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OBSOLESCENCE AND UPDATING OF ENGINEERS' AND SCIENTISTS' SKILLS. FINAL REVISED REPORT.

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DESCRIPTORS- *IMPROVEMENT, RETRAINING, VOCATIONAL ADJUSTMENT, *ENGINEERS, *SCIENTISTS, *JOB SKILLS, PROFESSIONAL TRAINING, RESEARCH NEEDS, *TECHNOLOGICAL ADVANCEMENT,

THE NATURE AND APPROXIMATE DIMENSIONS OF THE TECHNICAL SKILL OBSOLESCENCE PROBLEM WERE STUDIED AS A RESULT OF THE WIDELY ALLEGED OCCURRENCE IN RECENT YEARS OF DETERIORATION OF SKILLS AMONG PRACTICING ENGINEERS AND APPLIED SCIENTISTS RESULTING FROM THE MASSIVE EMERGENCE OF NEW SCIENTIFIC AND TECHNOLOGICAL KNOWLEDGE DURING THE PAST QUARTER CENTURY. INTERVIEWS WERE CONDUCTED WITH TECHNICAL MANAGERS, DIRECTORS OF PROFESSIONAL EMPLOYEE DEVELOPMENT, AND OTHER KNOWLEDGEABLE OFFICIALS IN 39 TECHNOLOGY-ORIENTED FIRMS AND IN TECHNICAL COLLEGES AND UNIVERSITIES, PROFESSIONAL TECHNICAL SOCIETIES, AND GOVERNMENTAL UNITS CONCERNED WITH THE OBSOLESCENCE PROBLEM. DATA INDICATED FOUR COMPONENT SUBAREAS OF THE PROBLEM FOR WHICH EFFECTIVE REMEDIAL MEASURES ARE DIFFICULT TO FIND -- (1) MOTIVATING PROFESSIONAL RESEARCH-DEVELOPMENT-DESIGN PERSONNEL WHOSE SKILLS HAVE BECOME OUTDATED, (2) DETERMINING DISPOSITION OF THE SKILL OF OBSOLESCENT PERSONNEL WHEN REDUCTIONS IN PROFESSIONAL TECHNICAL WORK FORCE ARE NECESSARY, (3) IDENTIFYING, DEVELOPING, AND UPDATING COMPETENT PROJECT LEADERS, SYSTEMS ENGINEERS, AND OTHER KEY PRACTICING PROFESSIONALS, AND (4) ASSESSING THE KIND AND DEGREE OF UPDATING NEEDED BY TECHNICAL MANAGERS AND PROVIDING MEANS AND INCENTIVES NECESSARY TO BRING ABOUT SUCH UPDATING. DATA SUGGESTED SIMILAR SIGNIFICANT DIFFICULTIES IN TECHNOLOGY-ORIENTED INDUSTRY AT LARGE, AND CONSEQUENTLY, A NEED FOR BROADER SCOPE RESEARCH INTO THESE PROBLEMS. (HC)

OBSOLESCENCE AND UPDATING OF ENGINEERS' AND SCIENTISTS' SKILLS

FINAL REVISED REPORT

Prepared for the Office of Manpower Policy, Evaluation and Research, United States Department of Labor, by the Columbia University Seminar on Technology and Social Change

Contract No. MDTA 15-64

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SYNOPSIS

This report presents the results of a study carried out by the Seminar on Technology and Social Change of Columbia University for the Office of Manpower Policy, Evaluation and Research of the U.S. Department of Labor, pursuant to Contract No. MDTA 15-64. The original project title was "Obsolescence of Scientific and Engineering Skills;" this has been amended in the Report title to "Obsolescence and Updating of Engineers' and Scientists' Skills." The study is principally concerned with the widely alleged occurrence in recent years of deterioration of skills among practicing engineers and applied scientists, resulting from the massive emergence of new scientific and technological knowledge during the past quarter century, and the permeation by this knowledge of applied research, development and design activity in industry. It was conceived, and has been conducted as a pilot project, aimed primarily at exploring the nature and approximate dimensions of the technical skill obsolescence-updating problem, and assessing the need for and feasibility of conducting broader and more thoroughgoing research in this and related problem areas.

Objectives of the Study

In carrying out the research for the study, our principal objectives have been (a) to identify the causes and characteristics of skill obsolescence among professional technical practitioners, (b) to identify the aspects of the problem -- and the corollary problem of updating the knowledge and skills of "obsolescent" professionals -- in which wider and deeper-probing investigation may be desirable; and (c) to develop approaches and techniques for conducting such investigations.

Procedure

The initial stage of the study was concerned with the "external" origins and causes of the current spate of technical skill obsolescence. We examined the character and rate of emergence of the salient discoveries and innovations in science and technology during and since World War II, in comparison with the corresponding developments in the pre-war period. The results of this survey, revealing a truly revolutionary outpouring of major innovations in recent decades, are summarized in Chapter II.

The main phase of the field research consisted of depth interviews in a selected list of 39 technology-oriented firms, with technical managers, directors of professional employee development, and other knowledgeable officials. Supplementing this investigation, we conducted a series of interviews in technical colleges and universities, professional technical societies and governmental units concerned with the obsolescence problem.

Summary of Major Findings

Despite the pervasive concern in management and educational circles over the technical skill-obsolescence phenomenon, the majority of the managers interviewed felt that the problem, in terms of the currently-existing situation in their respective firms, was of moderate seriousness -- at least with respect to the relative numbers of technical employees involved. The substantive information obtained during the course of the interviews tended to confirm this assessment, particularly with regard to professionals engaged in manufacturing, service, and other <u>non</u>-research-development-design activities. The substantive interview data indicated, however, that four component sub-areas of the over-all problem area, involving relatively small numbers of professional research-development-design personnel, entail serious difficulties for the subject managements, in terms of finding effective remedial measures. These sub-areas can be identified as follows:

(1) The problem of motivating those (largely mature-age) R-D-D professionals whose skills have become outdated, and who have not updated themselves, to make a serious effort to do so -- under the firm's continuing-education programs or in other ways.

(2) When reductions in the professional technical workforce become necessary, the problem of

determining the disposition (retaining, reassigning or terminating) of skill-obsolescent R-D-D personnel.

(3) The problem of identifying, developing and up-dating competent project leaders, systems engineers and other "key" practicing professionals, and motivating them to continue as practitioners in preference to moving into management positions.

(4) The problem of assessing the kind and degree of updating needed by technical managers, and providing the means and incentives necessary to bring about such updating.

The interviews also revealed the existence of two sub-areas of difficulty that cut across the several component sub-areas. These are:

(1) The problem of devising and applying dependable performance appraisal programs for professional technical employees.

(2) The problem of devising and conducting effective updating-education programs for all levels of professional technical personnel, including both practitioners and managers.

The Need for Further Research

In our considered opinion -- and despite the limited sample of firms studied -- the findings with regard to salient sub-areas of difficulty within the overall skill obsolescence-updating problem area strongly indicate that similar significant difficulties exist in technology-oriented industry at large, and that consequently there is a genuine need for broader-scope and deeper-probing research into these problems.

Any such research should embrace a considerably larger sample of firms, covering a number of additional technically-oriented industry categories and including a greater representation of firms in each category, particularly with regard to medium-size and smaller firms. In planning and conducting interviews, a special effort should be made to obtain the full cooperation of top managements -- probably through the good offices of the Federal Government agencies supporting the research -- in order to assure a diversity of knowledgeable and reliable information sources in each firm.

CHAPTER I

SCOPE AND OBJECTIVES OF THE STUDY

Original Statement of Objectives

In the original proposal submitted to the Office of Manpower, Automation and Training, setting forth the plan of this study, it was referred to as a "pilot study of scientific and engineering skills." The following is a condensation of the statement of objectives and procedure contained in the proposal.

The principal objectives were stated to be:

(1) To identify the characteristics and process of obsolescence of scientific and engineering skills in a selected sample of employing organizations, to identify the aspects of such obsolescence that need investigation, and to develop techniques for assessing the nature and dimensions of the problem area.

(2) To outline the staffing and operational problems which obsolescence of scientific and engineering skills poses for management in these employing organizations.

(3) To appraise and evaluate the educational programs conducted by certain of these employing organizations and certain academic institutions, aimed at equipping obsolescent scientists and engineers with new and

needed skills.

(4) To develop concepts, information and techniques of investigation which will be useful for private organizations and public agencies in dealing with problems involving obsolescence of scientific and engineering skills.

Information on obsolescence of scientific and engineering skills was to be sought from a total of approximately 40 industrial firms, government agencies, and other organizations employing professional technical personnel. The research was to be conducted through depth interviews, principally with research directors, engineering managers and other directly-involved executives in these organizations.

Definitions and Terminology

It will be noted that the terms "obsolescence" and "scientific and engineering skills" are used in the statement of objectives. In the course of conducting the research, however, it became evident that both of these terms involved ambiguities and limitations that were not apparent in the planning stage, and that inhibited a clear understanding of the nature and scope of the problem area we were dealing with. Hence in presenting this report it is necessary to clarify and round out the key terminology, and to reconsider the objectives in the light of these clarifications.

The term "scientific and engineering skills" connotes the kinds of talent, knowledge and experience required in scientific and engineering work; but only in an abstract sense. While the study is, of course, intimately concerned with these abstractions, it is also vitally concerned with the fact that individual scientists and engineers possess or lack such talent, knowledge and/or experience, and do so in varying degrees. In reporting the results of the study, therefore, we shall usually speak of "scientists' and engineers' skills" instead of "scientific and engineering skills," since the former term conveys the more specific meaning needed for purposes of the problem area being studied.

In the study proposal, also, we took as our definitions of scientists and engineers those used in the National Science Foundation's reports on science and engineering manpower. To be classified as scientists or engineers under these definitions, persons must be engaged in scientific or engineering work at a level "which requires a knowledge of physical, life, engineering or mathematical sciences equivalent to that acquired through completion of a four-year course with a major in (the respective) skills."*

However, while a four-year college course in the

*National Science Foundation, The Long-Range Demand for Scientific and Technical Personnel, NSF 61-65, 1961, page 61. The definition of scientists and engineers includes those engaged "in research-development, production, management, technical service, technical sales, and all other positions which usually require a scientific (or engineering) background." It excludes psychologists and social scientists.

particular discipline is usually a required condition for fruitful scientific and engineering achievement, it is by no means a sufficient condition. In most areas of technical work, some post-college experience is also necessary. Furthermore, in all types of scientific and engineering research and development work, and even in some non-R & D areas involving scientists' or engineers' skills, creative talent is equally essential. Again, as our study has forcefully brought out, many college-trained technical workers who obtained their basic education more than a dozen years ago are today unable to achieve usable results in their chosen field. Thus even the completion of a four-year college course in the particular discipline may not constitute a qualification for effective performance as a scientist or engineer.

In this pilot study of scientists' and engineers' skills, therefore, it has been necessary to take account of all three types of component factors -- educational, experiential and creative. Considerable emphasis has been placed on what we shall call the "obsolescence-updating" problem, which involves largely (though not entirely) the educational component of professional technical skill. The reasons for this emphasis are: (1) there was agreement among all-concerned in devising the original study plan that research in this problem area was urgently needed, and that consequently, it should be the major focus of attention; and (2) as the study progressed, it became increasingly evident that the areas of experience and creative talent -- and particularly the latter -- are far too ramified and complex to warrant extensive original research in the course of a pilot study of designedly short duration and restricted financial resources. However, some attention has of necessity been given to the experience factor, since experiential technical skills, as well as education-based skills, often become obsolescent or obsolete. Moreover, although creative technical talent is generally recognized as resulting from inborn traits and/or early environmental influences rather than education, it was felt that one aspect of creative talent, namely, the question of falling-off or deterioration of creativity with advancing age, closely resembles the obsolescence-of-education-based-skills problem, and hence warranted research attention.

The experience aspect is discussed in Chapter III, and is considered in relevant contexts in later chapters. The question of deterioration of creativity with age is also briefly dealt with in Chapter III, but since the interviews yielded little usable evidence on this question, the discussion is confined to the results of other recent studies which were specifically focused on the problem of age and creativity.

The term "obsolescence," as commonly used in discussions and writings on the problem area we are dealing with, also contains ambiguities -- of two kinds. In the first place, the term is not sufficiently broad to cover the phenomena which the problem area involves. We are basically concerned with skill <u>lacks</u> or <u>deficiencies</u> of professional technical workers, and with ways and means of correcting such deficiencies. There are at least three distinct types of such skill deficiencies: (a) those resulting from deterioration of creative talent; (b) those resulting from loss or deterioration of previously acquired knowledge that is still required in effective technical practice; and (c) those resulting from the establishment of <u>new</u> skill requirements, which are based on recent discoveries in science and technology, and which have superseded formerly required skills.

In much of the recent literature and discussion dealing with the subject area, the term "obsolescence" has been used loosely, to include all three types of skill deficiency. However, the term is obviously only properly applicable to the last-named type, since this is the only type that results from the supersession of "old" knowledge by "new" knowledge, and the failure of practicing scientists or engineers to acquire the skills involving the new knowledge. To avoid misleading ambiguity, the first and second types must be identified by the term "deterioration," or a close synonym thereof.

The second ambiguity involved in the term "obsolescence" is that as commonly understood it emphasizes the skills that have been superseded, whereas the crux of the problem which concerns us lies in the fact that professional technical practitioners lack the new and currently-required skills. We shall continue to use the terms "skill obsolescence," "obsolescent scientists" and "obsolescent engineers," but the reader should bear in mind that the practical problem we are primarily concerned with is not only the obsolescence of the old skills, but the failure of technical practitioners to acquire the new ones.

In most of the literature on the subject, the technical skill obsolescence-updating problem is said to affect "scientists and engineers," and the two terms are usually used in combination. In the course of carrying out the research for this study, however, it has become increasingly apparent that these two occupational designations -- either in combination or separately -- are not adequate to convey an unambiguous and productive understanding of the impact of scientific advance on professional technical skills.

The primary reason for this inadequacy is that the <u>degree</u> of impact on the individual technical practitioner depends more upon the functional area in which he is engaged than upon his particular technical specialty. The terms "scientist" and "engineer," especially when used in combination, tend to convey the impression that all persons having major or specialized training in one of the natural sciences are engaged in "scientific" work -- i.e., pure research or research-related endeavor, and that all persons having major training in one of the engineering disciplines are engaged in "engineering" work -- i.e., in applying the discoveries of science in the development, production, etc. of useful products. However, in nearly all of the firms in our sample, the technical activities consist entirely of engineering and related applied-science work; and even in the exceptional firms, pure or "exploratory" research is a very minor activity. Thus, while the great majority of these firms employ "science majors" (physicists, chemists, mathematicians, etc.) as well as "engineering majors," both types are engaged in essentially engineering activities. Moreover, most of the managers interviewed stated that the impact of the skill obsolescence problem has been essentially the same on both types and that, consequently, no useful purpose would be served by distinguishing between "engineers" and "scientists" in discussing the problem. Although their responses were usually phrased in terms of "engineers," they manifestly intended this term to include both engineering- and science-trained personnel. In this report we will adopt the same usage, and will employ the terms "engineers," "engineers and scientists," "technologists," and "technical professionals" interchangeably.

Methodology

Conduct of Field Research. The primary phase of the field research was an interview study conducted in 39 selected technology-oriented firms, and the secondary phase a similar series of interviews in technical colleges and universities, engineers' and scientists' professional societies, employment agencies and governmental units, again totaling 39 organizations. Twenty of the industrial organizations studied were actually divisions of the particular companies selected -- in most instances the division having the highest ratio of technical personnel to total workforce. For purposes of our study, however, these divisions were regarded as firms, since in nearly all cases the division managements possess a high degree of autonomy in the area of technical manpower.

In making the initial contact with top management in the selected firms, we requested interviews with the members of management having the closest familiarity with the firm's technical obsolescence-updating problems. As a result the interviews were arranged, in some instances, with top-level engineering or research-and-development managers; in others, with divisional or corporate managers of professional development. In a number of instances the interviewer met jointly with the engineering manager and the manager of professional development.

At the outset a list of topical questions, based on the study objectives set forth in the project proposal and on the results of preliminary research, was prepared for use as a guide in conducting the interviews. Subsequently it was found necessary to make several revisions in the guide, in the light of actual practices and experience brought out in the earlier interviews, which revealed conceptual and terminological ambiguities in the original statement. The revised interview guide is reproduced in Appendix A.

Selection of Organizations for Study In selecting the employing organizations to be studied, the following factors were considered:

(1) There is evidence that the impact of technical skill obsolescence is greatest in the technologically more progressive industries -- i.e., those employing proportionately large numbers of scientists and engineers. It was therefore decided to confine the selection to industry categories in which the ratio of professional technical personnel to total employment in 1960 was 4 percent or more.*

(2) Study of the literature on the subject indicated that many of the larger technologically-oriented firms have adopted educational programs providing opportunities for skill-obsolescent technical employees to acquire new and currently-required skills, but that such programs are relatively uncommon among medium-size and small firms. Accordingly,

*For most of the industry categories considered, the ratios were computed from the figures on employment-by-occupation in the 1960 Decennial Census of Population. For certain categories for which census employment-by-occupation figures are not available the ratios were estimated from specific company data, listed in Decision/Job Directory, 1964. The ratios in the industry categories from which the sample of firms was selected ranged from 4% (miscellaneous non-electrical machinery) to 30% (research laboratories). In addition, two firms in the primary nonferrous metals industry were included, in consideration of the major recent technical advances in that industry.

the selection included -- to the extent possible in view of the industry coverage -- medium-size and small as well as large firms.*

(3) Further, the preparatory research yielded considerable evidence that the impact of technical skill obsolescence in recent years has been especially great in firms engaged primarily in developing and producing military and space equipment. Since such firms are found principally in the aerospace and electrical-electronic equipment industries, a larger number of firms were selected from these than from the predominantly non-defense industries.

(4) Finally, the preliminary exploration indicated that scientists engaged in basic or "exploratory" research generally keep fully informed on significant advances in knowledge and technique in their disciplines, and that, consequently, in organizations engaged exclusively in such research (e.g., the Rockefeller and Sloan-Kettering institutes,

*The firms in the sample referred to as "small" range in size from 250 to approximately 2000 employees (total workforce); and those referred to as "medium-sized," from 2000 to approximately 10,000 employees; most of those referred to as "large," fall in the range 20,000-100,000 employees; with two firms employing somewhat fewer than the lower figure and two others sizeably more than 100,000.

the research laboratories of major universities, etc.) skill obsolescence is at most only a very minor problem. Accordingly, it was decided to omit such organizations from the survey sample, and instead to seek information concerning basic-research scientists from the industrial firms selected, several of which were known to have small units engaged in exploratory research. (One basic-research organization - an affiliate laboratory of the Atomic Energy Commission - was later included in the sample.)

In making the final selection of employing organizations for study it was necessary to depart somewhat from the original selection,* owing to difficulties in arranging appropriate interviews in certain firms. The distribution by industry category of the firms studied is shown in the following tabulation.

*See Report of Progress, Pilot Study of Obsolescence of Scientific and Engineering Skills, dated March 26, 1965, page 4.

Industry Category	Number of firms
Aerospace (airplanes, missiles and spacecraft; and engines and other parts)	10
Electronic equipment (including control and guidance equipment for airplanes, missiles and spacecraft)	13
Electrical machinery, equipment and supplies (including nuclear energy equipment)	4
Office, computing and control machines and equipment	2
Miscellaneous machinery, equipment and supllies (other than electrical and electronic)	3
Chemical products	1
Petroleum products	2
Primary nonferrous metals	2
Communications utilities	1
Research laboratories	1
Total	39

It was realized, at an early stage of the study, that in addition to the interviews in firms employing scientists and engineers, it would also be highly desirable to interview knowledgeable persons in a variety of other organizations closely involved in or concerned with the problem of obsolescence and deterioration of scientists' and engineers' skills. These organizations included technical colleges and universities, professional engineers' and scientists' societies, professional engineers' bargaining associations, private and public employment agencies, and Federal Government departments and independent agencies. During the course of the study, depth interviews have been conducted in a total of 39 such organizations, distributed as follows.

Type of Organization	Number of Organizations
Technical colleges and universities	14
Engineers' and scientists' professional societies	10
Professional engineers' bargaining associations	2
Public and private employment agencies	4
Federal and State Government departments and independent agencies	9
Total	39

Limitations of the Study

A "Pilot" Study; Limited Coverage. As noted in the statement of objectives, the investigation described in this report was designed, and has been conducted, as a pilot study. Our primary aims have been: (a) to identify the characteristics and process of technical skill obsolescence in a small, selected sample of firms; (b) to identify the aspects of the skill obsolescence problem needing definitive investigation, and (c) to develop approaches and techniques for conducting such investigations.

