance of research in the industrial future.

<u>Course of study</u>. The recommended course of study, a detailed outline of which is included in the Appendix, would be of one semester and would offer three units of credit. This same course might be expanded to a full year of six units when the available management knowledge in this field has been developed and stabilized to a greater extent than it is today.

The first ten weeks of the course would be concerned solely with the importance, objectives, and the problems relating to the management and control of a research group. The second ten-week period would be concerned basically with the research worker and associated personnel problems.

The correlative reading assignments appearing in the outline of the proposed course were not taken consecutively from Research in Industry.[1] It was felt that a slightly different sequence would provide a more logical teaching approach. The chapter assignments noted for each session are those which would be assigned for class preparation at the previous meeting to serve as background to the lecture.

Text. The suggested text for the course is Research in Industry, edited by C. C. Furnas, the Director of the Cornell Aeronautical Laboratory. The book was written by representatives of various member companies of Industrial Research Institute, Inc. Such companies as American Viscose, Standard Oil of Indiana, RCA, B. F. Goodrich and Proctor and Gamble are members of this institute. Each chapter of this book was an individual contribution by management personnel of the member companies having an active association with industrial research.

This book is not a recipe book for management. The contributors are not in full agreement with each other in many matters. However, the book does contain more useful information which meets professional standards than any other work reviewed for this paper.

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[1] C. C. Furnas (ed.), Research in Industry (New York: D. Van Nostrand Company, Inc., 1948).

III. CONCLUSION

Industrial research and development has become an important and integral part of American industry. It appears destined to play an ever-increasing part in making possible the growth of our industrial technology. As a result of the rapid growth and important of the research effort, management is being confronted with more and more problems in the proper administration of research within the business, both large and small.

It must be clear from the discussion in the preceding chapters that management techniques specifically adapted to research and development are at present only in the formative stage. It must also be clear that the techniques used in other management areas are not adequate for the special problems encountered in the administration of the corporate research effort.

Top and middle management in industry have an urgent need for professional instruction in the management of research. It is equally important that those being trained in science, engineering, and business also have the benefit of this special training. The universities and colleges should take steps to make this instruction available to those in need. It is hoped that this paper will aid in bringing this help to others who need to know the "how" and "why" of industrial research management.

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APPENDIX

OUTLINE OF RECOMMENDED COURSE

Subject: Industrial Research Management

Text: Research in Industry by C. C. Furnas

First Meeting

Subject: The Growth and Importance of Industrial Research in the United States

Reading Assignment: None

Lecture Outline:

History

The beginning

The growth

Need for industrial research and development

Value of industrial research

Brief outline of course

Second Meeting

Subject: What is Industrial Research and What is Its Place?

Reading Assignment:

Chapter I, "The Philosophy and Objectives of Research in Industry"

Chapter III, "Development"

Lecture Outline:

What is research?

What is industrial research and development?

Definitions of terms

Examples of different programs

Objectives of research

In the large company

In the small company

Alternatives to company-sponsored research

Third Meeting

Subject: The Place of Research in the Corporate Structure

Reading Assignment:

Chapter II, "The Research Laboratory as an Operating Department of the Company"

Chapter V, "Organization Charts in Theory and Practice"

Chapter XVI, "The Location, Design, and Construction of a Modern Research Laboratory"

Lecture Outline:

Corporate structure

Organization plans

Need for independent research

Departmental structure

Director's staff

Divisional classification

The project system

The new approaches

Fourth Meeting

Subject: The Research Director -- His Background and His Job

Reading Assignment:

Chapter IV, "The Research Director's Job"

Chapter XIX, "Translating Research into New Products and Factory Procedures"

Lecture Outline:

Job description

Adviser to top management

Administrator

Salesman

Background and training

Education

Experience

Outside interests

Personality traits

Future as a Profession

Fifth Meeting

Subject: Research Planning and Scheduling

Reading Assignment:

Chapter VI, "The Research Program"

Chapter VII, "Selecting Projects for Research"

Lecture Outline:

Responsibility for planning and scheduling

Top-management responsibility

Laboratory management responsibility

Importance of planning

Levels of planning and scheduling

Corporate plan and master schedule

Project plan and schedule

Selecting the right project

Long-range or short-range

Product improvement or development

Capital investment and return

<u>Sixth Meeting</u>

Subject: The Financial Aspects of Research and Development

Reading Assignment:

Chapter VIII, "The Research Budget"

Chapter IX, "Research Reports"

Lecture Outline

Cost of research and development

Total cost

Breakdown of costs

Capital investment

Financing research

Determining size of investment

Methods of financing

Return on investment

Forecast cost of research in future

Rising cost of labor and equipment

A management problem

Seventh Meeting

Subject: Control Techniques

Reading Assignment:

Chapter XXI, "Evaluating the Results of Research"

Chapter XX, "By-Products of Research"

Lecture Outline:

Budgetary controls

Value and limitations

Types of budgets

Record keeping

Reports

Uses of reports

Types of reports

Report writing

Project status determination

Analytical methods

Limitations on accuracy

Eighth Meeting

Subject: Service Functions and Support Facilities

Reading Assignment:

Chapter XVII, "The Tools of Research: Instruments and Supplies"

Chapter XVIII, "The Research Man's Helpers: Service Personnel and Facilities"

Lecture Outline:

The overhead functions

Organizational responsibility

Cost of operation

Ratio of direct to indirect employees

Support equipment

Initial cost

Replacement cost

Maintenance expense

Methods of amortizing

(Last half hour devoted to question and answer period before mid-term examination)

Ninth Meeting

Mid-term Examination

Tenth Meeting

Subject: The Research Scientist -- Background and Temperament

Reading Assignment:

Chapter X, "Characteristics of the Research Man and the Research Atmosphere"

Chapter XI, "Qualifications, Training, Aptitudes, and Attitudes of Industrial Personnel"

Lecture Outline:

The research assignment

Importance of the individual

Importance of environment

Job responsibilities

The research worker

Background and training

Personality traits

Eleventh Meeting

Subject: Personnel Policies

Reading Assignment:

Chapter XIV, "Personnel Policies and Personality Problems"

Chapter XV, "Professional Growth of the Research Man"

Lecture Outline:

Special policies for laboratory

Hours of work

Working conditions

Periodic reviews

Supervision

On-the-job training

Opportunity for study

Scientific conventions

University work

Technical papers

<u>Twelfth Meeting</u>

Subject: The manpower problem in research

Reading assignment:

Chapter XII, "Procurement and Selection of Research Personnel"

Lecture Outline:

Selection and procurement

Criteria for selection

Selection testing

Sources of scientific personnel

The growing shortage

Background of the problem

Better utilization of manpower

The part of the educational system

The Russian approach and its weakness

Thirteenth Meeting

Subject: Job Incentives

Reading Assignment:

Chapter XIII, "Salary Policy"

Lecture Outline:

Tangible Incentives

Wage payment plans

Job classification and rating

Area and industry comparisons

Special bonus plans

Intangible Incentives

Prestige factors

Publicity

Use of patents

Fourteenth Meeting

Subject: The Importance of Patents

Reading Assignment:

Chapter XXII, "The Research Director's Responsibility in Determining the Company's Patent Policy"

Chapter XXIII, "Pattern of Collaboration Between the Research Department and the Patent Department"

Chapter XXIV, "Licenses, Royalties and Patent Pools"

Lecture Outline:

Patents and patent policy

Employees' patent agreement

Procedure for obtaining a patent

Cost of obtaining a patent

Government's patent policy

Patent clauses

Industry's objections

Fifteenth Meeting

Subject: Government Research in Industry

Reading Assignment:

Chapter XXV, "Relations with the Public and the Government"

Chapter XXVI, "Relations with the Educational System"

Chapter XXVII, "Relations with other Firms and Industry"

Lecture Outline:

Government research and development

Growth

Types of projects

Methods of procurement

Sources and types of contracts

Special problems for industry

Effect on profit

Effect on organization

Effect on planning

Sixteenth Meeting

Subject: The Future of Research Management

Reading Assignment:

Chapter XXVII, "Research in American and Europe"

Chapter XXIX, "Goals and Problems for the Future"

Lecture Outline:

The growing dependency of Industry on Science

Nuclear power

Automation

Material substitution

Transportation

The competition for the scientist

By industry

By the government

By the schools

The management problem

Cost and finance

Availability of men and facilities

Effective utilization

Seventeenth Meeting

Subject: Review of Course for Final Examination

Reading Assignment: None

Lecture Outline:

(Entire period devoted to discussion and review.)

Eighteenth Meeting

Final Examination