It must be emphasized that the list of firms studied -- 39 in all -- cannot be regarded as a representative sample of technology-oriented firms in American industry at large. We believe the 23 firms (10 in aerospace and 13 in electronics) that are predominantly engaged in defense and/or space activities are fairly representative of this sector of engineering-oriented industry; but even this must be regarded as a tentative premise, owing to the small total number of firms. As for the eleven predominantly non-defense firms and the five large multi-plant, diversified-product firms making up the rest of the list -- these are obviously too few in number to be considered as representative of their respective categories.

The study findings, and the inferences and conclusions from these study findings that are set forth in the report must, therefore, be regarded as applying primarily to the particular list of firms studied -- or the particular category of individual firms within the list, as the case may be. Any presumption that these inferences and conclusions apply to engineering-oriented firms generally -- or even to defense-engaged firms generally -- must be considered highly tentative, and subject to confirmation through more comprehensive and definitive research.

Research Focused on Current Situation. It was evident from the outset that carrying out this research involved a serious conceptual difficulty. New and novel knowledge is continually being discovered in all branches of theoretical natural science, and new and novel technology is continually being developed in all branches of engineering and applied science. As a result, year-by-year and even month-by-month, new scientists' and engineers' skills and skill requirements are emerging and superseding existing skills and requirements. The situation is further complicated by the fact that many firms have established, or are in process of establishing, "continuing education" programs for the purpose of equipping technical personnel with newly-developed skills, and that through this means, some of the practicing scientists and engineers employed by these firms are acquiring new skills -- of various types and in varying degrees.

In studying this highly dynamic process as it affects individual employing firms, it would obviously be impossible to record, in an intelligible manner, such a continually changing situation -- particularly since the basic substance of the picture is radically different from industry to industry. In carrying out the field research for the study, therefore, attention was focused on the skill obsolescence-updating situation in each employing firm as it existed at the time of the interviews (1964-65) and on associated events and developments in the preceding years, extending in some instances back to World War II. In the absence of any tested research methodology in the problem area, this seemed the only feasible approach in a designedly exploratory study of such limited coverage and duration.

Overview of Other Relevant Studies

The preparatory research, conducted prior to beginning the interview studies of organizations employing technical personnel, consisted of (1) a search of the scientific, engineering and business literature for publications dealing with technical skill obsolescence and related problems, and (2) interviews with individuals and groups engaged in related research, or otherwise knowledgeable in the problem area from a broad point of view.

The search of the literature revealed that the published discussion of the problem area under study was confined almost entirely to brief articles and papers that have appeared in scientific and engineering journals and conference proceedings during the past five years. More than thirty such articles and papers were uncovered, but no studies of monograph or book dimensions were found. The great majority of the articles were concerned, not with the nature and extent of skill obsolescence but with ways and means for combating or preventing it. The largest number were devoted to describing the educational programs established by various large industrial firms to provide instruction in new knowledge and technology for technical personnel. Another group of papers described similar programs recently established in certain engineering colleges and universities. Still others set forth proposals for remedial measures. Of the entire list of relevant publications, however, only two contained any definitive discussion of the basic nature of technical skill obsolescence and the causes underlying it. In one of these*, Dr. Monroe Kriegel of Esso Production Research Co., discussed four factors which he believes constitute the principal causes of technical obsolescence among research and development personnel. These are: (1) the rapidly accelerating growth rate of scientific knowledge, (2) the major revision of engineering school curricular during the middle 1950's, giving greatly increased emphasis to basic science, and mathematics; (3) the growing use of electronic computers, in conjunction with advanced mathematics, in solving engineering problems, and (4) the widespread management practice of assigning engineers and scientists to narrowly specialized fields for prolonged periods. In the second article**, Dean Gordon Brown of MIT outlined the major new types of engineering technology that have displaced older methods on a wide scale in recent years, and some of the new areas of basic science that have also become widely applied in engineering practice. He pointed out that "a large majority of (currently) practicing engineers .... were graduated from college before most of these disciplines were even visualized,

*Monroe W. Kriegel, "Updating the Training of Research and Development Personnel," IEEE Transactions on Education, December, 1963, pp. 51-56.

**Gordon S. Brown, "Closing the Engineering Gap," Electrical Engineering, July, 1963, pp. 456-460.

and certainly before the scientific bases upon which they rest were efficiently taught." Thus new technologies and scientific disciplines constitute the basic causes of most existing skill obsolescence among practicing engineers.

During the course of the interview research, we learned of several other ongoing or recently-completed studies in the problem area. In the case of the completed studies, copies of the study reports were obtained; in the case of the ongoing projects, we interviewed the individuals or groups in charge, and later received copies of their completed study reports. These studies, together with those examined during the preliminary exploration, are listed and briefly described below.

Study of Continuing Education Needs of Engineers in Pennsylvania. This study was conducted by Dr. Samuel S. Dubin, Department of Continuing Education, State University of Pennsylvania. The study, conducted by questionnaire and interviews, was confined to engineers five or more years out of college. Its main purpose was to obtain detailed information as to the areas and topics (in basic science, mathematics, engineering technology etc.) in which engineers need instruction in order to keep them up-to-date with current skill requirements, i.e., to restore obsolescent engineers to current skill competence. Some 2300 practicing engineers in 150 companies responded to the questionnaire. Interviews were held with engineering managers (45 small groups) and practicing engineers (40 small groups). The final report on this study, titled "Research Report of Continuing Professional Education for Engineers in Pennsylvania," was published in 1965, together with 53 "sub-reports" presenting data relating to different industry categories, fields of engineering, geographical districts, sizes of firm, and other varying factors.

The Goals of Engineering Education Project, Purdue University, Lafayette, Indiana. This project was conducted under the joint sponsorship of the American Society for Engineering Education and the National Science Foundation. Its principal aims were to assess the adequacy of present engineering education and to make recommendations for improving the curricula of the nation's engineering colleges and universities, in line with continuing rapid developments in science and technology. Information in current curricula and recommendations for revision were obtained through "study reports" from all accredited engineering institutions. Where "continuing education" programs for practicing engineers were in effect, the reports included information on such programs. Information on the strengths and weaknesses of current engineering education in terms of what engineers need in practice were obtained by questionnaire from engineering managers, personnel managers and practicing engineers in a sample of 150 industrial governmental and consulting organizations. The questionnaire included information on the problem of skill obsolescence and updating among engineers. The "Preliminary Report" on this study was issued in October, 1965, and the "Interim Report" is scheduled for issuance in December, 1966. Brief mention of certain "key" recommendations in the Preliminary Report is made in Chapter II.

The Engineering Societies Joint Advisory Committee on Continuing Engineering Studies. This committee includes officials of the Engineering Council for Professional Development, the Engineers Joint Council, the American Society for Engineering Education, and the National Society of Professional Engineers, and through them represents the national professional societies of the several engineering disciplines. The Committee, through a series of task forces, has conducted an "overview" study of continuing education activities in industry, academic institutions, the professional engineering societies and government. The aim of the committee was to appraise, in general terms, the types of programs currently in effect in each organizational area, and to make recommendations for improving and coordinating these programs. No detailed survey of specific programs was conducted. The committee's report, titled "Continuing Engineering Studies: A Report of the Joint Advisory Committee," was issued in June, 1966. Copies may be obtained from the committee office, 345 East 47th Street, New York, New York 10017.

Defense Industry Advisory Committee's Study of Continuing Education for Scientific and Technical Personnel. The Industry Advisory Committee to the Department of Defense undertook this study at the request of Secretary Mc Namara. A "working group" composed of executives of five major defense-oriented industrial firms, a technical university, and the Defense Department, conducted the study. Its main purpose was to assess the degree of seriousness of the technical skill obsolescence problem and the parallel problem of providing "continuing education" opportunities for practicing engineers and scientists. The study report, dated May, 1964, is titled "Implications of Continuing Education for Scientific and Technical Personnel." The working group's main conclusion was that, while it believed "that the problem (of skill obsolescence and continuing education) is a real problem", it did not consider it to be "of sufficient dimensions yet to warrant any large-scale Defense program." It recommended "that the DIAC again review the subject .... in a year or two."

National Society of Professional Engineers' Survey of Continuing Education. In this study, a questionnaire survey covering some 2500 of its members, the NSPE was primarily concerned with ascertaining the extent of participation in continuation education programs conducted by companies, colleges and universities and professional societies; and with the reasons for participation and nonparticipation in these programs. The survey report, titled "Continuing Education of Professional Engineers," was issued in March, 1966, and is obtainable from the NSPE headquarters, 2029 K Street, N.W. Washington, D.C. A main conclusion of the report, based on the survey results, is that "the principal burden of providing continuing-education opportunities -- including allowance of time for engineering employees to pursue updating studies -- lies with the employer; but that "colleges and universities as well as technical engineering societies must (also) assume a much greater role in meeting the problems of technical obsolescence" than they are now doing.

Survey by Princeton Creative Research, Inc. of Engineers' and Engineering Managers' Views on Skill Obsolescence and Continuing Education.. This questionnaire survey, conducted in 1964, canvassed a sample of 1000 practicing engineers and engineering managers. It sought their opinions on the extent of obsolescence in their respective companies, the disciplines in which they and their colleagues are deficient, the time and expense involved in keeping up-to-date, and a wide variety of other questions. The results of the survey were presented as articles in three issues of Machine Design: "Engineers Talk About Obsolescence," June 18, 1964; "Who Pays For Technical Retooling," July 2, 1964; and "Attitudes on Education," July 16, 1964.

The Engineering Manpower Research Project, R.P. Loomba, Director, San Jose State College, San Jose, California. A questionnaire survey dealing with the post-termination experience of 1800 engineers laid off by defense-oriented firms in the San Francisco Bay area during 1965, as a result of contract cutbacks and cancellations. Questions relating to the skill obsolescence-updating status of respondents were included in the questionnaire. At the time of writing (June 1966) the draft survey report had just been submitted to the Office of Manpower Planning, Evaluation and Research of the U.S. Department of Labor, which sponsored and supported the survey.

A more comprehensive list of relevant study reports, symposia, and journal articles is included at the end of this report, as Appendix B.

CHAPTER II

ORIGINS OF THE SKILL OBSOLESCENCE PROBLEM

The basic underlying cause of the current skill-deficiency problem among engineers and scientists is the massive volume of new scientific and technological knowledge that has emerged during the past two decades. The stock of knowledge was, of course, being augmented continually prior to World War II; but the rate of discovery was relatively moderate, and it was not unduly difficult for the average practitioner to keep abreast of the new knowledge as it appeared.

Since the early 1940's, however, the rate of scientific and technological innovation has increased phenomenally. According to one reputable estimate, the rate over the past twenty years has been nearly three times the rate during the preceding quarter century, and five times that during the preceding half century.* And the difficulty for practicing technologists in keeping adequately updated has increased correspondingly.

But the explosively high rate of growth of new knowledge in recent years, by itself, provides only a very inadequate explanation of the technical obsolescence problem. The qualitative characteristics of the new developments in basic and engineering science and in engineering technology, introduced during the past two decades, are far more significant

*Report of the Joint Advisory Committee on Continuing Engineering Studies.

in explaining why many currently-practicing engineers and scientists are lacking in needed skills. It would not be practicable, in the space available, to attempt an exhaustive account or even a synopsis of these developments. However, an enumeration of some of the more important new areas of basic science and of a sampling of the applied or "engineering" sciences stemming from them, together with a brief description of some of the innovations in engineering and applied-science technology, will serve to indicate the immense scope and variety of the advances made in recent years.

Basic and Applied Science

1. Nuclear physics. Although nuclear physics and the closely related field of quantum mechanics were originated early in the century, many vitally important new discoveries were made in the 1920's and 1930's; hence this revolutionary new theory of the basic nature of matter and energy did not approach its present state of mature development until the World War II years. Beginning during the war, a major field of applied nuclear science or "nuclear engineering" has been developed, which in turn has engendered the utilization of atomic energy for generating electric power, the use of radioactive isotopes in medical research and therapy, and many other practical applications of nuclear fission.

2. Solid-state physics. With regard to its origin and essential content, solid-state physics is a sector of

nuclear physics -- the study of nuclear and quantum phenomena as applied to solid materials. However, owing to its complexity and to its practical importance, it is generally regarded -- and studied -- as a distinctive basic-science field. Although a "young" science, solid-state physics has resulted in greatly increased knowledge of the electrical, magnetic, optical, and other vital properties of metals and other materials. From it has evolved the important applied-science field of semi-conductors, which in turn has produced the transistor and other revolutionary new electronic amplifying devices, and -- more recently -- integrated circuits and micro-circuitry.

3. Plasma physics. This is the recently-originated study of physical phenomena at extremely high temperatures, and of the ionized or "fourth state" of matter found at these temperatures. It is already playing a practical role in the development of techniques for space propulsion. It also has great potentialities, via the offshoot applied science of magnetohydrodynamics, for developing new and highly efficient methods of electric power generation.

4. Cryogenic science -- the study of physical and chemical phenomena at extremely low temperatures. This new field has already had important practical results in the development of liquified-gas fuels for rocket engines. It also has major potentialities for practical electro-mechanical and electronic applications, stemming from the phenomenon of

"superconductivity" found at these ultra-low temperatures.

5. Physical chemistry. This is the recently-developed study of the chemical properties of elements and compounds in relation to their atomic and molecular physical structure. Physical chemistry has given rise to a number of important applied-science disciplines, including advanced polymer chemistry, important in the development of plastics, synthetic fibers and other versatile materials, and the chemistry of human and animal anatomy and digestive and assimilative processes.

It is important to note that all of the above-enumerated areas of basic and applied science are intrinsically new areas -- i.e., they either did not exist prior to World War II, or were in their early formative stages. In any event, courses in these fields were not included in the curricula of technico-science colleges and universities prior to the war nor -- except in a very few cases -- for at least a decade following the war.

It should be noted also that the list is by no means inclusive. For example, major advances have been made in recent years in the development of "interdisciplinary" sciences, involving the utilization of modern chemical and physical science in the study of biological phenomena. While these new disciplines are commonly referred as either "biochemistry" or "biophysics," they include a wide variety of distinctive sub-disciplines, and many more are in process of being developed. Moreover, there has alos emerged a number of disciplines involving the application of electronic and other modern engineering techniques in the conduct of research in the inter-science fields -- generically identified by the recently-coined term "bioengineering."

Engineering and Applied-Science Technology

This term embraces the concepts, approaches and techniques utilized by engineers and applied scientists in conducting research, development and design activities and, more generally, in solving engineering and applied-science problems. The innovations developed and adopted in this aspect of R-D-D work during the past two decades are no less radical and far-reaching than the discoveries in basic and engineering science.

Prior to World War II most R-D-D work in engineering and applied science was conducted by empirical, largely cut-and-try methods -- the "handbook and slide-rule" approach. During and after the war, however, a radically different and far more effective approach, utilizing scientific concepts and advanced mathematical techniques -- including differential equations, statistical and probability theory, complex variables, and numerical analysis, and linear programming and related optimization techniques -- came into increasing use. This approach was originally introduced during the war by theoretical and pure-research scientists and mathematicians who became involved in defense-related engineering projects -- e.g., designing and constructing the atomic energy installations. In the course of the ensuing decade and a half its use spread widely in the defense and space-oriented industries, and even to a considerable extent among producers of highly-engineered civilian products. However, the desire on the part of engineering managements to adopt the new approach outpaced its actual utilization, owing to the dearth of engineers with the requisite knowledge and skills.

The effectiveness of the new approach was greatly enhanced with the invention of the electronic digital computer in the late 1940's, and the subsequent rapid improvement in the speed and versatility of computers. This development made it possible to obtain quick and accurate numerical solutions to complex multi-variable statistical correlations, differential equations, and other mathematical statements of engineering problems that had theretofore been impossible of quantitative solution. At the same time, however, the difficulty of the practicing technologist's problem of mastering the new technology was further increased, since in addition to acquiring (or re-acquiring) a knowledge of higher mathematics, he was now also required to become proficient in computer technology and computer programming.

Successive Innovations in Electronics - An Illustrative Case

The foregoing highly synoptic and far from complete enumeration of new science and technology subject areas merely indicates the range and diversity of the radical innovations that have emerged over the past twenty years. To convey an adequate picture of the nature and significance of these innovations, and of the difficulties involved for the practicing technologist in mastering and applying them, would require a sizeable volume. However, some idea of this aspect of the "science-technology upsurge" can be gained from the following summary of developments over the past sixty years in one illustrative area, namely, electronic science and its applications -- nowadays commonly referred to as "electronic engineering" or simply "electronics." The creation and subsequent development of this discipline has engendered a whole series of highly important end products and operational devices, including radio, television, radar, the digital computer, the electron microscope, and control and guidance systems for a wide variety of civilian and military equipment.

The basic-science foundation of electronic engineering was established in the late nineteenth and early twentieth centuries, with the discovery of electromagnetic waves by Clerk-Maxwell and Hertz, and the subsequent development of the electron theory of matter by Thomson, Einstein and Bohr. Electronics as a distinctive applied-science discipline is usually considered to have originated about 1912, with the invention by DeForest and others of the thermionic vacuum tube, which made it possible to transmit and receive voice and other sounds via radio waves.

For the next forty years vacuum tubes and tube circuitry formed the essential and exclusive basis of electronic development-and-design engineering, and of radio and television communications and the many other end uses which it engendered. During this period new types of vacuum tubes and improvements in existing types were continually being developed. However, the basic concepts and characteristics of tube circuitry remained substantially unchanged; and in due course much of the essential knowledge was incorporated in engineering handbooks and other reference publications. Consequently, engineers who obtained their basic grounding in the earlier years of the period could, in the 1940's, still rely on this earlier-acquired knowledge in performing their development functions.

In the 1950's, however, electronic engineering underwent a rapid transition to a new and radically different technical basis -- that of the solid-state semi-conductor amplifying and transforming devices. The transistor -- the first of these to be developed -- was invented by three Bell Laboratories physicists in 1948. Its discovery was soon followed by the invention of other distinctive semi-conductor devices. In the immediately ensuing years the development of processes for the manufacture of the materials required for semi-conductors and of the devices themselves proceeded apace. And because they were far superior to vacuum tubes, possessing greater amplifying power, accuracy, and reliability as well as being much smaller in size and much longer lasting, the semi-conductors came rapidly into use in place of tubes in the development and design of many types of electronic equipment, including radio transmitters and receivers, control and guidance systems, and digital computers. By the middle 1950's they were well on the way to completely displacing tubes in these usage areas, and were rapidly invading many others.

This rapid and revolutionary new departure in electronic development-design practice, however, posed a serious problem for electronic engineers whose training and experience had been gained prior to the advent of semi-conductors. Because the intrinsic makeup and manner of functioning of the new devices, as well as the electronic circuitry involved in their utilization, were radically different from the corresponding characteristics of vacuum tubes and tube circuits, a major effort of re-education and skill re-orientation was required, if these "tube engineers" were to equip themselves for successful transition to semi-conductor R-D-D practice. Indeed, many instances could be cited -- including a number encountered in the course of the present study -- in which engineers with long experience in tube circuitry were assigned to semi-conductor development-design problems, but proved incapable of effective performance, and had to be re-assigned to non-R-D-D work where proficiency in the new knowledge and skill areas was not essential.

The substantial replacement of vacuum tubes by semi-conductor devices marked only a very temporary pause in the rapid evolution of electronic engineering in the post-war period. By the early 1960's another, and potentially even more significant, electronic innovation was well along in the development process. This is the integrated circuit, or "chip," so-called because of its extremely small size. At the present writing (mid-1966) techniques of manufacturing integrated circuits have reached a stage that permits limited-volume production, and the devices are being used to a limited extent, in the development and design of computers, hearing aids and other types of electronic equipment. (The developing technology involving the use of integrated circuits is called "microcircuitry.") Constructed of the same types of semi-conductor materials as transistors (e.g., super-pure silicon) integrated circuits incorporate in a tiny flat chip of such material -- less than one-tenth of an inch in diameter -- a complete electronic circuit, consisting of as many as twenty transistors, plus the necessary associated resistors and other components. In practical applications -- e.g., computers -- large numbers of such circuits are connected together to form the required circuit systems.

The greatest advantage of integrated circuits over discrete-component semi-conductor devices (and *a fortiori* over vacuum tubes) is the enormous reduction in the size of the final machine or end-product which they make possible. Thus, in contrast to the first vacuum-tube computer, which filled a 30 by 50-foot floor space, today a much more powerful and capable computer, utilizing integrated circuits, can be housed in an enclosure no larger than a small desk. Integrated circuits are also faster acting and more reliable than discrete-component circuits.

However, as in the case of the recent major shift from vacuum tubes to semi-conductors, the forthcoming large-scale introduction of integrated circuits in electronic R-D-D practice means that practicing engineers must master the new knowledge and skills, if they are to perform effectively. According to one knowledgeable engineering project leader interviewed in the course of the study, the shift from semi-conductor circuitry to micro-circuitry will involve a re-education effort no less great than that required in shifting from vacuum tubes to semi-conductors. Thus even competent transistor engineers, like the tube engineers in the earlier transition (but with a much shorter time lapse), will likely face a formidable skill-obsolescence-updating problem in the near future.

Rapid emergence of major innovations in the post-World War II period as compared with the pre-war period, similar to that in electronics, could be cited in many other areas of applied science and engineering. Developments in aircraft propulsion provide another prominent but not un-typical example. The piston engine, originally developed early in the century for driving automobiles and later adapted to airplanes, was the exclusive concern of aircraft engine designers until after the end of World War II. Then, in the late 1940's and early 1950's the jet engine came rapidly into the picture, forcing engineers to acquire radically new and different knowledge and skills in metallurgy and heat transfer. In the late 1950's rocket engines invaded the military equipment field, and preempted the newborn spacecraft field, requiring propulsion engineers to master further new and greatly different areas of knowledge and technology.

The Movement to Update Technical College Curricula

Summing up the foregoing, it was a combination of the novel and basic character of the scientific and engineering discoveries and the rapidity of their emergence and conversion into professional disciplines that gave rise to the skill-deficiency problem among engineers and scientists in the years following the second world war. More specifically, the problem arose because the great majority of technologists practicing during the period, in their basic technical college training, had received no grounding in the new areas of knowledge and techniques. Those among them who had attained familiarity with the new disciplines had had to do so through intensive and continuous after-working-hours study. With regard to the practitioners educated prior to the war the lack of opportunity for the requisite basic grounding was unavoidable, since most of the new areas were either non-existent, or at best in the embryonic stages of development, when they were attending college. However, for more than a decade after the war's end, although many of the new disciplines had emerged or were emerging, virtually none of the nation's technical colleges and universities incorporated any of the new subjects in their curricula; and consequently the new technical graduates entering professional practice during this period, like their predecessors in the pre-war and war years, had either no grounding or at most only very inadequate grounding in the new disciplines. The failure of the technical schools to provide instruction in the new subjects was due largely to their novel character, their intrinsic difficulty, and the rapid rate of their emergence and development. Inertia and conservatism on the part of technical-school administrators and faculties undoubtedly also played a part.

Actually, however, a major first step toward revising and updating engineering and science curricula was taken before the end of the first post-war decade. In 1951 the Engineers' Council for Professional Development, following discussions of the gap between current engineering skill requirements and the existing educational programs, proposed to the American Society for Engineering Education that it undertake a study and action program aimed at bridging the gap. In line with this proposal the ASEE, in May 1952, established a "Committee on Evaluation of Engineering Education," which forthwith launched a nation-wide survey to ascertain the content of existing undergraduate curricula in the engineering colleges and universities and the administrators' and faculty members' views and suggestions for changes and revisions that would enable the schools "to keep pace with the rapid developments in science and technology." The initial result of this survey was the issuance by the Committee, in October 1953, of a Preliminary Report embodying tentative recommendations for revising and updating engineering-school curricula. The Committee distributed this report to the "Institutional Committees" established in all of the accredited schools, and received criticisms and suggestions from nearly all of them. Following study and analysis of these comments the Committee, in June 1954, issued a revised and expanded report. This "Interim Report" in turn was distributed to the Institutional Committees, and also to several hundred industrial concerns. Upon analyzing the resultant comments, the committee concluded that the great majority of educational institutions and industrial firms concerned accepted the recommendations in the Interim Report as pointing the way for needed revision and future development of engineering curricula. Accordingly, its Final Report, embodying basically the same approach and content as the Interim Report, with only minor revisions and emendations, was issued in September 1955.*

The following synopsis of the "Curricular Areas and Content" section of the report will serve to indicate the

*"Report of the Committee on Evaluation of Engineering Education", Journal of Engineering Education, September, 1955, pp. 26-59.

nature and scope of the Committee's recommendations and, by inference, the contrast between the proposed revised curricula and the typical then-existing undergraduate program.

I. <u>Mathematics.</u> Expansion of the required basic mathematics program to include, at the minimum, differential equations and their application to the solution of physical problems (as contrasted with existing basic requirements, typically extending only through introductory calculus). "For students who plan to engage in research, development, or the higher phases of analysis and design, or who contemplate subsequent graduate study in engineering, additional (and more advanced) mathematics will be ... necessary."

II. <u>Physics.</u> Revision of the required basic physics program, placing the major emphasis on <u>modern</u> physics, including nuclear and solid-state physics (as contrasted with existing typical requirements, which gave classical physics the main emphasis). "The duplication (in existing curricula) between classical physics and engineering sciences (mechanics, thermodynamics, electricity, etc.) can be largely removed if the introductory physics course is reoriented to place much greater emphasis on sub-microscopic phenomena and the conservation principles, with virtual elimination of semi-engineering examples."

III. <u>Chemistry.</u> Revision and expansion of the basic chemistry program to take account of recent major advances in inorganic, organic and physical chemistry, including rates and kinetics of chemical change, chemical equilibria, electrochemistry, and colloids. It was recommended that particular emphasis be given to physical chemistry, the recently-developed field which deals with the relationships between the chemical properties of elements and compounds and their nuclear structure.

IV. The Engineering Sciences. The term engineering science refers to the detailed study of a particular area of basic science, with the aim of relating and adapting it to the solution of engineering problems. The engineering sciences are commonly classified under the following six broad heads:

Mechanics of solids (statics, dynamics, and strength of materials)

Fluid mechanics

Thermodynamics

Transfer and rate mechanisms (heat, mass and momentum transfer)

Nature and properties of materials (relating particle and aggregate structure to physical properties)

Electrical theory (fields, circuits and electronics)

The committee noted that few of the then-existing curricula contained all six of these engineering-science areas, "despite wide agreement as to their basic desirability." It recommended that all six be included, and that approximately one-fourth of the total undergraduate program be devoted to their study.

V. Engineering Design. The term engineering design denotes the creative phase of R-D-D engineering -- the conceiving and devising of new and useful applications of abstract scientific laws and generalizations. The committee noted that in many engineering schools much of the existing curriculum time devoted to design emphasized the description of existing structures, equipment or machines, the use of handbooks, and other "outdated practices." It stated that, in place of this emphasis, the design sector of the curriculum should focus on the analysis and solution of actual unsolved engineering problems, utilizing the mathematical techniques and updated basic- and engineering-science knowledge outlined in the prior recommendations. It advocated that the study of design be undertaken during the last two years of the college career, and that it constitute about one-fourth of the total undergraduate program.

VI. Humanities and Social Sciences. The committee felt that engineering school curricula, in addition to preparing the student for effective practice in his profession, must also foster "his fullest development as an individual." To this end, it recommended the inclusion of courses in history, economics and government, as being essential to building "competence as a citizen," and courses in literature, sociology, philosophy, psychology, and fine arts, as a "means of broadening (the student's) intellectual outlook."

To make room in the curricula for the increased emphasis on advanced math, modern physics and chemistry the new and updated engineering sciences, engineering design, and the humanities and social sciences, the committee recommended that the portion of the curricula currently devoted to laboratory, shop practice, drawing and drafting, and other "practical" courses be sharply reduced.

The committee's recommendations had an early and substantial effect in bringing about revisions of the curricula of engineering and applied-science colleges and universities. This was shown in a survey conducted by the committee chairman, L.E. Grinter, in 1958. Dr. Grinter canvassed the accredited schools, requesting information on the extent (if any) to which their curricula had been revised in line with the committee's report. He received usable returns from 106 schools -- nearly two-thirds of the total number contacted. The results of the survey are summarized below.*

Nearly four-fifths of the respondent schools reported that their mathematics requirements had been strengthened

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*L.E. Grinter, "A Survey of Current Changes that are Modernizing Engineering Education," Journal of Engineering Education, March, 1959, pp. 559-572.

since 1954 (when the Interim Report was issued) and nearly half of these stated specifically that differential equations had been made a requirement for some or all students. About two-fifths of the schools had strengthened their physics requirements, and about three-fifths had increased the number and/or scope of engineering science courses. In two other areas emphasized in the report -- chemistry and engineering analysis and design -- the proportion of schools that had increased their requirements was smaller: about one out of ten in the former area and one out of five in the latter. Finally, some three-fifths of the schools had increased the humanities and social-science content of the curriculum. In order to make these various increases in mathematics, science and humanities requirements possible, more than four-fifths of the schools had reduced or eliminated "engineering practice or art, or other technical courses."

In view of the relatively short period that had elapsed when this survey was made, and of the inherent time lags involved in instituting curriculum revisions, it is apparent that the committee's recommendations had already brought about significant mathematics-and-science-directed reorientation of curricula in a substantial proportion of the nation's technical colleges and universities. Moreover, although no follow-up survey of curriculum changes has been made since 1958, it is evident from information obtained during the course of the present study that many additional schools have instituted similar revisions in subsequent years.*

The revision of required-course programs by a large proportion of technical schools less than a decade after the issuance of the committee's recommendations, is of major significance in our study of the skill obsolescence problem. Many of the engineering managers and research directors interviewed during the study stated unequivocally that they find the recent graduates on their R-D-D staffs more competent and productive than the professionals who attended college earlier, including even those who finished as little as eight or ten years ago. And most of these managers attributed this difference in performance directly to the broader and more thorough grounding in higher mathematics and modern basic and engineering science obtained by the recent graduates.**

*For example, Dr. Grinter reported that besides the schools that had already revised their curricula, substantial additional numbers were considering, or studying the feasibility of, instituting revisions, Ibid., pp. 561, 563.

**The "Preliminary Report" on the very recent "Goals of Engineering Education," study (see below) summarizes the findings of the survey of practicing engineers and engineering managers apropos this point as follows:

> "These Industry-Government Survey replies strongly support the view that recent engineering graduates are being utilized in much higher technical and supervisory positions than their counterparts of an earlier vintage. Similarly, recent graduates are much more likely to be employed in R & D functions on their first job. Such findings also cast doubt upon the somewhat popular image of the over-trained and under-utilized engineer. For while such characterization may in the past have been true of engineering graduates just out of college, it has certainly become less true of recent graduates." (Preliminary Report, p. 23)

Despite the widespread compliance by engineering schools with the Committee's recommendations, the organizations of engineering practitioners and educators felt that the 1952-55 projects and the resultant report were not sufficient to assure that further curriculum revisions would be made as the need arose. They noted that further major discoveries in science and technology were emerging and would continue to emerge over the indefinite future. Early in 1961, therefore, the ECPD requested that the ASEE conduct a new study of engineering; and shortly thereafter the ASEE established a new study group called the "Committee on Goals of Engineering Education." The new Committee, with the aid of a National Science Foundation grant, launched its study in the spring of 1962. The Committee's Preliminary Report was issued in the fall of 1965, and as this is written (May, 1966) it has just issued a memorandum inviting "continuing comments" and announcing that an Interim Report will be issued in December 1966. Since the findings and recommendations of the "Goals" Committee are,at the present writing, still in the preliminary stage it would be inapropos to describe and discuss them in detail in this report. However, one of the key recommendations included in the "Goals" preliminary report has a direct bearing on any predictions that may be made concerning the magnitude of the skill-obsolescence problem in the future. The recommendation reads as follows:

"It is the recommendation of this report that in the future, four-year bachelor's-degree programs be considered "Introductory Engineering Programs" and that a master's degree awarded for successful completion of a fully-integrated, five-year program be considered the first professional degree. It is expected that to obtain professional status in the fields of design, research, development and teaching this degree will become mandatory." (Goals of Engineering Education Study, Preliminary Report, p. 26.)

The rationale of this recommendation is that owing to the higher level of knowledge and skills required for effective performance of engineering design, research, development and teaching, the traditional four years of college education are no longer sufficient to provide the necessary grounding, and that a five-year program, with the master's degree as the terminal academic goal, must therefore be made mandatory for admission to professional practice in these fields. For individuals who intend to pursue careers in non-R-D-D functional areas, such as operations engineering,maintenance and service engineering, construction engineering, and sales engineering, the four-year program, with the "introductory" bachelor's degree as the terminal objective, will still be sufficient.

CHAPTER III

THE NATURE OF THE OBSOLESCENCE PROBLEM

Fears that engineers and scientific personnel have, to a significant degree, become subject to "obsolescence" have been frequently expressed in recent years. Various professional journals have called attention to the problem, and several conferences* have made it the subject of their deliberations.* By "obsolescence", what is often suggested is that the rate at which new knowledge accumulates is now growing so rapidly that engineers and scientists find it increasingly difficult to keep up in their fields. In many cases, it is argued the battle has been lost, with the result that engineers and scientists find themselves unable to function effectively in their jobs. This problem of "obsolescence," however, is but a part of the larger problem of skill deficiency, and in order to be properly understood must be dealt with in that context.

Skill Deficiency

Since skills are embodied in the persons of individuals, a certain degree of deterioration from physical causes alone may be inevitable. Little is known of this process, particularly as it relates to mental activities such as characterize the

*For example, the Midwest Conference on Reducing Obsolescence of Engineering Skills, sponsored by the Illinois Institute of Technology, March 26-27, 1963, and a conference on "Continuing Education," sponsored by the New York State Advisory Council for the Advancement of Industrial Research and Development, November 7-8, 1963.

hours, the newly graduated and hired engineer or scientist has virtually shut himself off from the source of learning about new knowledge. This statement needs to be qualified in two ways: first, to the extent that he keeps abreast of current developments through the reading of technical journals, and second, to the extent that he comes into contact with new developments through his work experience, particularly, in his exposure to fellow workers. There is probably a considerable degree of interaction between the two factors, that is, an engineer or scientist is more likely to read professional journals if he finds himself in a working environment in which the latest technical and scientific developments are frequent topics of discussion or in which keeping abreast of the latest developments is demanded by the job assignment. Moreover, these two factors are closely related to the probability that the engineer or scientist is continuing his formal education after working hours. In other words, the various ways in which an individual can remain cognizant of the latest developments in his field are mutually reinforcing.

The Deterioration of Intellectual Capital

While there are various ways in which an engineer or scientist can keep "current", there appear to be a significant number of instances in which the individual treats the stock of knowledge which he acquired in college as sufficient for his professional needs, subject only to the further addition the engineering and scientific professions. One can only state that its probability of occurring increases with age.

Somewhat related to the problem of physical deterioration, and sometimes confused with it, is the problem of declining creativity that comes with advancing age. What little research has been done on the subject* suggests that creativity, measured by recognized professional accomplishments, tends to reach a peak somewhere around the age of 35, then declines steadily thereafter with a slight upsurge, in some cases, 10 to 15 years later. There is also evidence that the peak of creativity comes somewhat earlier in the case of those engineers and scientists engaged in "pure" research as distinct from those engaged in developmental research.* While these findings seem to be accepted now by most persons who have studied the problem, the dynamic process by which the decline in creativity occurs "is no clearer than when the findings were first reported."** Five alternative hypotheses have been suggested. One, that intellectual abilities as such decline with age, has not been

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*H.C. Lehman, Age and Achievement, Princeton University Press, 1953; J.W. Haefele, Creativity and Innovation, McGraw-Hill, 1962; Donald C. Pelz, "The 'Creative Years' and the Research Environment," IEEE Transactions on Engineering Management, March 1964, pp. 23-29; Human Factors in Research Administration, Report of a Seminar Conducted by the Foundation on Human Behavior, November 17-18, and December 1-2, 1955, Ann Arbor, Michigan, 1955.

**Pelz, op. cit., p. 23.

borne out by subsequent studies. "A favorite alternative hypothesis, pleasing to the scientific ego," notes Donald C. Pelz,

> is that the more able achievers are drawn off into teaching, administration, and committee work not directly productive of scientific output. A third interpretation is that after the young scientist has struggled hard and built his reputation, he can afford to relax. A fourth hypothesis is that as the scientist becomes an expert in his field, he loses the freshness of viewpoint needed for pioneering breakthroughs.*

A fifth view, according to Pelz, and one which will be discussed more fully below, is that with age comes obsclescence, causing the scientist to lose touch with recent advances in his field. Except to acknowledge this possible factor of physical deterioration, we shall have nothing further to say about the matter, and we therefore turn to the deficiency of skills which occurs as a result of the working environment in which engineers and scientific personnel operate.

An engineer or scientist, according to the National Science Foundation, is someone with the background or training equivalent to that acquired through completion of four years of college with a major in one of the physical, life, engineering or mathematical sciences. But while graduation from college and the landing of a job may serve to characterize an individual as an engineer or scientist, it does not necessarily mean that he is able to contribute in a meaningful way to the firm or organization which has hired him. The new

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*<u>Idem</u>.

graduate, as a commodity, is only a semi-finished product. His education, if it has been a good one, has prepared him to understand a wide range of technological or scientific problems, but not to cope or otherwise deal with any specific one of them. He must therefore undergo a period of on-the-job training to enable him to acquire the knowledge relevant to his firm or organization's particular activities, this knowledge being much too specialized to be taught in school. The firms interviewed in this study indicated that it generally requires an extended period on the job before a newly hired college graduate begins to "earn" his salary, that is, until his contribution to the firm's output is equal to what it costs to have him on the payroll. This is particularly true in the case of certain "key" engineers. Experience gained on the job is thus an important part of any individual's acquired skill, continuing to grow in significance for a considerable length of time even after the breaking-in period is over. For some firms the experiential factor is more important than for others, but there is no firm for which it is not significant. Were this factor alone operative, an engineer or scientist's skill would tend to increase over time, subject only to the almost imperceptible effect of physical deterioration. There is, however, a third factor affecting the skill of engineers and scientists, and it is this factor which has given rise to the fears of skill obsolescence.

Unless he continues his formal education after working hours, the newly graduated and hired engineer or scientist has virtually shut himself off from the source of learning about new knowledge. This statement needs to be qualified in two ways: first, to the extent that he keeps abreast of current developments through the reading of technical journals, and second, to the extent that he comes into contact with new developments through his work experience, particularly, in his exposure to fellow workers. There is probably a considerable degree of interaction between the two factors, that is, an engineer or scientist is more likely to read professional journals if he finds himself in a working environment in which the latest technical and scientific developments are frequent topics of discussion or in which keeping abreast of the latest developments is demanded by the job assignment. Moreover, these two factors are closely related to the probability that the engineer or scientist is continuing his formal education after working hours. In other words, the various ways in which an individual can remain cognizant of the latest developments in his field are mutually reinforcing.

The Deterioration of Intellectual Capital

While there are various ways in which an engineer or scientist can keep "current", there appear to be a significant number of instances in which the individual treats the stock of knowledge which he acquired in college as sufficient for his professional needs, subject only to the further addition of on-the-job experience. This knowledge is, in fact, his intellectual capital, and he is not usually aware of the ways in which it is subject to erosion and depreciation.

Unlike capital in the usual sense, that is, plant and equipment, the stock of knowledge is more likely to deteriorate from disuse than from use. As already indicated, the newly graduated engineer or scientist brings with him to his first job a wide-ranging capability based on the broad range of subjects he studied as an undergraduate or even as a graduate student. Only a small portion of this preparation will be directly applicable to his job, however, which means that the rest will remain unutilized. With time, these unused skills and areas of knowledge will tend to be lost. The rate at which this phenomenon occurs will depend on how well the subjects were taught in college and how deeply they were absorbed.

In the ordinary course of events, this loss of skills may not be important. As long as the individual continues doing the same type of work as he entered into immediately following graduation, his ability to perform on the job may not be impaired. But if for some reason the nature of his work should change and he is forced to move into another area -- an area calling for the same general type of knowledge which the individual had when he graduated from college but different from the knowledge required on the old job -- then the deterioration of skill which has set in from disuse can become a serious matter. On paper -- that is, based on the knowledge certified to by the diploma -- the engineer or scientist should be able to perform adequately in his new task, but as a practical matter he will not be able to.

The problem will be intensified by the degree to which the engineer or scientist has felt compelled to specialize in his work. The narrower the field one concentrates one's endeavors in, the more quickly and assuredly one can achieve proficiency, and this is frequently a powerful incentive to specialize. But at the same time, the greater will be the number of skills and areas of knowledge acquired in college which will fall into disuse and thereby be lost.

Like the factor of physical deterioration, the tendency toward specialization is not new. What is new is the rate at which technological change is occurring. This is having a two-fold effect. On the one hand, it is changing the nature of the final products on which engineers and scientists are apt to work. The skills which they have may be perfectly adequate for the old type of product, but the new type of product which replaces it may require entirely different types of skill and knowledge. Even if they may once have had the general competence to work on the new type of product, skill deterioration through disuse may now preclude that possibility.

An illustration can perhaps make the point better. When the aircraft industry shifted from piston engines to jet engines in the late 1940's, many propulsion engineers with long experience in designing the old type engine had great difficulty in making the switch to jet engine design. What they principally lacked was the basic knowledge required in dealing with the new types of metals and the radically different heat exchange problems involved in jet engine development and design work. Most of these engineers had taken courses in metallurgy, thermodynamics and heat transfer in college; but since it had not been necessary to apply this knowledge in their day-to-day design activities, it had been largely forgotten.

Technological change may also have a second effect. It can make the specialized skills themselves obsolete through the emergence of new techniques requiring entirely new disciplines and new knowledge. Thus the development of electronic data processing equipment, solid state circuitry, atomic energy systems, etc. has made redundant many of the old skills and ways of doing things. Moreover, the changes in techniques have often coincided with a change in the nature of the final product, thus further aggravating the problem of skill deterioration. In the case of electronic engineers engaged in developing and designing amplifying and rectifying devices, the supersession of the vacuum tube by the transistor and the diode has rendered obsolete virtually all the specialized knowledge utilized in designing tubes, while mastery of solid-state physics -- for practical purposes nonexistent until a few years before the invention of the transistor -- has become an absolute must. It is this last effect of technological change which is sometimes referred to as the "obsolescence" problem per se. For in the case of the older engineer and scientist who received his education at a time when the newer subjects and disciplines were not even being taught, the impact, as this study brings out, can be particularly devastating.

The Differential Impact of Technological Change

The rate of skill obsolescence, then, is in part -- but only in part -- a function of the rate of technological change. What has undoubtedly caused this one factor to be emphasized over others is the awareness that it is the only factor to have changed significantly within recent years. New knowledge, it has been said, is growing at a rate which doubles the existing stock every ten years. While the quality of this knowledge and the actual impact on technology are not really known, they are certainly not insignificant.

Still, the effect on different sectors of the economy varies considerably. For the most part, the impact of the new technology is dampened by institutional factors -- the difficulty which even the most dramatic of improvements has in displacing products with a long history of consumer loyalty, the reluctance of management to switch from a proven to an unproven item, the resistance on the part of the technical staff to adopting new and untried ways of doing things, in short, the natural conservatism of any ongoing, established institution. In this respect, the aerospace industry, which is heavily represented among the firms interviewed in this study, presents somewhat of an anomaly. Its market, in a certain sense, is an artificial one, created largely by the demands of the government itself. Thus it is free of many of the customary restraints tending to inhibit the development of new products in the civilian sector of the economy, restraints that manifest themselves through normal demand conditions. In effect, the government is able to order the rate of technological change it deems most desirable in the aerospace industry, subject only to the limitations imposed by the current state of scientific knowledge.

This being the case, one might easily conclude that a study of skill deterioration among engineers and scientists in the aerospace industry would have little relevance to the problem in general. Even though it is in itself an important industry, employing by far the largest number of industry-connected scientists and engineers, it would seem to represent an atypical development. However, this very atypicality can be useful in throwing into bold relief problems and trends which are obscured in other industries.

How Widespread and Serious is the Obsolescence Problem

Having laid out a conceptual framework for analyzing the problem of skill deficiency, we now turn to the question of how widespread and serious is "obsolescence" among engineers and scientists, as indicated by the interviews conducted as part of this pilot study. It would, of course be most desirable to obtain estimates of the number or proportion of professional technical staff members who were deficient in currently required skills. However, with few exceptions, the managers interviewed felt that it was not possible to make a meaningful estimate of that sort. In probing this aspect of the problem, therefore, a less specific query was adopted. Each manager was asked whether skill obsolescence (i.e., lack of or deficiency in currently required knowledge or skill) was a problem among the members of his company's professional technical staff. And if so, how serious a problem was it.

In all but four of the 39 firms studied, the managers answered the first question in the affirmative. The responses to the second question, however, varied rather widely, both with respect to assessing the seriousness of the problem and the manner of expressing the assessment.

In summarizing these responses, it was found that a three-way classification, namely: "major problem," "sizeable problem," and "minor problem", was most useful. On the basis of this classification the problem of "obsolescence" was considered to be of "major" proportions in 12 firms, "sizeable" in 15 firms, and "minor" in 8 firms. In four firms, the interviewer felt that skill obsolescence did not constitute any problem. Breaking the responses down in terms of the industry-group classifications, the results show the following:

Industry Group	Number of firms replying (in effect)			
	"Major Problem"	"Sizeable Problem"	"Minor Problem"	"No Problem"
Aerospace (including airplanes and parts, missiles, and spacecraft)	5	4	1	0
Electronic equipment	5	3	4	1
Electrical machinery, equipment, appliances and supplies (including nuclear energy equipment)	0	0	3	1
Office, computing and control machines and equipment	0	2	0	0
Miscellaneous machinery, equipment and supplies	1	2	0	0
Chemical and petroleum products	1	1	0	1
Primary metals	0	1	0	1
Communications utilities	0	1	0	0
Research laboratories	0	1	0	0
	12	15	8	4

Numerous journal articles and other published papers have contended that, in industry generally, technical skill obsolescence is found most often among mature-age or older engineers and scientists and relatively seldom among younger professionals. Our findings confirm this view. According to the managers in 27 of the 34 firms having significant obsolescence problems, most of the deficient individuals are found in the middle and upper age brackets. While few of the managers could identify specific age-range boundaries, the overall gist of the estimate was that skill obsolescence is found mainly in the 35-and-over category. All but two of the industry categories included in the sample -- electrical machinery and research laboratories -- were represented among the 27 firms. Only two managers -- in an aerospace company and a nuclear energy equipment firm respectively -- stated that there was no discernible difference between the mature-age and younger engineers in this regard. In the remaining six cases, no information was obtained on this point.

The reason generally given for the fact that the skill deficiency problem is most serious among engineers and scientists over 35 is that these older professional technical people attended college prior to the middle 1950's and that it was only afterwards that engineering colleges began to revise their curricula to give greatly increased emphasis to basic science and mathematics. The managers interviewed noted that previously few engineering or science curricula included courses in any of the important new areas of science and technology discovered or developed during the post-war years, such as nuclear physics and nuclear engineering, solid-state physics and solid-state electronics, and electronic computers and their utilization in research and engineering design. Thus the earlier educated engineers and scientists did not receive the basic educational grounding which is essential to developing and maintaining the skills required in the 1960's.

Many of the managers emphasized that while skill obsolescence was most in evidence among the middle and upper age groups, a sizeable proportion of the 35-and-over professionals (the estimates varied considerably) have developed and do maintain currently-required skills. That is to say, some of them have overcome the twin handicaps of inadequate college grounding in basic science and mathematics and the absence of instruction in the newly-developed disciplines through subsequent study. It was thus apparent that, in addition to the lack of adequate educational grounding, other factors -- personal or circumstantial -- were deterring or preventing the skill-deficient professional technologists from updating their skills.

In the view of many of the managers queried on this point, the failure to keep abreast of developments in the relevant field was due primarily to lack of motivation. Most often this opinion was based on the observed fact that relatively few of the mature-age professionals had enrolled in "in-plant updating" courses or other continuing education programs offered by the firm. In several instances, however, the respondents were more positive and emphatic -- for example, the statement by the director of research and development in a chemical firm that "some of our people (mainly Ph.D.'s) take the view that, once they have that degree, they can coast on it for the rest of their career." On the other hand, several other respondents held that the failure of the skill-deficient technologists in their firms to keep up to date was due more to extenuating circumstances than to low motivation per se. Two of these pointed out that since company policy precludes providing time for such efforts during working hours, the individual desiring to update his knowledge and skill must do so after hours. Thus the motivation to keep up to date has to compete with other important motivations, including family obligations and community and church activities. They noted that these motivations are more numerous and demanding among mature-age than among younger men. Two other respondents emphasized that most of the technical professionals in their firms are required to put in long overtime hours in the course of performing their regular work, and that this fact alone constitutes a major obstacle to updating educational efforts.

Four of the respondents attributed the failure to up-date to unavoidable factors associated with advancing age rather than simply to "lack of motivation." (These managers believe that most of the skill-obsolescent professionals in their firms are found in the older age groups -- i.e., 45-50 and over.) In two instances, this was characterized as "slowing down" of faculties and energy. In the other two instances the managers were more explicit: they felt that the older professionals had reached the stage where they are unable to master the basic disciplines that are prerequisite to acquiring skills required in the 1960's.

As noted above, nearly all of the managers interviewed stated that skill obsolescence and deterioration is a current problem in their professional technical work force, though they differed considerably in their estimates as to its seriousness. Nearly all were in agreement, also, that the recent rapid and radical advances in the physical sciences and in scientific and engineering technology are the primary external factors giving rise to the problem, and that its principal manifestation is a failure on the part of some members of their technical staffs to keep abreast of these advances.

However, in querying the interviewees as to the number or proportion of skill-obsolescent technologists on their technical staffs, it soon became apparent that the question was not properly phrased to fit their actual technical manpower requirement situation. The difficulty these managers found in responding to the question as stated, and the reasons given, can be briefly paraphrased:

> Full updating with new scientific and technological developments is an essential qualification only in the research-development-design (R-D-D) units. The

primary function of R-D-D engineers and scientists is to originate ideas and designs for new products and processes, and to do this effectively they must be able to utilize the newest available knowledge and methods. However, a substantial proportion of the professional technical work force is engaged in non-R-D-D work. The work of these professionals is concerned exclusively with products and processes that are already in commercial production, including such functions as improving production layouts and methods, testing finished products for quality performance, promoting sales, and servicing equipment in the hands of customers. While it is desirable that these technical practitioners keep up to date on the latest developments in science and technology, in most cases they are able to perform their functions satisfactorily even though they do not possess the latest knowledge. Thus, while undoubtedly a large proportion of the non-R-D-D technical professionals are lacking in the newer scientific and technological knowledge, these people do not constitute a serious operating problem.

Some evidence was obtained indicating that even within R-D-D departments there are notable differences in the degree of urgency of updating as between higher and lower-level professional practitioners. The managers in six different firms (in four different industries) on their own initiative stressed the importance of project leaders, systems engineers, and other "key" practicing technologists in their firms' R-D-D activities, and held that full and continuous updating on the part of these practitioners is especially urgent. The comments of the Director of Engineering in an electronics firm, to the following effect, typify their views on this point.

> The business of the R & D Division is developing and designing new control systems. The basic ideas for these systems are originated, not by the engineering staff as a whole but by a small segment of it -- the project leaders, systems engineers and other key engineering personnel. Altogether, they comprise only about one-fifth of all our professional engineers. Most of the work performed by the rest of the professional staff is essentially detail work -- translating the ideas originated by the key engineers into the specifications, drawings or prototypes of complete systems that constitute the Division's final product
>
> It is vitally necessary for the key engineers to keep continually abreast of new developments over a broad range of technology and science. Although desirable, it is less urgent in the case of the detail engineers, since they are essentially direction followers. There is no shortage of such run-of-the-mill engineers. There is, however, an acute shortage of

engineers with sufficient creative ability to qualify for key engineering positions. Finding or developing such engineers is engineering management's most difficult manpower problem.

As to how the division obtains qualified engineers for these key positions, the director said, "We get some of them by intensive recruitment from other companies, including our competitors; and others by careful selection, based on past performance, from within our own engineering staff."

It is this problem of finding or developing the so-called "key" engineers which led many of the managers interviewed to state that while there seems to be a surplus of engineers and scientists in many areas, there is actually a shortage of the most desirable type, those capable of doing original research. This has led to various efforts on the part of firms to meet the problem, such as the training program recently established by one of the aerospace firms. This program is specifically designed to qualify selected engineers to fill systems engineer, project leader and other key engineering positions. At six-month intervals, 15 engineers in "the critical 5-10 year experience group," carefully selected on the basis of technical proficiency, initiative and other leadership criteria, enter their first assignment under the program. The core of the program consists of a six-month, full-time "productive tour" in each of three major areas of the firm's R-D-D engineering establishment, and a fourth tour in an area outside of engineering, such as business development or manufacturing. The rotating assignments are supplemented by a variety of lectures on organization, planning, operations and finance, and by participation in various in-house technical courses. A performance evaluation is obtained on each man every three months from his current supervisor. The manager interviewed expressed confidence that this program provides an effective means of accelerating the development of qualified systems and project engineers. It is worth adding that another firm -- a large producer of electrical equipment -- has established an intensive "updating" educational program specially designed for and confined to key engineering personnel.

The difficulty in obtaining "key" engineers capable of developing new ideas is in part responsible for the practice, widespread in nearly all of the firms studied, of organizing R-D-D activities on the basis of project groups, some consisting of as few as two or three individuals and some consisting of more than 50. For this practice permits the maximum use of the available key engineers, the team leader providing the creative leadership and the other members providing the wide assortment of engineering and scientific skills which a project may require.

One advantage of this practice is to permit specialization by the engineers and scientists comprising the group -- in different phases of the project, or in different scientific or engineering disciplines. As one manager pointed out, conducting development work on a group basis tends to mitigate the skill obsolescence-updating problem from the standpoint of the particular project, since it is only essential that each specialist be up-to-date in his own specialty. From a longer-run point of view, however, the effect of the practice may be to aggravate the problem -- especially if the participant technologists are engaged in narrow specialties, such as a single component of the equipment being developed or a single engineering discipline. If, as often occurs in defense-oriented R-D-D work, the equipment being developed is displaced within a few years by a new and different type, the specialized engineers will face a serious obsolescence problem, since there will no longer be a demand for their narrow skills, and since they will likely have lost their earlier skills through disuse.

Is There a Skill-Obsolescence Problem Among Basic-Research Scientists?

As we noted in Chapter I, in most of the firms studied the technical activities consist exclusively of engineering and related applied-science work. The study findings summarized in the preceding pages, therefore, refer to engineering and science-specialty professionals engaged in such activities. However, we also noted that some technical professionals (mainly scientists) are engaged in basic or "exploratory" research, and that efforts were made to obtain information as to whether this category of practitioners is affected by the skill obsolescence problem.* We noted further that the firms studied included only one organization -- an A.E.C.-affiliated laboratory -- engaged exclusively in basic research. However, in the course of conducting the interviews we learned that nine of the engineering- and applied science-oriented firms also have small units engaged in exploratory research. In these firms, therefore, we queried the manager-interviewees concerning the extent of skill obsolescence in their exploratory-research units, as compared with the engineering-applied science R-D-D departments. In eight of the nine firms (as well as in the atomic-energy laboratory) the managers felt that the problem in their basic-research units was either nonexistent, or of only very minor proportions.** The gist of their -- markedly similar -- assessments can be summarized as follows:

> The great majority of the scientists in the basic-research units are well versed on recent advances and new knowledge in their fields, and keep informed on new developments on a continuing basis. There is a

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*Because the exploratory-research units are staffed predominantly by science Ph.D.'s we shall for simplicity refer to these professionals as scientists. It should be kept in mind, however, that most of these units include engineering as well as science Ph.D.'s. It should also be noted that not all of these units are wholly engaged in basic research -- some of their activities are more accurately identified as "quasi-basic" or "exploratory" research.

**In the remaining firm -- a major chemical company -- the director of research stated that a sizeable number of the exploratory-research chemists fail to keep current on new developments in their field.

decided difference in this regard between the basic-research units and the engineering and applied science research-development-design units, where many of the engineering and science practitioners -- especially in the middle and upper age brackets -- fail to keep abreast of new developments. Moreover, the basic-research scientists keep currently knowledgeable largely on their own initiative, whereas for the applied-research professionals who do keep up-to-date it is necessary to provide in-plant updating-education programs and other forms of employer-initiated assistance and encouragement.

The interviewees gave a variety of reasons to explain why the basic-research scientists are more assiduous in updating and broadening their knowledge and skills than the engineering and applied-science professionals. The reasons most often given are paraphrased below:

> In each of the nine firms, all (or nearly all) of the basic-research staff members hold Ph.D. degrees. (In contrast, the bulk of the engineering and applied-science R-D-D staff members are "B.S.'s" -- i.e., their formal professional education is limited to undergraduate study.) The fact that the basic-research professionals have achieved the doctoral status is sufficient evidence that they possess a deep interest in basic science and are strongly motivated to excel in it. This exceptional

interest-motivation is a major factor accounting for their continuing spontaneous efforts to keep informed on new scientific discoveries and developments. In most cases, it is also the primary reason why they have chosen basic research as a career.

Secondly, the exploratory research in which these scientists are egaged is in most instances directly and immediately related to recent discoveries in basic science. In fact, their explorations are frequently aimed at extending or expanding these basic findings. For example, the basic-research unit of one of the firms, in which a major "breakthrough" in solid-state physics was achieved some years ago, has subsequently devoted a major part of its efforts to extending basic knowledge of this area still further. Obviously, scientists engaged in such explorations <u>must</u> be thoroughly versed in existing basic knowledge before they can go on to break new ground.

Finally, by the very nature of their activities, the explora ory-research scientists have wide latitude and discretion in the manner of devoting time and effort to the different phases of their work. Individuals or groups are assigned to investigate an unexplored area or unexplained set of phenomena in a particular sector of their general field (physics, chemistry, biology, etc.); but they are not charged with arriving at any positive discoveries or explanations; and no limits -- or at most only a very flexible limit -- are set on the duration of their investigations. Moreover, the assignments have only a conjectural and remote-future connection (if any) with the firm's regular business operations. Consequently the researchers are free to devote a portion of their customary on-the-job time to keeping informed on recent and current findings of other scientists in the particular area and the general field. And in practice most of the exploratory researchers do so.

Their situation in this respect differs markedly from that of the professionals in the engineering and applied-science research-and-development departments, whose assigned tasks projects nearly always have as their objective the development of saleable new products or efficient new processes or equipment. Definite target dates are set for completion of the projects, and the researchers-developers are often subject to heavy pressure from management to complete them on time. Consequently, there is little, if any, time available during their regular work day or work week for "continuing education" in new discoveries in science and technology. If they are to keep themselves updated, they must do so outside of regular working hours, which not only entails much extra educational effort, but also interferes with family relationships, church and community activities, and other off-the-job duties and responsibilities.

Summary of Findings

The managers' assessment of the seriousness of the technical skill-obsolescence problem may be recapitulated in a brief space. In the great majority of the firms studied, up-to-date mastery of scientific and technological knowledge on the part of engineering and scientific personnel is regarded as an essential qualification only in the firm's research-development-design activities. In the non-R-D-D activities -- including the various phases of production and operations, maintenance, sales and service engineering -- full and continual updating, while desirable, is not essential to effective performance.

The relative size of the R-D-D units varies considerably from firm to firm. For example, in one of the predominantly non-defense-oriented firms approximately 35 per cent of the total engineering staff personnel are engaged in R-D-D activities (including R-D-D management), while in one of the defense-oriented electronics firms nearly three-fourths of the total are so engaged. In an aerospace firm the corresponding proportion is about three-fifths. For all the defense-oriented firms studied, we estimate the proportion of professional technical personnel engaged in R-D-D to be, on the average, about two-thirds of the total; and for all the predominantly non-defense firms (excluding the communications-equipment and atomic energy laboratories, which are virtually 100% R-D-D) we estimate the corresponding average proportion to be in the vicinity of two-fifths.*

Having noted that the requirement of continual updating applies only to the R-D-D engaged professionals, the large majority of the managers recognized that some members of their engineering and applied-science R-D-D staffs -- the estimated numbers varied widely -- have not kept abreast of recent developments, and consequently are deficient in currently-required knowledge and skills. It was asserted, in most instances, that the skill-deficient individuals are found largely in the middle and upper age brackets.**

*These ratios may be compared with the corresponding percentage for engineers and scientists in all U.S. industries in 1960 shown in Chapter IV. The engineers engaged in research and development (including R & D management) comprised 34.5 percent of all engineers employed in industry; and the corresponding proportion for scientists engaged in research and development was 47.8 per cent of the industry-employed total. The combined total number of industry-employed engineers and scientists was 813,000; and the combined number engaged in research and development was 303,000, or 37.3 percent.

**On the basis of quantitative data on the age distribution of their "technical" staffs furnished by several of the firms, we estimate that approximately 45 percent of the engineers and scientists employed in the defense-oriented firms, and approximately 55 percent of those employed in the predominantly non-defense firms are in the 35-and-over category. Thus it may be said that the middle-and-upper age individuals among the engineering and applied-science professionals, who constitute the principal "problem group" in the firms studied comprise roughly one-half of all R-D-D personnel; who in turn comprise from one-third to three-fourths of all professional technical personnel.

However, those managers whose technical organizations include <u>basic</u> -- or <u>exploratory</u> -- research units were nearly unanimous in affirming that there is virtually no backsliding among the scientists engaged in this type of work in any age bracket.

The findings summarized above might, at first thought, seem to indicate that the deterioration of skills among engineers and scientists is a considerably less serious problem than the fears expressed in the recent literature on the subject would suggest. However, before we attempt any further examination of this question, it is necessary to discuss some of the difficulties involved in recognizing the nature and extent of the technical skill obsolescence problem, both for the individual practitioner and for the employing firm.

CHAPTER IV

THE RECOGNITION OF OBSOLESCENCE

The Problem for the Individual

By its very nature, skill deficiency is not easily discernible, either by the individual directly affected or by the firm for which he works. A gradual process, it will usually go unrecognized until the onset of some crisis -- by which time the ability to deal with it may be greatly limited.

In the case of the individual, awareness of the problem may come about in any one of several ways. As Alfred Malmros, Assistant to the President of IBM Laboratories, Owego, New York, has pointed out:

> (1) Busy as he may seem in trying to solve day to day problems, [the engineer or applied scientist] finds himself less inclined toward rigorous mathematical solutions to his problems. In many instances he may find he has forgotten much of what he has learned, or comes to the conclusion many of the things he learned he never really needed to know.
>
> (2) As he attempts to read newly presented papers in his particular field, he finds that they are exceedingly difficult or almost impossible to understand with the somewhat frustrating feeling that he cannot follow the mathematics.
>
> (3) As he reads and is able to understand some of these papers, or as he comes upon something new, developed by one of his competitors, he may ask himself, "Why didn't I think of that?" Further investigation somehow tends to reveal that there are a lot of new concepts coming up in all directions, all of which are confusing and make him wonder in what direction his field of technology is going.
>
> (4) Then new task assignments begin to look

> preposterous and far too difficult to be "practical." He is unable to grasp the sense of doing things in these new ways and [feels certain] that these new assignments will surely lead to disastrous results.
>
> (5) Finally, he comes to the realization that his contemporaries no longer seek out his advice. He doesn't seem to catch on to new-fangled ideas and he finds himself quite often countering with the question, "What's wrong with the way we are now doing it?"*

Even as the engineer (or applied scientist) first begins to become aware of the problem, his ability to cope with it may be hampered by a reluctance to do anything which might be interpreted by the outside world as evidence of personal inadequacy. Or he may not yet be prepared to admit to himself that his skills have, to any significant degree, deteriorated. This psychological barrier can be seen in the experience of those large firms which have organized in-plant training programs or have established tuition-refund plans for employees attending local universities or schools. Almost all of them report that while the problem of "obsolescence" or skill deterioration seems to be most serious among the older engineers and scientists whom they employ, the courses are filled primarily by the younger members of their staffs, with relatively few employees over 35 taking advantage of either the in-plant training programs or the tuition-refund plans.

*Alfred Malmros, "Obsolescence of Engineering and Scientific Personnel in Industry," Proceedings of the Midwest Conference on Reducing Obsolescence of Engineering Skills, Sponsored by the Illinois Institute of Technology, March 26-27, 1963. p. 20.

One explanation for this finding seems to be that after a certain age, the deterioration of initial knowledge acquired at college but not subsequently used is so great that it presents an insurmountable barrier to the engineer or scientist who would now like to take up one of the recently developed areas of knowledge. His intellectual base having been eroded away, he may find himself lacking the basic mathematical or other skills necessary in order to approach the new topic; and if he is not discouraged from even registering for the course, he may soon be forced to drop out of class by his inability to keep up with the work assigned.

The problem is made all the more acute by the extent to which the new technical subjects taught either in in-plant courses or at nearby colleges have, as their prerequisite, knowledge of advanced mathematics or one of the modern basic sciences -- subjects which may not have even been offered when the engineer or applied scientist was an undergraduate. An engineer for one of the large oil companies, for example, after returning to school to obtain his doctorate 20 years after he received his bachelor of science degree, reported back to officials of the company that he would probably be "the last of his vintage to be able to bridge the gap between the disciplines of his day and the present, simply because of the barrier to comprehension created by the new mathematics which has come into existence since his time."* If engineers

*Robert Gunness, Executive Vice President, Standard Oil Company of Indiana, "Keynote Address," Midwest Conference, op. cit., p. 58.

who have made a reasonable effort to keep abreast in their fields find the gap so hard to bridge, those who have not even tried to keep up will find the obstacles impossible to overcome.

Aside from the difficulty created by the hiatus since graduation, engineers and scientists over 35 are less likely to take advantage of in-plant courses and tuition-refund plans for another reason. With age comes increasing family and community responsibility, leaving less time after the normal working hours for attending classes. This is a factor frequently cited by company officials in charge of continuing education programs in explaining why the older engineers and applied scientists take such little advantage of these opportunities for replenishing their intellectual capital. The situation is made worse to the extent that a company is likely to require its more important engineers to put in long hours of overtime in order to complete crucial projects.

Ways of Escaping the Problem

One means of escape, of course, for the engineer who feels himself becoming obsolescent is to move into some other area of the firm's operation, one which makes less demands on the individual to keep up to date in his technical field. It is possible, in fact, to define a hierarchy of engineering and applied-science activities, relating the various types of work performed to the level of advanced technical competence and creativity required. At the top of this hierarchy are the engineers and applied scientists engaged in research, development and design, the area of activity where being conversant with the latest techniques is most essential and thus where skill deterioration poses the most serious problem. This category of technologists can be divided into those doing the actual applied research and development, that is, taking new ideas and showing that they can be practically applied, and those doing the design work, that is, turning the researcher-developers' prototypes into marketable products.

While numerically smaller, the former group is by far the most important, for it is from them, the research and development engineers and applied scientists, that any new products which a firm may have to offer will ultimately stem. In the defense-oriented companies, which in a sense are in the primary business of developing new products, they play an even more significant role. At the same time, since they are engaged at the frontiers of technology, the need to be up to date in terms of the latest developments in their respective fields is all the more crucial.

Even within the research-and-development staff, one finds a hierarchy in terms of the level of advanced technical competence and creativity required. At the pinnacle are the so-called "key" engineers and applied scientists. It is they who are responsible for originating the ideas that will eventually become new products, and to do so they must not only be knowledgeable about what is occurring at the forefront of their field but must also be able to use the mathematical and other advanced techniques necessary to move forward in the area. It is here, among these "key" personnel, that the distinction between scientist and engineer ceases to have much significance, for whatever the type of formal training they may have, both are engaged in a high level process of creation. As project leaders or "systems engineers," these key scientists and engineers usually work in cooperation with other professionals who, though often less creative, have a closer and more detailed knowledge of the particular specialized areas involved in the development project being conducted.

Moving down the scientific and engineering hierarchy, past the design engineers, the next major category consists of the production engineers, those engaged in the actual manufacturing process. They include industrial engineers, quality control engineers, manufacturing engineers, etc.. Here the demands to keep abreast of the latest developments in their field or to be creative are considerably less than those made on even the design engineers. Finally, at the bottom of the hierarchy in terms of the need for up-to-date knowledge are the engineers and applied scientists engaged in sales, service and related activities.

The following table indicates the relative distribution of scientists and engineers among major functional categories:

Scientists and Engineers in all U.S. Industries,
by Functional Area, January 1960

	Total	Research and development	Production and operations	Other activities	Management and administration of Research and development	Management and administration of All other activities
			Number			
Scientists	163,800	66,700	41,200	34,900	11,600	9,300
Engineers	648,900	190,400	268,800	97,500	33,800	58,400
			Percentage Distribution			
Scientists	100.0	40.7	25.2	21.3	7.1	5.7
Engineers	100.0	29.3	41.4	15.1	5.2	9.0

Source: National Science Foundation, Scientific and Technical Personnel in Industry, 1960. (NSF 61-75), page 25.

As can be seen from the table, only 40 per cent of the scientists and 30 per cent of the engineers employed by private industry are engaged in what may be broadly classified as research and development work, the areas of activity where skill deterioration is likely to be a serious problem. (The percentages would, of course, be much higher for scientists and engineers holding advanced degrees, but at the same time the nature of graduate training is such that scientists and engineers with advanced degrees are much more likely to make a serious effort to keep abreast of new developments in their fields.)

The decision to go into one of the other areas of scientific and engineering activity in which there is less need to keep up to date is usually made upon graduation, when the individual may opt for a career in production or sales engineering. But a switch into one of these other areas later in one's life is also possible, thus providing some alternative to the scientist or engineer who finds that he is no longer able to keep pace with the demands made in research and development activity. However, the transition is not necessarily easy, especially the older the individual is, and it will usually be accompanied by some loss in income as a result of the lower salaries paid the lower one descends in the hierarchy outlined above The only exception to this general proposition is that of sales engineering (in those cases in which the amount of compensation is based on commission.)

Moreover, as one would expect, the movement can only be in one direction. While a design engineer may possibly switch to production engineering and a production engineer to sales, a sales engineer will generally have great difficulty in moving into production work and a production engineer in moving into design work. In the research and development area, the career patterns are somewhat more complex, in that many of the so-called "key" engineers begin as design engineers and then, as they display creative talents, are gradually brought into the earlier phases of the developmental process. However, within a few years after an engineer or applied scientist begins working in research and development, he will have been judged as being capable of doing creative work or not, and if the latter is the case, he will be typed as simply a design engineer, with movement into the research area *per se* virtually precluded. At this point, movement down the scientific and engineering hierarchy is possible, but movement up is not.

Movement Into Management. Because of the decline in earning power which is usually attendant on movement down the hierarchy, this may appear as an unattractive alternative to the scientist or engineer apprehensive about his ability to keep abreast of development in his field. Far more appealing is a movement out of engineering itself into general management (as distinct from R-D-D management), where the individual not only avoids a loss of income but is in fact likely to increase his salary. From the above table it can be seen that almost 6 per cent of all scientists and 9 per cent of all engineers employed by private industry are engaged in either non-R-D-D management or administration: and the attractiveness of this alternative is evidenced by the fact that the most popular of all the subjects taught in in-plant programs or offered under tuition refund plans are courses in the business management area. Movement into administration is made easier by the fact that technical competence is less important than other abilities in determining success on the job. These other abilities involve being able to work with people, getting them to do what is desired of them.

This is not to say that all of those who go into management do so in order to escape the problem of deteriorating skills. In fact, in many cases, quite the opposite appears to be the case. For one thing, many individuals go directly from engineering school into management training programs, with the result that their technical abilities are not even tested. Moreover, those who are the most creative and the most up-to-date in their fields are often attracted to administrative positions by the generally larger salaries they pay, and in this way highly productive engineering and scientific practitioners are lost to the profession. This drain of the best talent poses a serious problem, both to individual companies and to the society as a whole, and some of the firms interviewed in this study have taken steps to deal with it. Several companies have established for their professional technical staffs separate ladders of promotions and salaries, together with perquisites, equal at each equivalent stage to those received by management personnel. In the case of yet another company, an attempt has been made to eliminate the distinction between management and staff, making each of its research people responsible for a different aspect of management. How successful these innovations have been could not be determined, but they are at least suggestive of how the problem can be approached.

If the disadvantage of using the best technical people to fill management positions is the resulting drain on the company's scientific and engineering resources, the disadvantage of using the not-so-good people is the danger that those with the power to make important decisions may lack the competence to do so. The whole direction which a research project takes may be altered for the worse by the fact that the person in charge is not familiar with or cannot comprehend the approach which the latest scientific knowledge would dictate. This is, of course, a much more important consideration in R-D-D than in other areas of engineering and scientific activity. On the question of which is the greater evil, opinion among those interviewed in this pilot study was divided. Of the 14 company officials who spoke directly to this point, eight felt that it was not as important for the R-D-D managers to be fully up to date as for the persons they supervised. Their view was that the managers must be sufficiently abreast of new developments in the several disciplines represented on their staffs to judge the competence of their subordinates and to make sound choices on ideas and designs developed by them, but that this does not require the same degree of detailed expertise as is required for originating and designing fruitful technical innovations. In contrast, the six other officials interviewed held that it was just as important for the managers to be fully up-to-date in all relevant disciplines as the persons working under them. One reason given for this view was that the managers must make decisions with regard to adopting new R-D-D approaches and techniques, and that this requires a detailed and sophisticated knowledge of the latest developments. Those who made this point also noted that the manager, in addition to planning and supervising the technical aspects of his unit's activities, must perform all the necessary human relations and administrative functions involved in managing a group of highly individualist professional people. These responsibilities, it was held, are so arduous and time-consuming that the technical managers have little time to keep abreast of new scientific and technological developments. In the opinion of one company official, himself a high-level engineering manager, it is not possible for a R-D-D manager to maintain mastery over both these aspects of his job.

Whatever the truth may be as to the extent that R-D-D managers need to be as fully up to date as those whom they supervise -- and this is a question involving a clearly subjective evaluation -- it would appear that some engineers and applied scientists who feel themselves slipping are likely to find refuge in <u>general</u> management or administrative positions, just as some of the most creative and knowledgeable technical professional people who go into those areas will, because of the demands made upon them, find they are unable to remain up to date. This fact is reflected in the concern expressed by several of the company officials interviewed, entirely on their own initiative, over the problem of skill deterioration among <u>technical</u> managers.

Still, there will be many engineers and scientists for whom the alternative of entering management is not feasible, either because they lack the necessary skills or motivation to become administrators or because the number of such positions is limited. They will remain at their old jobs, unable or unwilling to take the steps necessary to reverse the process of skill deterioration, hoping that nothing will happen to make their worst fears a reality. If they, and the company they work for, are fortunate, nothing may, in fact, occur to disturb the uneasy equilibrium. But on the other hand, the day of reckoning may finally come, and they may suddenly find themselves, at an advanced stage of life, not necessarily exposed as "obsolescent," but simply let go from their job as a result of the reduction in the work force made necessary by a decline in the company's business. With the loss of a job may finally come the recognition of skill deterioration which can no longer be avoided.

Many skill-deficient engineers and applied scientists, of course, remain on the job, even in the critical R-D-D areas of the firm. The majority of managers interviewed in this study, when questioned on this point, expressed the view that since these individuals do not carry their weight in their assigned project groups, they should be shifted to non-R-D-D work or, if that is not feasible, should be dismissed. However, it appeared that in only a small number of cases has such action actually been taken. In the large majority of the firms the backsliding technologists have been retained in R-D-D capacities. As to how, and with what effectiveness, they have continued to function, we were able to obtain explicit information in four instances. In each of these cases, the managements assigned younger men, recently educated and well grounded in currently-required knowledge and skills, to project groups composed of or including older, non-updated engineers -- either as project leaders or group members -- in the belief that the new men would supply a sufficient core of needed skill to carry the projects forward effectively, and that their broader and more up-to-date knowledge would in time "rub off" on the older group members. In a number of other instances, the interviewees either frankly admitted or implied that it was not possible, under the performance appraisal schemes in effect in their firms, to identify obsolescent technical staff members in terms of demonstrably unsatisfactory performance in their designated assignments. In still other instances, the respondents justified the retention of obsolescent technologists on the ground that even in R-D-D activities it is not essential that all professionals in a given project group be fully updated and skill-proficient. These managers held that the successful consummation of R-D-D projects is usually dependent on the talents of a few highly creative and highly skilled members of the particular group, and that the remaining members are essentially direction-followers and hence need not be fully and continually up-to-date in knowledge and technological skill. Finally, since virtually all of the subject firms have established in-plant educational programs specifically aimed at updating obsolescent technical personnel,* the managements undoubtedly felt that

*See Chapter V

some of the backsliders could be induced to "update" themselves by taking the necessary courses under the programs.

The Problem for the Firm

Difficulty of Identifying the Problem. Like the individual scientist or engineer, a firm may first have to undergo a serious crisis before it becomes aware of the problem of skill deterioration among its employees. This is a reflection of the blocked information flows which exist in any large organization between the junior executives at the levels where the problems actually occur and the executives at the top with the power to make the decisions needed to deal with the problems. In the case of skill deterioration, where the information may lead to the loss of jobs by certain individuals, the difficulty of obtaining information from below is even greater, with the result that the top management of a firm may remain almost entirely ignorant of the problem until it reaches serious proportions.

The case of one of the companies interviewed in this pilot study illustrates the round-about method in which the top management of a company may eventually become aware of the problem of skill deterioration or "obsolescence." The vice president in charge of industrial relations for the company, a firm with a strong civilian market in its specialized field as well as being a leading defense contractor, reported that the first manifestation of the problem came from its long-service professional people themselves. Some of these scientists and engineers complained that younger, more recently educated and shorter experienced persons were being given preference in assignments and promotions over them, the long-service professional people.

A second indication of the problem came when the employment office reported that it was receiving requests from engineering managers for unusually large numbers of additional design teams. In the past, when the need for a design team arose, it had usually been met by assigning a group which had recently completed some other project and thus was free to take on the new task. When the engineering managers were queried as to why they needed the new design teams, they replied that the old ones were all fully occupied on other projects; but it soon became evident that the real reason was that they did not have confidence in the abilities of the design engineers already to be found in the company. They needed people with scientific and technological knowledge which the existing engineers did not have, and they feared that the persons already on the staff would be unable to cope with the creative design problems involved in the new type of research and development work.

Still a third sign of skill deterioration appeared in connection with the in-plant training program run by the company. Previously, members of the company's own technical staff had conducted the courses, but then it was found that even if they were themselves up-to-date in the new techniques, they were unable to teach them to others.

In the case of this company, the top management was reasonably alert to the indications of the problem, and proceeded to try to do something about it. But in the case of other companies interviewed in this study, it was clear that the top management had either failed to detect the tell-tale signs or else was simply unwilling to admit to others that a problem had at one time or still existed.

The existence of the problem of skill deterioration can be deduced from either one of two possible pieces of evidence -- from the admission that a company has lost the ability to bid on certain types of government contracts and/or the disclosure that the company has in the recent past been forced to lay off a large proportion of its work force. These two possibilities of course are closely related. In the absence of some earlier recognition of the problem, they are the ultimate sign to top management that its company is suffering from the problem of skill deterioration. In the case of those companies engaged in defense work, it would be a particularly serious problem, since the prime commodity which they have to sell to their customer, the government, is the combinations of skills embodied in their work force.

Almost without exception, the firms specifically queried on the subject denied that the existence of skill deficient engineers and scientists precluded them from bidding on government contracts. One official interviewed said that if the required skills were not to be found among his company's present professional staff, management sought out and hired qualified engineers from outside the organization to do the preparatory work. If the company succeeded in obtaining the sought-after business, it then secured the additional qualified engineering personnel needed to carry out the project by retraining members of the existing professional staff or -- if retraining was not feasible -- by further recruitment and hiring of outside persons.

In only one instance did a firm actually concede that the inadequacies of its professional technical staff prevented it from securing government contracts. The company, an electrical equipment producer, has been unable to obtain any major defense business since 1961. That year it briefly held a contract for work on the Titan III missile, but the contract was taken away and given to another firm, apparently because the Defense Department felt the company did not have a sufficiently competent engineering staff to carry out the assigned project. The company's manager of training declared that the large proportion of obsolescent engineers among the professional technical staff had been a major consideration in planning future engineering development work. On several occasions, when difficult military contract projects had come up for bidding, the company had refrained from entering the competition because its top managment felt the engineering staff was not qualified to handle the development problems involved. As a result of this failure to obtain defense contracts, the company's total employment had fallen from 5,700 in 1961 to 1,000 at the time of the interview in 1964, while the employment of engineers had fallen from 1,800 to 250.

It is conceivable that the condition of this company was not unique -- except perhaps in the seriousness of the experience. Failure to obtain contracts because of skill deficiencies on the part of the professional technical staff is as elusive a factor to elicit as the existence of skill deficiency itself, and while a truism, it is nonetheless important to keep in mind that the more creative and up-to-date are the engineers and scientists employed by a firm, the more likely it is to be successful in bidding for government contracts. Thus the response of the firms to the question of whether the prevalence of skill deficient engineers and scientists precluded them from obtaining new defense business needs to be interpreted with due allowance for the methodological weaknesses of the direct interview technique. For example, one of the firms giving a negative answer to the above question was a company which had seen its work force decline from 4,000 people in 1958 to 1,000 people in December, 1964. This same company conceded that none of the 170 engineers presently on its staff was adequately grounded in modern optics, logical circuit design and other recently developed electronic technology necessary for the areas in which the company thought it had the best chance of obtaining future defense contracts. While the company was attempting to solve the problem through the recruitment of outside technical staff, in the meantime it was clear that the inadequacies of its present work force were a serious impediment to its ability to operate successfully.

Given the possible serious ramifications of the problem, one might assume that the companies interviewed in this study would make a major effort to keep track of the quality of skills available within their organizations, paying particular attention to the degree of deterioration or obsolescence which has set in. Yet they have not done this in a systematic manner. Many of the companies do have performance rating systems which require that supervisory personnel evaluate once or twice a year the scientists and engineers working under them. However, these performance rating systems are generally conceded to be of little use in detecting skill deterioration or "obsolescence." The only function they serve, according to an engineering manager for the defense-oriented division of a data processing equipment manufacturer, is in detecting the bottom 5 or 10 per cent whose performance is so poor that they have to be let go, as well as to identify the top 10 per cent who should be groomed for more responsible and demanding positions. As for the other 80 per cent, the rating system, according to this manager, does not afford even a reliable measure of performance, much less an indication of whether skill deficiency is a factor in causing poor performance.

Experience with Layoffs of Technical Personnel. Thus most of the companies interviewed in this study had no way of knowing how serious the problem of skill deterioration was within their professional technical work force -- or who, specifically, among their employees were affected by it -- until the firm, because of a loss or cutback in government contracts, or a decline in civilian business, was forced to lay off workers. Of the 39 firms interviewed in this study, 28 were engaged in whole or in part in defense or space-related activities, and of the latter, all but four had within recent years experienced a significant curtailment or cancellation of contracts. For 18 of these firms -- eight "aerospace" companies producing aircraft, missiles, space vehicles or engines and ten "avionics" companies producing control, guidance and related electronic equipment under sub-contracts to the aerospace firms -- the curtailment or cancellation of contracts necessitated the dismissal of some of their professional technical employees. The usual procedure in such circumstances was for top management officials to decide the overall percentage by which the number of employees must be reduced. It then became the task of each technical supervisor to determine who among those working under him would be let go in order to meet the quota of dismissals. Since in such a situation the supervisor has an incentive to retain the engineers and scientists whom he considers most essential to his designated function, this arrangement tended to weed out those considered least useful and productive, although the actual makeup of the personnel laid off was somewhat surprising.*

Since obsolescence was widely held to be most prevalent among the mature-age engineers and applied scientists, one would expect that this age group would have been the hardest hit by the reductions in work force that have been effected. However, the information obtained from the various interviews indicated that this was not necessarily the case. In fact, the layoffs that have occurred seem to have been concentrated disproportionately among the younger, more recently graduate engineers. The explanation for this surprising finding becomes clear, however, when one examines the experience of individual firms.

In many cases the layoffs were of modest proportions, enabling the firms to trim their work forces without dismissing any but the youngest and shortest service employees -- those whose more recent and better training was not sufficient to compensate for their lack of experience on the job. For, despite the pre-eminent importance of up-to-date knowledge, experience on the job is still a significant component of

*While supervisory judgment of usefulness to the firm was the most common basis of administering layoffs, there were a number of exceptions, most notably in the case of several firms whose professional technical staffs are represented by unions, where the layoffs were based on "inverse seniority." The implications of this basis of determining layoffs are discussed below.

overall skill and productivity. Moreover, since the bulk of the layoffs were concentrated in the non-R-D-D categories, the more up-to-date knowledge which the younger engineers might be expected to have was of less value to the firms.

In those firms where the lay-offs reached major proportions, however, older engineers and scientists -- when the existence of a union seniority clause did not prevent it -- were also let go in considerable numbers. Particularly hard hit in the case of one company was a group of long-service mechanical engineers whose experience was limited to analog computers when the company required engineers knowledgeable about digital computers. In several other companies, those dismissed included many long-service <u>non-degree</u> engineers who had been hired when technical graduates were in short supply.

It should be pointed out at this point that skill deterioration is only one of many factors which may lead to company lay-offs, and that for this reason what has sometimes been cited as the problem of skill deterioration or "obsolescence" actually represents a configuration of many separate and diverse forces. For one thing, the chain of events by which the problem of skill deterioration becomes manifest is usually the loss of business by the firm, whether through a decline in civilian sales or through a failure to obtain government contracts. In some cases, the loss of business can be directly attributed to the deterioration in skills which has set in among the engineering and scientific staffs. Certainly the failure on their part to come up with new ideas and new products will ultimately result in a decline in the demand for the company's products. However, a decline in sales can occur for a great many reasons wholly unrelated to the quality of a company's engineering and scientific personnel. This is true even in the aerospace industry where the calibre of the research and development staff is perhaps most important for obtaining new business.

A decline in sales can, in fact, occur for reasons entirely beyond the control of an individual company, such as the decision by the Department of Defense to abandon one strategic defense concept for another, or the decision by electrical utility companies to use nuclear rather than conventional power units. It is no mere coincidence that the specter of "obsolescence" was first raised at a time when the Department of Defense was undergoing a major change in procurement emphasis. As a result of policies instituted by Secretary McNamara, the construction of prototypes of new defense weapons systems was abandoned in favor of "systems" -- i.e., detailed plans not carried to the prototype stage. This change from "hardware" to "software" was part of a larger economy drive instituted by the Department of Defense, which also included the change from cost-plus to competitive bidding contracts and the cancellation of various weapons systems programs which had been superseded by more advanced systems or methods. Together, these policies had a profound effect on the defense-oriented companies, particularly in the aerospace and avionics industries, where the largest proportion of engineers and scientists are employed. It meant a greatly reduced demand for production and, to a somewhat lesser degree, design engineers; it was shortly after this change in Defense Department policies that the problem of "obsolescence" began to occupy public attention.

'Stockpiling' of Engineers. That this change in Defense Department emphasis had such a profound effect was due, at least in part, to one aspect of the way in which the defense business is conducted, an aspect which at the same time further conceals the problem of skill deterioration. This is the fact that in order to obtain government contracts, individual companies must be able to demonstrate that they have the engineering and scientific capacity to carry out the projected assignment. Since the judgment is usually based on the quantity of such personnel, the requirement leads to what is known as "stockpiling," the hiring and retention of engineers and scientists, regardless of whether they are directly productive to the firm, simply in order to be able to bid on government contracts. On the one hand, this practice means that the firm has less reason to be concerned about the extent of skill deterioration among its professional staff, and on the other, it means that many engineers and scientists are easily expendable when it becomes necessary to order large lay-offs. Needless to say, these are corollary propositions to the main points, the waste of valuable resources implicit in the practice of "stockpiling."

The accelerator effect which "stockpiling" can have on defense company layoffs was explained by the official of one company interviewed in the study. Describing the reductions in their work force which many companies had experienced as a result of the McNamara policies, he said, "I believe the layoffs have been proportionately greater than the reduction in business volume resulting from the defense cutbacks. Prior to the beginning of the cutbacks, many defense companies were stockpiling engineers, that is, they were employing more engineers than they needed in anticipation of possible future expansion of engineering activities. With the announcement of the economy drive in the military procurement program, including cutbacks, cancellations, etc. the managements have realized that there is little prospect of any expansion in the near future; hence they have laid off not only the engineers made redundant by the cutbacks but also the stockpiled engineers."

The same company official added that he felt that a large proportion of those laid off were obsolescent in the sense that they were ill-suited for jobs in civilian-oriented companies. "For one thing," he said, "many have been working for extended periods on narrowly specialized tasks on particular types of military equipment. Second, in the military work they have been doing; they have not had to consider costs to any significant extent, whereas in civilian-type engineering cost-consciousness is a primary requirement. Third, the salary ranges for engineers in defense-contract establishments are substantially higher than in civilian-product establishments, for example, $17,000-$18,000 a year as against $13,000-$14,000 a year for comparable work and responsibility."

To sum up the foregoing: the <u>exposure</u> of the problem of technical skill deterioration was due largely to the economy-oriented revisions in Defense procurement policy and practice and -- in lesser part -- by the existence of stockpiles of professional technical personnel. That is, the inability of "obsolescent" R-D-D engineers and applied scientists to show effective performance would probably not have come to light -- or, at any rate, would not have become a major issue -- had not a spate of defense firms been forced by cancellations and cutbacks to reduce their technical workforces.

<u>Unionized Engineers and Obsolescence</u>. Still, this is not to say that skill deterioration is not a serious enough matter to warrant public attention. From the point of view of society as a whole, it represents the loss of a most valuable resource, one which required a considerable social investment at some earlier period. For the individual firm, too, it is an ominous matter. As has already been suggested, the deterioration of its engineering and scientific work force

may ultimately lead to a decline in the firm's business, which in turn will lead to a reduction in employment. Once the problem has reached these serious proportions, it becomes increasingly difficult to do something about it. The firm which is experiencing declining business and falling employment will have difficulty, not only in attracting new engineers and scientists but also in holding on to those it already has. And since it will be the better, more up-to-date professionals who will have the best choice of obtaining jobs elsewhere, those who remain behind in the firm's employ will be those least able to reverse the downward slide.

Again, the existence of a union in the technical workforce can make it all the more difficult for a company to get out from under its problems. For if the union insists on a seniority clause in its contracts, the company is forced to retain its older engineers and scientists when lay-offs become necessary and let go those with less time on the job. Since it is the older engineers and scientists who are usually most affected by the problem of skill deterioration while it is the younger, more recently graduated professionals who have the needed new skills and techniques, the existence of the seniority clause simply compounds the company's problems.

For the most part engineers and scientists have proved resistant to the appeals of unionism. Of the 39 firms studied, only six were companies whose professional technical staffs were organized for collective bargaining, three of these being located on the West Coast and three on the East Coast. In this connection there was an interesting difference between the engineers' unions on the West Coast and those on the East Coast. The latter were affiliated with the AFL-CIO, and were not only more militant but also were prone to follow the practices of labor organizations in the blue-collar occupations. The West Coast unions, on the other hand, were independent organizations which acted more like professional associations than trade unions. This difference was reflected in the fact that the East Coast engineers' unions had seniority clauses in their contracts while those on the West Coast did not.

An official of an East Coast defense firm, one whose sales to the government have greatly fallen off as a result of a shift in basic military technology, explained what the effect was of having the company's engineers organized in a union affiliated with the AFL-CIO labor movement. "Our contract with this organization," he reported, "contains a strong seniority provision governing layoffs and other changes in employment status. Consequently, in effecting reductions in engineering staff over the past four years we have had to lay off our younger, shorter-service engineers, and as a result most of the remaining staff are people who have been with us twelve years or more, and who graduated from college prior to 1951 or 1952. Few of these engineers are adequately grounded in optics, logic design and other subjects required for our projected future development and design program." Thus, the company was further handicapped in its efforts to shift the direction of its activities more in line with current defense needs. Another company, however, faced with a similar problem, was able to persuade the union representing its professional technical staff to let it deviate somewhat from the seniority provisions of the contract so that it might hire a certain number of younger engineers, grounded in the new technical subjects in which the firm needed to have a competence in order to be able to bid for future defense contracts. This concession by the union, it must be added, came only after the firm had undergone a serious decline in both business and employment.

As already indicated, only a few of the firms interviewed were companies whose engineers and scientists were organized into collective bargaining units. But of this small number of firms, a significant portion were also companies which had at one time or were presently plagued by the problem of skill deterioration and resulting layoffs. This might suggest, then, that to the extent that skill deterioration becomes a much more serious problem for some firms, leading to increased fears as to job security, the chances of further organization of engineers and scientists may increase.

CHAPTER V

WHAT THE FIRMS HAVE DONE ABOUT THE PROBLEM

Educational Programs

It is primarily through educational programs that firms have attempted to deal with the problem of skill deterioration among their engineering and scientific personnel, and the two most widely adopted types of such programs, as previously indicated, are tuition refund plans and in-plant continuing education courses. Under the first type, professional technical employees who pursue after-hours studies at nearby colleges or universities are reimbursed by their companies for all or a major portion of their tuition costs. The in-plant courses, as the name indicates, are conducted on the companies' own premises, with the companies assuming the entire cost. Special courses or programs, arranged between a particular company and a university and conducted by the latter, constitute a third though much less common type.

Tuition Refund Plans. Tuition refund plans are the most common of all such programs, and they were found to be in effect in 36 of the 39 companies studied. The proportion of tuition costs reimbursed upon successful completion of the courses ranged from two-thirds to the full amount, with the great majority falling in the latter category. While employees are free to take any courses related to their work, most of the engineers and scientists who participate in the tuition refund plans either are working toward a master's degree or else are enrolled in non-credit university programs designed to update their knowledge and skills. Such programs are established in technical colleges and universities in nearly all of the urban areas visited, including Boston, New York, Philadelphia, Pittsburgh, Los Angeles and San Francisco, and in a number of others. These programs are, for the most part, offered in the evening after working hours. Several of the universities also conduct short daytime up-dating courses on a full-time basis.

In-Plant Programs. Twenty-four of the firms surveyed also were found to conduct in-plant technical education programs. In addition, three other firms hold intermittent in-plant courses or lecture series. Unlike the tuition refund plans, most of which have been in effect for ten to forty years, the in-plant programs have mostly been established within the past five years. Also unlike tuition refund plans, most of which apply to both technical and non-technical subjects, the in-plant programs are designed specifically to combat technical skill obsolescence. They consist almost entirely of mathematics, science and similar courses aimed at extending the skills of the company's technical personnel.

In 21 of the firms, the curricula of the in-plant programs are quite extensive and include many courses found in continuing education programs in nearby universities. The reason for this overlap, it was explained, was that the universities, while located in the same general area as the companies, were still sufficiently far away so that it required considerable traveling time to reach them, and this had the effect of discouraging employees from attending classes there. The in-plant programs, moreover, since they begin immediately after the normal quitting time, merely extend the normal workday instead of consuming an entire evening, and this also made the programs more attractive. In another three instances, in-plant training programs had been or were in the process of being established because no university facilities were available within a reasonable traveling distance.

It is noteworthy that the in-plant programs encountered in the study were confined largely to defense- and space-oriented firms. Ten of the 11 aerospace firms studied and 9 of the 13 "avionics" -- that is, defense-oriented electronics -- firms conducted comprehensive in-plant programs consisting of at least 20 separate courses. Moreover, two smaller avionics firms studied offered somewhat more limited in-plant programs comprising five and three courses respectively. Broad curriculum in-plant programs were also found to be in effect in the five large diversified firms studied which, though not predominantly defense-oriented, were all involved in defense projects on a major scale. In contrast, seven of the nine non-defense-oriented firms do not have in-plant programs, or at most conduct only occasional in-plant courses; only two -- a large oil company and a communications research-and-development firm -- have comprehensive in-plant programs. It is worth noting that in five of the seven first-named firms the managers considered that they had either no skill obsolescence problem, or only a minor one; whereas 17 of the 23 defense-firm managers classed the problem as serious or sizeable.

Other Types of Educational Programs. As noted earlier, programs conducted for particular firms by technical colleges or universities constitute a third, though much less important, type of continuing education arrangement. Four such programs were found among the companies interviewed in this study. Another type of educational arrangement, the doctoral study program, also deserves mention in this connection. It enables selected professional employees who have already obtained their master's degree to pursue full-time or major part-time studies toward their doctorate, with their companies continuing to pay at least a major portion of their salaries. This arrangement was found among nearly half of the firms studied. Finally, to complete the roster of continuing education efforts, three of the firms interviewed in this pilot research project had established special updating educational programs specifically designed for technical managers.

Determinants of Type of Program

The ability of firms to provide any one of these various alternative means of updating and maintaining professional skills seems to be determined by three factors. As already indicated, the in-plant training programs are to be found primarily among defense- and space-oriented firms. There are two possible explanations for this finding. One is derived from the fact that the pace of technological development is more rapid in the defense- and space-oriented industries, this because government agencies are able to mandate changes in products and techniques independent of market considerations and the other social forces which tend to inhibit technological development in other industries. Because the pace of technological development is more rapid, the problem of skill deterioration, for reasons outlined earlier, is greater; and the defense- and space-oriented companies, aware of the more serious problem, have therefore been more active in doing something about it. The second explanation for the existence of in-plant training programs primarily among defense- and space-oriented firms relates to the ability of these firms to charge off a certain proportion of their expense to the government under the provisions governing defense and space contracts. Under present regulations, they are allowed to include, as part of their costs in determining bids, 156 hours of study a year for each of their technical professional employees. Thus, they are able to pass along part of the cost of such training programs to the government, an option not available to firms engaged entirely in civilian work.

The ability to provide continuing education programs is also dependent on the firm or plant's proximity to technical schools and universities. In the case of tuition refund plans, this point would appear to be obvious. But even in the case of in-plant training programs it is still valid, since many of the instructors, especially in the more general subject areas, are drawn from nearby institutions of higher learning. Companies with plants in the Boston, New York, San Francisco Bay and Los Angeles areas have little difficulty in this regard, for they can draw on the several distinguished engineering schools in those areas, many of which have continuing education programs specifically directed to meeting the problems of private industry. Companies with plants in other areas, however, may well encounter serious problems in trying to provide up-dating for their professional technical people, and this, in turn, not only will handicap efforts to prevent skill deterioration but will also make it more difficult to attract high caliber engineers and scientists. Confronted by this situation, several companies have succeeded in persuading engineering schools to provide continuing education programs in the communities where they are located, but this has not been possible in all instances.

Seen from this viewpoint, it is clear why proximity to top-rated engineering schools is an important factor in determining where a company should locate a new plant. It is for this reason that so many technically-oriented firms have located along Boston's Route 128, and in the New York, Philadelphia, Chicago, New York Los Angeles and San Francisco Bay metropolitan areas. The fact that other firms have done the same brings a further benefit, for in many cases the instructors in the particular in-plant program are drawn not only from nearby universities but also from other firms. This, then, gives rise to a true type of external economy.

Economies of a different type, economies of scale, characterize the third factor which determines the ability of a firm to provide continuing education programs, for it is clear that a firm must be of a certain minimal size before it can bear the expense involved in setting up an in-plant training program. One small company, for example, which had experienced such a severe problem of skill obsolescence that it was unable to bid further on government contracts, tried to establish an in-plant training program, but because of limited financial resources it was unable to offer more than half a dozen courses. Another firm, at one time a major aerospace company, reported that it had conducted a comprehensive, in-plant continuing education program until contract cancellations reduced the size of its professional technical staff from 1,800 to 700. "When the slump came," an official of the company said, "we were forced to discontinue this program because it was too costly. However, we plan to re-establish such a program as soon as our business volume is sufficiently great to cover the expense."

Content of In-Plant Programs. Thus the probability of a firm having a broad, well-rounded program to provide continuing education for its engineering and scientific personnel is maximized when it is a large defense contractor, located near Boston, New York, Philadelphia, Chicago, San Francisco or Los Angeles. But even when these optimal conditions are met, the present programs may still be unable to touch at the heart of the problem of skill deterioration. It is not that the programs fail to offer the courses that are necessary for updating. In the case of modern mathematics -- the principal tool of engineers and scientists -- almost all companies offer as part of their in-plant continuing education programs courses in the three most important sub-areas: (1) calculus and differential equations, (2) probability and statistics, and (3) numerical analysis and the use of electronic computers in solving research problems. In the case of modern physical science, courses are also offered in the three most important sub-areas: (1) nuclear physics, (2) solid state physics and (3) optics. In addition, most programs offer courses in plasma physics, cryogenics, thermodynamics and electrochemistry. Apart from these widely included subjects, the in-plant program of each company is geared mainly to its own needs. For example, a major aerospace firm offers courses in advanced space-age materials, bioastronautics, cryogenic engineering, aerodynamics of compressible fluids, and structures for high speed aircraft subject to elevated temperatures. A large electronics firm offers courses in logic design, theory of semiconductors, transistor circuit design and microelectronics.

Shortcomings of In-Plant Programs.

The shortcoming of these programs is that they presuppose a high degree of motivation on the part of those whom they are designed to help, with the result that those engineers and scientists who are most in need of updating benefit the least from them. This becomes at once clear from the statistics on which engineers participate in the various continuing education programs. Sixteen of the 19 firms queried on this matter reported that attendance was markedly greater among the more recent graduates. Two firms indicated that there was no difference between the older and younger engineers and scientists in this respect, while only one firm said that participation was greater among the older members of the professional technical staff. On the whole, therefore, it would appear that the older engineers and scientists, for whom the problem of skill deterioration was reported to be most serious, were the ones least likely to take advantage of the continuing education programs offered by their companies. The reasons given for this situation, as already indicated, included the greater family and community responsibilities of the older engineers and scientists, as well as the waning of energies and creativity that comes with advancing age. But perhaps the most important reason was the fact that many of these older professional technical people lack the basic mathematical and scientific grounding to take advantage of the advanced courses offered in the various programs.

To deal with the particular problem of the older engineer and scientist, several firms have adopted experimental approaches. One firm, a large electrical equipment manufacturer, has established three separate programs specifically designed for engineers ten or more years out of college. Under the first of these programs, a full-time, two-week series of courses is offered in modern mathematics, matter and materials and basic systems concepts. The other two programs comprise a series of evening seminars, conducted in cooperation with a nearby technical university. One series deals with new areas of science and technology applicable to particular phases of the firm's operations; the other deals with modern mathematics. These separate programs designed for older engineers and scientists serve to eliminate the uneasiness which the older people have when they are forced to take courses with younger, more recent graduates who not only have a more thorough grounding in the new mathematics and the new physics but also may occupy subordinate positions within the company hierarchy. Another company offers special counseling for its older professional technical people.

While it is easier to pinpoint the older engineers and scientists as being affected by the problem of skill deterioration, they are by no means the only ones so affected; and what is true of the older engineers and scientists in regard to updating is probably also true of the others affected by the problem of "obsolescence" -- that those who need the updating the most are probably the ones least likely to take advantage of continuing education programs as they are presently constituted. In the 20 firms for which it was possible to obtain such information, the average rate of participation in continuing education programs of any type among all technical professional people was 22 per cent. However, the percentage varied quite widely among the 20 firms, as low as 4 and 9 per cent in the case of two miscellaneous machinery firms and as high as 40 and 50 per cent in the case of two electronics firms. In general, defense- and space-oriented firms had a larger portion of their technical professional staffs enrolled in continuing education programs. Moreover, the rates of participation also varied quite widely within firms, most of the persons involved in the continuing education programs being engineers and applied scientists engaged in research and development work.

Some Implications

One might, on the basis of the above, conclude that the updating of professional technical personnel occurs where it is most needed -- in defense- and space-oriented firms (and a limited number of large civilian goods producers which have been active in developing new products and processes) and among research and development personnel -- though even in this narrowed category there are still significant numbers of engineers and scientists uninvolved in programs to keep their skills current. Certainly many of the persons interviewed in this study did agree that research and development personnel in defense- and space-oriented firms do have the greatest problem of keeping abreast of new developments in their fields.

However, there is a broader aspect of the problem. While it is true that the greatest danger of unemployment arising from skill deficiency is among R-D-D engineers and scientists engaged in defense and space work, there is no reason to assume that the basic problem itself, that of skill deficiency, is similarly confined. In fact, the manifestation of the problem among the R-D-D staffs in defense and space companies may be merely the visible portion of the iceberg that is the skill deficiency problem in American industry. The rest may remain hidden not only because it is so difficult to evaluate and measure skill deficiency but also because of the factors peculiar to civilian types of industry which tend to impede the rate of technological change. In those non-defense areas, the manifestation of the problem is not redundant engineers and scientists unable to obtain employment at levels consistent with their training and experience but rather the failure of the product to evolve and change in response to the new techniques and the new areas of science. The engineers and scientists are able to continue functioning in a manner satisfactory to management, not because they have succeeded in keeping abreast of new developments but because the new techniques and approaches not having penetrated, there have been no significant new developments. If it is true that skill deterioration is a function of changing technology, it is also true that a changing technology is a function of the level of skill. This problem, of course, is much broader than simply a lack of updating among professional technical personnel. It involves as well the level of managerial skills and the willingness of management to innovate -- topics which are beyond the scope of this study.

We would conclude that while the manifestation of skill deterioration has created a serious problem mainly among R-D-D engineers and scientists engaged in defense and space work, the basic problem applies across all of industry, raising the issue of how engineering and scientific resources might be better utilized. This question is relevant, not only to certain of the civilian sectors of the economy but also to those professionals who do not take advantage of existing continuing education programs in the defense and space fields. As already indicated, the present programs for continuing education are directed primarily to those who are highly motivated. The point being raised here is whether programs can not also be devised for those less highly motivated -- in particular, the providing of updating courses at company expense and <u>on company time</u> -- and whether such programs would be worthwhile in terms of the alternative use of the resources required to establish them. This question pertains not only to the problem of the older engineers and scientists, for whom there are particular considerations -- the reduced drive and energy associated with greater age on the one hand and the shorter time left to recover the costs on the other -- but also to others who, under existing arrangements, lack the motivation to keep themselves current in their fields. Thus the ultimate issue is: to what extent can skill deterioration be halted among those for whom little is now being done, and would the cost be justified by the benefits to be derived therefrom? While we cannot provide the answer, we can at least point up the urgency of the question.

CHAPTER VI

MAJOR FINDING AND CONCLUSIONS; AREAS AND PROBLEMS OF NEEDED FURTHER RESEARCH

In the preceding chapters we have set forth, in summary terms, the experience of the firms studied with the technical skill obsolescence problem, as recounted by the engineering and research managers and other executives interviewed. In this concluding chapter we first recapitulate the most important of these study findings, indicating the salient relationships among them; and attempt to assess the significance of these aspects of the firms' experience for dealing effectively with the obsolescence problem. In the second section we discuss certain sectors and aspects of the problem area in which a need for further research is indicated, and some of the methodological considerations involved.

Major Findings and Conclusions

As shown in Chapter II, the basic reasons why the problem of skill obsolescence among engineers and scientists has come to the fore in recent years are: (a) the unprecedentedly rapid rate at which new developments in science and technology have emerged during the past twenty-five years, and (b) the radically novel character of many of these developments. As has also been shown, these innovations have had a major impact not only on the defense-oriented industries (aerospace and "avionics") but on a wide range of industries primarily engaged in producing civilian products, including electrical and electronic equipment and end products, machinery and mechanical equipment, transportation equipment, primary metals, chemicals, pharmaceuticals, and many others. The current widespread concern over, and discussion of, the problem in managerial, educational and government circles is, in short, mainly due to the ultra-rapid advent of new knowledge, and the consequent obsolescence of much widely-used old knowledge.

Despite the pervasive concern over technical skill-obsolescence among businessmen, the majority of the managers interviewed in the course of this study felt that, in terms of the actual currently-existing situation in their own firms, the problem was of moderate seriousness. Although this view was usually expressed at the outset, and as merely informed opinion, information obtained in subsequent stages of the interviews tended to confirm the initial assessment, insofar as the relative numbers of technical employees involved was concerned. The substantive interview data also indicated, however, that four particular sub-areas of the over-all problem, while they affect relatively small numbers of personnel, involve serious difficulties for management, in terms of finding effective remedial or administrative measures. These sub-areas are: (a) the problem of motivating those (largely mature-age) R-D-D staff members who have not kept their knowledge and skills updated; (b) the problem (in defense-oriented firms) of administering reductions in the technical staff necessitated by curtailments and shifts in the defense procurement program; (c) the problem of getting and keeping, as well as developing and updating, an adequate number of "key" practicing engineers and scientists; (d) the problem of means and measures by which members of technical management can keep themselves adequately updated, both in terms of technical knowledge and managerial skills. Following a brief explanation of the proportionate numbers of professional personnel comprising the over-all practical problem, we shall discuss these four problem sub-areas in turn.

Proportion of Technical Staff Affected by Obsolescence

With regard to the quantitative dimensions of the practical problem, three factors were stressed by a majority of the managers. First, it was stated that while full and current updating is essential for members of their research-development-design staffs, it is usually not essential for professionals engaged in other technical functions. The reason for the distinction, it was noted, is that while the primary function of R-D-D staffs is to originate ideas and designs for new products and processes, operations engineers and other non-R-D-D professionals are concerned only with products and processes already in commercial production. Since the R-D-D staffs comprised, on the average, only slightly more than half the total professional technical workforce, skill obsolescence as a practical current problem was manifestly confined within this "upper half."

Second, there was wide agreement that, within the R-D-D staffs, the skill obsolescent professionals are found mainly in the middle and upper age brackets -- i.e., among those who completed their technical education ten or more years ago, before the advent of the movement to revise technical-college curricula, stressing modern basic and engineering science and advanced mathematics. We estimate that in the aerospace and other defense-oriented firms studied, the "mature-age" (35-and-over) R-D-D professionals comprise somewhat less than half the total of R-D-D personnel. Thus the managers' practical skill-obsolescence problem -- numerically speaking -- is largely focused within a group that constitutes on the order of one-fourth of the total professional staff. In the large diversified-product and non-defense firms studied, the R-D-D staffs are relatively smaller and the non-R-D-D groups relatively larger, than in the defense-oriented firms; but on the other hand the 35-and-over professionals comprise a somewhat larger proportion of the total. Hence in these firms, also, the "focal group" comprise roughly one-fourth the professional technical workforce.

The fact that the practical problem is confined within the R-D-D units and, further, largely to the middle-aged and older members of these units should not, however, be taken to mean that the importance of the problem for the managements, or the difficulty of dealing with it, is correspondingly reduced. A number of managers emphasized that, even apart from the skill obsolescence problem, building a productive R-D-D staff is considerably more difficult than building competent non-R-D-D groups, owing to the ever--present scarcity of engineering and science graduates possessing the creative talent required for effective performance in R-D-D work. In other words, the occurrence in the R-D-D units, of skill deterioration due to failure to keep updated intensifies and further complicates what is already one of the managements' most troublesome staffing problems.

With regard to the professionals (chiefly physics, chemistry and engineering Ph.D.'s) employed in the exploratory-research units of ten of the firms studied, there appears to be no significant skill-obsolescence problem. The (almost unanimous)consensus among the managers in these firms was that these "basic-research scientists" are well versed on recent advances and new knowledge in their fields, and that they keep themselves continually updated on their own initiative.

Mature-Age Obsolescent R-D-D Personnel. Turning now to the question of how the problem of these skill-obsolescent members of the technical staff can be dealt with, it should be noted first of all that most of the firms have for various reasons continued them in R-D-D capacities, instead of downgrading them to non-R-D-D work or dismissing them. The practical problem facing the managements, therefore, is that of enabling and/or persuading these (mainly 35-and-over) R-D-D practitioners to update and maintain their knowledge and skills. The majority of respondents attributed their backsliding simply to lack of motivation, pointing to the fact that they have not taken advantage of the firms' in-plant or other continuing-education programs. However, most of the programs are conducted exclusively in the evening, thus requiring the updating-minded individual to pursue his studies on his "own time." Moreover, he must often do so at the sacrifice of family, community and other after-hours interests -- and this is especially true of mature-age engineers and scientists. The problem of motivating the skill-deficient professionals to update themselves, therefore, involves the question of whether the continuing-education programs should be conducted during working hours -- i.e., whether the professional employee should be compensated while pursuing his studies. When this question was posed, the most frequent response was that existing competitive conditions would not permit conducting the programs on company time. However, the managers taking this position were undoubtedly assuming that such programs, in the interests of fairness would have to be open to <u>all</u> professional personnel. It is worth noting, however, that several of the large diversified-product firms have established "during-working-hours" programs specifically designed for and confined to R-D-D engineers ten or more years out of college.

<u>Defense-connected Layoffs</u>. Of the 23 defense-oriented firms which had experienced curtailments or cancellations of

defense contracts in 1963-64, 17 had been forced to lay off some -- although in only two cases a large proportion -- of the affected professional technical employees. Since, as noted, skill obsolescence was most commonly found among the mature-age practitioners, one would expect that the individuals laid off would be mainly middle-aged and older personnel. In the majority of firms, in administering the layoffs, however, the main criterion used was "seniority" -- i.e., brevity of service with the firm -- with the result that the great majority of professionals separated were younger, recently-graduated men. Furthermore, even in the firms in which designation for layoff was based on performance or "worth to the firm," the resultant layoff rosters still consisted largely of younger, shorter-service engineers. While this appears inconsistent with the widely recognized fact that recent graduates are better updated than older, earlier-educated practitioners, most of the managers felt that layoffs according to inverse seniority was the soundest approach. Their main justification was that brevity of service is the fairest criterion, and the one least likely to cause resentment in the technical staff as a whole. Moreover, since most of the layoffs were of small or modest proportions, it was seldom necessary to go beyond the youngest, shortest-service professionals in listing for layoff. Finally, it should be noted that nearly all of those slated for layoff were people engaged in non-R-D-D activities, or (less often) in the lower levels of development and design work. Few if any of the managements affected by defense cut-backs and cancellations laid off any of the systems engineers or project leaders in their R-D-D staffs.

"Key" Practicing R-D-D Professionals. The problem of "key" practicing engineers and applied scientists involves considerations and difficulties quite different from those of the backsliding rank-and-file R-D-D practitioners. This category includes project leaders, systems engineers, "advanced development" engineers and applied scientists and other upper-level sub-categories. Although these practitioners usually comprise no more than one-fifth of the professional R-D-D workforce, their importance far exceeds their numerical strength, for it is on them that management depends for originating ideas and plans for useful and practicable new products, processes, or equipment systems. Most of the functions performed by the rest of the R-D-D staff are essentially detailed, direction-following work -- translating the ideas originated by the key engineers into the drawings, prototypes and specifications which the R-D-D units turn over to the production departments.

The initial problem posed by these key professionals is not one of motivating them to keep themselves updated, since -- in the experience of the respondent managers -- they usually keep abreast of new knowledge on their own initiative, especially if adequate continuing-education programs are available. It is, rather, that individuals possessing the necessary creative talent to perform effectively in these positions are perennially in short supply. In other words, such individuals are few and far between among the members of the incumbent technical staff, and equally scarce among new college graduates and others recruited from outside the firm; whereas there is a more-than-adequate supply of run-of-the-mill practitioners.* The key technologists are, moreover, difficult to identify, owing to the ineptness of existing performance rating and selection techniques in distinguishing creative from non-creative individuals.

Apart from the problem of obtaining an adequate supply of key professionals, however, developing them and keeping their knowledge and skills updated also constitutes a major problem. In the opinion of the managers who spoke to this point, it is essential for key engineers to be even more widely and thoroughly updated, and also to have a wider knowledge of the particular firm's technical problems, than lower-level R-D-D professionals. Yet only a handful of the firms studied have adopted measures specifically aimed at dealing with this problem. Of these few, the program recently launched by a major aerospace firm is of interest. Under this program some 15 engineering staff members in the "critical 5-to-10 year experience group," carefully selected every six months on the basis of technical proficiency and creative talent, are given a two-year full-time "training tour" of the firm's engineering and production establishments. The tour

*Several managers expressed strong belief that there is also a nation-wide shortage of productive key R-D-D professionals but that the alleged general shortage of engineers and applied scientists is a myth.

is supplemented by special lectures on new technical developments and by extensive participation in the firm's regular updating technical education program. The official in charge of the program expressed confidence that it provides an effective means of selecting and developing high-caliber project and systems engineers, but conceded that it is still too new to have proved its effectiveness.

Still another problem concerning key engineers and scientists is that of providing sufficient incentives to induce them to continue in technical practice, instead of switching to technical or general managment. The crux of the problem is that both salary and status opportunities are better in the management sphere. In an effort to meet this problem, several of the firms have established "parallel ladders" of salary levels and positions (including status and "fringe" perquisites) for practicing professionals, aimed at keeping them on a par in compensation and prestige with managers at the corresponding levels. As to the effectiveness of these arrangements, the opinions were mixed: some interviewees held that the parallel ladder device is working satisfactorily, while others felt that the practitioners still regard management as affording the more desirable opportunities.

Technical Managers and Obsolescence

The weight of opinion among the interviewees was that the problem of keeping managers of R-D-D activities in their firms technically updated is at least as important as the parallel problem among R-D-D practitioners, despite the much smaller numbers of personnel involved.* They noted that R-D-D managers must keep informed on new developments in each of the disciplines represented on their staffs. While their knowledge in each field need not necessarily be as detailed as that of the practitioners whom they supervise, it must nonetheless be sufficient to enable them to select competent subordinates and judge their performance, and to make sound final decisions on ideas and designs developed by them. In addition, they must perform all the difficult human relations and administrative functions involved in managing a group of highly individualistic professionals, many of whom are more knowledgeable than their superiors in their particular fields. In the typical case these duties are so time-consuming as to leave little time for the manager to keep abreast of new technical developments.

Yet despite the manifest seriousness of the problem, the large majority of the firms studied have not seriously attempted to develop remedial policies or measures. The

*It is worth adding that at least four of the nation's leading technical universities -- Massachusetts Institute of Technology, Carnegie Institute of Technology, Brooklyn Polytechnic Institute, and the University of California's School of Engineering -- strongly sharing this view, have established intensive continuing-education programs in modern mathematics and science and other recently-developed technical subjects, specifically designed for "outdated" engineering managers.

reason most commonly given was that the members of R-D-D management could not be spared from their posts for the period required to attend (for example) UCLA's six-week updating program for technical managers. Only three of the firms -- two large electrical equipment manufacturers and a large aerospace firm -- have established updating-education programs specifically designed for engineering managers. While none of these programs has been in effect more than two or three years, the respective top managements believe that they have already proved their worth. However, there was little or no evidence that any of the other firms plan to follow suit in the near future.

The Problem of Performance Appraisal. The difficulty of securing accurate and dependable appraisals of the performance of practicing engineers and applied scientists cuts across and affects each of the above-discussed problem sub-areas. Most of the firms studied have performance rating programs in effect for both practicing technical personnel and technical managers, whereby each practitioner's or manager's performance is reviewed by his immediate superior, either once or twice a year. However, a majority of the respondent managers felt that their appraisal programs leave much to be desired. In the first place, in no case is any systematic effort made to correlate low performance with degree of outdating of knowledge and skills -- nor of high performance with degree of updating. Second, a number of interviewees felt that appraisals made under their rating schemes cannot be depended upon to reflect the actual performance of all technical staff members. In particular, they feared that poor performers tend to be rated higher than their actual performance would warrant. One reason for this is the inherent difficulty of assessing the quantity and quality of output of a professional-level employee engaged in creative or quasi-creative activity, especially when he works as a member of an R-D-D project group. Another, no less important reason is that many technical supervisors are reluctant to stigmatize members of their units -- and inferentially themselves -- by rating their performance as unsatisfactory. Several of the interviewees conceded that this "uprating" of mediocre performers among their firm's technical staffs might be a factor affecting their own assessment of skill obsolescence as a moderate or minor problem. In any case, on the basis of the findings of this study and of the authors' earlier experience and knowledge of performance rating, it is no exaggeration to say that accurate and objective appraisals of the performance of engineers and scientists is one of management's most difficult technical-manpower problems.

<u>Obsolescence-Combating Educational Programs.</u> One of the major findings of the study was that nearly all of the firms studied have educational programs for their engineer-scientist personnel, aimed at preventing and remedying technical skill obsolescence. The study revealed that many

technical colleges and universities, in the urban areas visited and elsewhere, have also established "continuing education" programs for practicing engineers and scientists.* All but three of the firms have tuition-refund plans, under which professional employees who pursue after-hours studies related to their work at (nearby) colleges or universities are reimbursed for all or part of their tuition costs. Some two-thirds of the firms also conduct in-plant technical education programs -- usually (though not in all cases) after working hours. Unlike the tuition-refund plans, which cover both nontechnical and technical courses, the in-plant programs consist mainly or entirely of mathematics, science and technology courses specifically aimed at updating and extending the skills of technical personnel. In most cases the in-plant programs have been established within the past five years. This reflects the growing concern on the part of the subject managements over the skill-obsolescence problem, and a concomitant increasing sense of responsibility for providing updating opportunities for their technical employees. However, since most of the programs are conducted after working hours, the development has also given rise to the issue of whether

*It should be noted that the movement to update technical college undergraduate curricula, launched in the mid-1950's and now in its second updating phase (see Chapter II) is also essentially an obsolescence combating program, since its primary aim -- and in large measure its effect -- has been to equip new graduates with an adequate grounding in modern advanced mathematics and modern basic and engineering science to meet current and future skill requirements in their chosen field.

company-sponsored continuing education programs should be conducted during working hours -- i.e., as part of the technical employee's regular, fully-compensated working period.* Adoption of this arrangement would undoubtedly go far toward solving the problem of employees who, owing to family obligations or other counter-motivations, do not participate in the after-hours programs. However, as noted earlier, most of the managers queried on this point felt this plan would be excessively costly in the case of any individual firm -- unless all competing firms adopted the same policy.

Areas and Problems of Needed Further Research

As emphasized in Chapter I, the investigation described in this report has been a pilot study, aimed primarily at identifying the characteristics of technical skill obsolescence in a small, selected sample of firms, identifying the aspects of the problem that need more thoroughgoing investigation, and suggesting approaches and techniques for conducting such investigations. It was noted that while we

*An alternative or supplemental proposal, frequently raised but so far adopted by only one of the firms, is that of providing paid "sabbatical" leaves of absence for technical professionals, for the purpose of pursuing full-time updating studies under college-university continuing education programs. (Several of the firms grant such leaves to a few selected professionals for the purpose of completing doctoral studies already well under way.)

believe the 23 predominantly defense-engaged firms are in some measure representative of this sector of technology-oriented industry, the eleven predominantly non-defense firms and the five very large diversified-product firms constituting the remainder of the sample are too few to be considered as representative of their respective categories.

In the foregoing summary of study findings, therefore, we have avoided implying that the experience with the skill obsolescence problem encountered in these firms is necessarily characteristic of engineering-oriented firms or industries generally. However, we believe the study has enabled us to identify and differentiate between the major origins and causes of the overall technical skill obsolescence phenomenon, and also to identify, within the over-all practical problem area confronting technical managements and practitioners, significant and distinctive sub-areas on which further, more definitive study can usefully be focused. Both sets of findings have been set forth in the earlier chapters; the findings relating to distinctive problem sub-areas are re-capitulated in the preceding section of the present chapter.

In our considered opinion -- and despite the limited number of firms observed -- the study findings strongly indicate that similar significant problems exist in technology-oriented industry at large, and that consequently there is a real need for broader-scope and deeper-probing research into these problems.

Need for Wider Coverage and Larger Sample of Firms. It is apparent that in any further research into technical skill obsolescence, if it is to yield results representative of relevant problems and experience in technology-oriented industry generally, the sample of firms studied must include more industries, and a larger and more representative selection of firms in each industry, than the list covered in the present study. As noted in Chapter I, the industry categories represented therein -- in all but two cases very meagerly -- included aerospace; electronic equipment; electrical machinery and equipment; office, computing and control machines and equipment, miscellaneous machinery (other than electrical), chemical products, petroleum products, primary nonferrous metals, communications utilities, and research laboratories. All of these categories except primary nonferrous metals fall within our (somewhat arbitrary) definition of highly technology-oriented industries -- i.e., the ratio of technical professional to total personnel employed in each is 4 percent or more. In each category the sample chosen for a definitive study should be substantially larger than in the present study -- e.g., 5-20 firms; and in several cases the main category should be broken down into subcategories -- for example, industrial chemicals, drugs and medicines, and other chemicals -- and each subcategory adequately represented. In addition, two other "more-than-4-percent" industries --

engineering services (consultants) and professional and scientific instruments -- should be adequately represented, as should several other industries, notably motor vehicles and primary iron and steel, which although somewhat below the 4-percent boundary ratio, are important because of the numerically very large technical workforce they embrace. In the research laboratories category, the selection should include organizations engaged exclusively in basic research (e.g., the laboratories of major universities), as well as engineering and applied science research organizations. This will enable the researchers to say more definitely than was possible in the present study whether basic-research scientists are more assiduous in keeping updated than engineers and applied scientists. In all cases care should be taken to include medium-size and smaller as well as large firms.

Problems of Approach and Procedure in Obtaining Information. In the planning stage of the present study it was decided to employ the depth interview approach in gathering information concerning the firms' experience with technical skill obsolescence, in preference to the questionnaire method. In view of the ramified and complex nature of the problem area as revealed by the subsequent research effort, it is apparent that this was a wise choice. We believe that, in conducting further study in the area, it would be advisable to rely wholly or largely on the interview method.

In utilizing this approach, however, we encountered two types of difficulty which it would be well to anticipate and if possible forestall in any future study. The first was that when we contacted top general or technical managers to arrange interviews, in a number of instances they responded by delegating the interview assignment either to a lower-level technical manager or to the staff official in charge of continuing-education programs. Although these individuals often proved to be well-informed, we would have preferred to interview the higher-level executives, since it seemed probable that they would have a more comprehensive grasp of the problems and experience in the organization as a whole.

To guard against this difficulty in future research, it is suggested that advance assurance of positive, wholehearted cooperation of top managements be obtained, through the influence and good offices of the Federal agency or agencies directly involved in the study -- e.g., the Department of Labor, the Department of Defense, or the National Science Foundation.

The second difficulty encountered was a tendency on the part of some interviewees to describe the firm's experience with skill obsolescence and its efforts to deal with the problem in a manner that appeared biased on the favorable side. While this tendency could not, of course, be proved, it seemed fairly apparent in a number of instances.

We believe that this difficulty can be met, at least in part, by interviewing individuals at several levels, or in several different capacities, in each firm. Thus for example, if the "director of professional development" tends to paint an unduly rosy picture of the results of the firm's continuing education program, a technical manager confronted with a practical problem of "outdated" development or design engineers may present a quite different assessment. It would seem particularly desirable to include project leaders and even rank-and-file R-D-D people among the interviewees, since practitioners usually perceive matters pertaining to their own capabilities and performance from a perspective quite different from that of their superiors.

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Aspects of the Problem Area Needing Further Research. The aspects of the over-all problem area which in our judgment need broader and more thorough study -- from the standpoint of public policy as well as that of efficient conduct of private enterprise -- fall into two major sub-areas: the problem of devising and conducting effective continuing-education programs, particularly for research-development-design professional technical personnel; and the problem of identifying and effectuating fruitful "second careers" for R-D-D engineers and scientists whose skills have become permanently impaired. A third, separate but closely related problem area with important public-policy implications, is that of estimating the future national requirements and supply of engineers and scientists. We shall briefly examine these problem areas in turn.

<u>The Problem of Developing Effective Continuing-Education Programs</u>. A comprehensive study of this problem would involve three component studies, as follows:

1. Assessment of the effectiveness of existing programs. This would entail investigating, in an adequate sample of technology-oriented firms, (a) the number and proportion of R-D-D professionals who have and those who have not participated, and (b) with respect to those who have participated, the adequacy of the updating acquired. It would be necessary to confine the sample to firms having demonstrably valid performance appraisal programs, and adequate records of individual R-D-D staff members' past performance, as well as records of their participation or non-participation in the updating programs. In conducting phase (b), it would be desirable to compare the performance of the more assiduous "participators" with that of the "non-participators" over a period of several years; and also, if possible, to examine the performance of "participators" prior to starting and after completing the updating-education program.

2. A survey (by interview and/or questionnaire) of individual R-D-D professionals in the subject firms for the purpose of probing their motivations and time-availability problems apropos participation or non-participation in their firms' continuing education programs. This survey would be concerned primarily with (a) assessing the off-the-job

motivations and obligations that prevent or deter the non-participants from enrolling in the (after-hours) programs; (b) the extent to which effective updating among the non-participants could be expected if the programs were conducted during regular work periods; and (c) the extent to which broader and more thorough updating among the participants could be expected if the programs were so conducted.* The sample of firms, as noted earlier, would include basic-research laboratories as well as engineering and applied science-oriented firms. Hence the survey would make possible a comparison of the extent of the updating effort among basic research scientists with that among R-D-D engineers and applied scientists.

3. As an adjunct to the survey outlined above, a study should be undertaken to explore the problems of staffing, organization and costs that would be involved if managements were to provide continuing updating-education programs for R-D-D engineer and scientist personnel as part of the regular work schedule. In conducting this study, it would be desirable

*A recent questionnaire survey conducted by the National Society of Professional Engineers revealed that 45 percent of the respondent members had not taken any type of formally-organized updating-education course during the preceding five-year period. A major proportion of these non-participants gave as the primary reason for their failure to do so, either higher-priority obligations and motivations (family, community service, etc) or lack of time due to excessive time demands of their job. In summarizing the results of the survey, the NSPE concluded that employers should make time available to their engineer employees to pursue continuing-education studies, as part of the regular work schedule. Continuing Education of Professional Engineers, March, 1966, pp. 5, 23.

to enlist the cooperation of the R-D-D planning units of the sample firms, or of a selected sub-sample. In making the staffing, organization and cost estimates, account should be taken of the prospect that, with continuing updating education provided as part of the regular work schedule, a considerably larger number of R-D-D staff engineers and scientists would be continually updated and that consequently the effectiveness of the existing staff would be enhanced.

As a second, public policy-connected phase of this study, it would be desirable to explore the question: What would be the effect on the aggregate national demand-supply situation apropos R-D-D engineers and scientists if continuing-education programs were integrated into regular work schedules on a widespread basis?

The Problem of "Second Careers" for Engineers and Scientists with Permanently Imapired Skills. This problem focuses primarily on research-development-design engineers and applied scientists who, owing to permanent deterioration in their stock of knowledge and/or skills, are no longer capable of functioning effectively in R-D-D work. As in assessing the effectiveness of continuing-education programs, it would be necessary to confine the study of this problem to firms having demonstrably valid performance appraisal programs. It would involve a two-phase approach, as follows:

1. Probing the causes of permanent impairment of R-D-D skills. This phase of the study would be concerned with

exploring the extent to which permanent impairment is due to such causes as decline in ability to master and utilize new mathematical and scientific concepts and techniques, decline in creative talent as a result of advancing age, and lack of motivation to pursue updating-education studies; and the types or categories of professionals characterized by particular causal impairment factors.

2. Exploration of subsequent careers of technical professionals separated or downgraded because of permanently impaired skills. This phase of the study, in turn, would fall into two sub-phases: (a) studies of the experience of representative firms in shifting such professionals to other types of work, such as non-R-D-D engineering practice, engineering administration, non-technical management, etc. and (b) follow-up studies of the post-layoff employment experience of individual engineers and applied scientists separated from defense firms as a result of contract cancellations and cutbacks.*

The Problem of Estimating the Future National Requirements and Supply of Engineers and Scientists. To the individual technically-oriented firm, the skill obsolescence problem is only a part (although an important part) of a larger and more ramified problem area, namely, that of the recruiting, employing

*Follow-up studies of technical professionals laid off during the 1964-65 "cutback period" have been made in two local areas -- Seattle (The Dyna-Soar Contract Cancellation," U.S. Arms Control and Disarmanent Agency), and San Francisco Bay (see p. 24 above).

and placing -- as well as assuring the continuing competence -- of an adequate professional technical staff. Similarly, for the nation as a whole, technical skill obsolescence is but one aspect of the larger problem of effectively developing and utilizing the country's technical manpower resources. One aspect of this national problem area that is highly important for public policy is that of the nation's prospective needs for professional technical personnel and the prospective supplies of qualified engineers and scientists that will be, or can be made, available to meet these needs.

Although this broader problem area was outside the planned scope of the present study, the subject of the overall national labor-market situation regarding engineers and scientists cropped up during the course of various interviews, with both managers and science-engineering educators. In discussing this subject, several of the interviewees referred to the estimates of future national demand and supply in the area of engineering and scientific manpower over the decade 1960-70, prepared by the U.S. Bureau of Labor Statistics and published by the National Science Foundation in 1963. This study concluded that, under the conditions assumed, there will be an estimated overall shortage of 266,000 professional engineers in 1970.*

*The NSF-BLS study, titled Scientists, Engineers and Technicians in the 1960's: Requirements and Supply, (Report NSF 63-34) utilized the method of projecting recent past trends in employment of engineers into the near-term future to obtain estimates of demand; and projecting recent past trends of bachelor's

All of the managers and educators who spoke to this point felt that there was a current (1963-64) shortage of R-D-D engineers and scientists, although several felt that the shortage was confined to "key" (i.e., highly creative) R-D-D practitioners and project leaders. However, none felt that there was any national shortage of non-R-D-D technical personnel, nor that any was likely to occur in the near future. The managers cited their own firms' experience as indicating an adequate supply, or even a surplus, of engineers with satisfactory qualifications for operations, service, and other types of non-R-D-D work. In this connection, several of the interviewees made specific reference to the NSF-BLS "projections" study, characterizing the resultant estimate that a major

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engineering degrees (with a small upward adjustment to allow for "entrants from outside") to obtain estimates of supply, up to the year 1970. Estimates of the future demand and supply of scientists were made in a similar manner. The report estimates that the demand for engineers will increase from 822,000 (actual employment) in 1960 to 1,375,000 in 1970. Adding an estimated 164,000 to the 1970 figure to allow for losses due to deaths, retirements and transfers during the decade, the resultant estimated increase in new engineering entrants required over the decade is 717,000. The projected increase in the supply of engineers over the period is 451,000, leaving an estimated cumulative shortage over the decade of 266,000.

The corresponding estimates for the demand for scientists are 335,000 in 1960 and 580,000 in 1970. Adding an estimated 50,000 for deaths, retirements and transfers results in an estimated increase in new science entrants required over the decade of 295,000. The projected increase in the supply of scientists is 314,000, leaving an estimated cumulative surplus of 19,000 for the decade. Thus the net estimated shortage over the decade, for engineers and scientists taken together, is 247,000.

overall shortage of engineers would develop during 1960-1970 as unfounded and misleading.

The continuing adequate supply situation in the non-R-D-D areas, in contrast to the shortage of qualified R-D-D personnel, was attributed to the fact that the skill and knowledge requirements for all types of non-R-D-D activity are far less rigorous than the requirements in the R-D-D area. Not only are the creative-talent requirements lower, but it is feasible in many situations to utilize people who have completed only one or two years of engineering or science college work, or a two-year technician training program.* In addition -- again in contrast to the requirements in the R-D-D area -- full and continuing updating in new developments in one's field is not essential in most types of non-R-D-D work.

Closely similar experience was recounted by a "working group" of the Industry Advisory Committee to the Department of Defense, which recently conducted a study of the "nature and extent of the (alleged) shortage of scientists and engineers," and the "nature and extent of the problem of continuing education." The experience of the industry members of the group -- five executives, representing five large defense-contractor firms -- with respect to the "shortage question" is set forth in the study report as follows:**

*At the time of the interviews, nearly half of the defense-oriented firms studied were employing substantial numbers of "non-degree" engineers in various types of non-R-D-D technical activity.

**Implications of Continuing Education for Scientific and Technical Personnel - Report of a DIAC Working Group, U.S. Department of Defense, May, 1964 (mimeographed), pp. 2-3.

A question asked (of the industry members) was: Do you have any shortages of scientific and engineering manpower? If so, what kind? Their answers were: "Yes, we have shortages of good structures analysts, (or systems managers, or mathematicians, or advanced degree people) . . . ." But when they were asked: Are you experiencing an overall shortage of scientists and engineers?. . . . Here the answer was firm and definite: "No, certainly not. We've never had any difficulty in hiring just engineers since the mid-1950's.". . . . Nobody admitted to an overall shortage; some even spoke of a possible overage in the future. One member remarked that his company was a bit embarrassed to find that, after pressuring the local universities to produce more scientists and engineers in the 1950's, it was now unable to provide jobs for them. Our first impression, therefore, amounted to a feeling that, while there would always be a shortage of highly creative people in all fields, and a probable shortage of well-trained competent people in specific fields, there does not seem to be any overall shortage of scientists and engineers, and none is expected. These first impressions were strengthened by later discussions with other people, and by sampling the literature and statistics available.

Thus the results of our study, supported by those of the DIAC study, indicate that at approximately the half-way point of the 1960-1970 decade there was probably a national shortage of qualified research-development-design engineers and scientists, but no national shortage (and possibly even a surplus) of personnel qualified for non-R-D-D engineering and applied-science work. The findings suggest further that the BLS, in developing its projections of the future demand-supply situation over the decade, erred in one of its basic assumptions, namely, that all types of engineering activity can be validly treated as a single, homogeneous category in estimating future demand and supply with respect to engineers -- and correspondingly with respect to scientists. The demand for R-D-D engineers and scientists may be growing considerably faster than the demand for non-R-D-D engineers and scientists; and the supply of qualified R-D-D technical personnel may be much less readily expandable than the supply of competent non-R-D-D professionals.

Carrying the implications of the study still further, they suggest an approach to the problem of estimating future demand and supply on the area of professional technical manpower that may provide more realistic -- and hence more useful, from the public standpoint -- estimates than those presently available. In implementing this approach, it would be necessary first to conduct a study of employer experience and opinion in a larger and more representative sample of engineering- and science-oriented firms, in order to verify the indication from our study that, in estimating employers' future requirements for engineers and scientists, it is necessary to distinguish between R-D-D and non-R-D-D personnel -- and also to check on the possible need for a further distinction, within the former category, between "key" R-D-D and other qualified professionals. This study might be conducted in conjunction with the expanded-coverage study of skill obsolescence outlined above.

Assuming the follow-up survey verified the earlier findings, the near- and medium-term future national demand (for R-D-D and non-R-D-D engineers and applied scientists separately) could be estimated either by projecting past trends of aggregate employment in these categories or -- perhaps preferably -- through a survey of the future-activity and staffing plans of a large sample of technically-oriented firms.* In most such firms, the R-D-D departments plan both future activities and staffing on a continuing basis -- usually for five years and in some cases for longer periods ahead. Plans for future non-R-D-D technical staffing would also, undoubtedly, be obtainable in most instances.

For estimating the future supply of R-D-D engineers

*This was the method adopted by the Engineering Manpower Commission of the Engineers Joint Council, in its recently-published estimates of the demand for engineers and physical scientists over the period 1962-1973; published in the report titled Demand for Engineers, Physical Scientists and Technicians - 1964. However, the EJC did not attempt to obtain separate requirement figures for R-D-D and non-R-D-D personnel -- hence the estimates are in terms of demand for all types of engineers and all types of scientists.

and scientists, the most practicable basis would appear to be projections of past and current trends in college degrees granted in engineering and science, together with the corresponding trends in the proportion of new graduates entering R-D-D employment. (The latter trends could be determined from the records of college placement offices.) Reasonably realistic estimates of the future supply of non-R-D-D engineers and scientists could probably be made in a similar manner, from the past and current trends in the proportion of new technical graduates entering non-R-D-D technical employment, and from the trends in the proportion of non-graduates (dropouts) entering such employment. However, the last-named estimates would be subject to rather wide plus-or-minus variances since, from all indications, the supply of non-R-D-D technical personnel changes readily and rapidly in response to changes in demand.

In reporting the results of any study of future requirements and supply of R-D-D engineers and scientists, it would be desirable to include estimates of the extent of skill obsolescence in the available professional technical labor force, since an indicated net shortage would be accentuated thereby, and an indicated surplus lessened. However, as we have shown, considerable further research will be required before any dependable estimates of the current extent of technical skill obsolescence or of recent and prospective changes or trends in the situation become possible.

APPENDIX A

Interview Guide

1. Is skill obsolescence (i.e., lack of or deficiency in currently-required knowledge or technical skill) among members of the professional technical staff a current problem in your firm? If so, how serious do you consider the problem?
2. To what extent does the skill obsolescence-updating problem affect the different functional areas of technical activity in your firm (research, development and design, operations engineering, standards and quality engineering, sales engineering, service engineering, etc.)?
3. In what age or experience brackets are the skill lacks or deficiencies most in evidence?
4. (Question addressed to interviewees who answered "middle and upper-age brackets," "more than ten years out of college," etc., to Question 3.) How do you account for the greater occurrence of skill obsolescence in the middle and upper age brackets? Why do so many of these mature-age men fail to keep their knowledge and skills up-to-date, in comparison with the younger men?
5. In your opinion, what circumstantial or personal factors have prevented or deterred the skill-obsolescent middle and upper-age-bracket technical professionals

from acquiring the needed new skills?

6. In the firm's research and development activities, what essential functions do the "project engineers" perform, as distinct from other practicing R & D engineers? What essential functions do "systems engineers" perform? What are the implications of the skill obsolescence-updating problem for these two categories of engineers, as compared with other engineers engaged in R & D work?

7. (a) In your opinion, how important is it for managers of research-development-design departments and sections to be fully and currently grounded in newly-developed scientific knowledge and engineering technology, as compared with the practicing engineers and/or applied scientists whom they supervise?

   (b) In your opinion, how serious is the problem of technical skill obsolescence among the R-D-D managers in your firm?

8. Does the fact of skill obsolescence among some members of the firm's R-D-D professional staff pose a problem for management in carrying out development projects or in planning future development work? If so, how serious is the problem? How is management dealing with the problem?

9. (Question addressed to interviewees in predominantly defense/space-oriented firms.) Has the firm experienced

a major reduction or reductions in defense-related business in recent years? If so, to what extent (if any) have the reductions made professional technical employees redundant or skill-obsolescent? What disposition has been made of such employees (retained, transferred to other work or plants, laid off, etc.)? If laid off, what has been the basis of designating individuals for layoff? What functional groups have been affected? What age, length-of-service, etc., brackets have been affected?

10. What policies and programs has your firm adopted to aid or encourage professional technical personnel in updating or expanding their skills in line with current skill requirements?

11. To what extent have the members of the firm's professional technical staff(s) participated in the firm's continuing education programs? Can you supply details by age brackets? Length of service? Functional categories?

12. What is your (or your firm's top managers') appraisal as to the effectiveness, to date, of the continuing education programs, in terms of mitigating and/or preventing skill obsolescence among the members of the professional technical staff?

APPENDIX B

Selected Bibliography

Dubin, Robert S., Research Report of Continuing Professional Education in Pennsylvania, State University of Pennsylvania, University Park, Pa., 1965.

Engineering Societies Joint Advisory Committee on Continuing Engineering Studies, Continuing Engineering Studies: A Report of the Joint Advisory Committee, Engineering Center, New York, N.Y., 10017, June, 1966.

Goals of Engineering Education Project, Preliminary Report, Purdue University, Lafayette, Indiana, October, 1965.

Defense Industry Advisory Committee, Implications of Continuing Education for Scientific and Technical Personnel, (mimeographed) U.S. Department of Defense, Washington, D.C., May, 1964.

National Society of Professional Engineers, Continuing Education of Professional Engineers, NSPE, Washington, D.C., 20006, March, 1966.

U.S. Arms Control and Disarmament Agency, The Dyna-Soar Contract Cancellation, Washington, D.C., July, 1965.

Engineering Manpower Commission of Engineers Joint Council, Enrollments and Degrees in Selected Engineering Curricula (Engineering Manpower Bulletin No. 2) EJC, Engineering Center, New York, N.Y. 10017.

Engineering Manpower Commission of Engineers Joint Council, Professional Income of Engineers, 1964, EJC, Engineering Center, New York, N.Y. 10017.

National Science Foundation, The Long-Range Demand for Scientific and Technical Personnel, Report No. NSF 61-65, Washington, D.C., 1961.

National Science Foundation, Scientists, Engineers and Technicians in the 1960's, Requirements and Supply, Report No. NSF 63-64, Washington, D.C., 1963.

Ingersoll, Alfred C. A Sampling of Industrially-Sponsored Programs in Continuing Education (mimeographed), School of Engineering, University of Southern California, Los Angeles, June, 1964.

Ingram, Sidney B., Motivating Engineers to Continue Their Education While Employed (mimeographed) Bell Telephone Laboratories, Murray Hill, N.J., January, 1965.

Committee on Utilization of Scientific and Engineering Man-Power, Toward Better Utilization of Scientific and Engineering Talent: A Program for Action, National Academy of Sciences, Washington, D.C., 20418, 1965.

Foundation on Human Behavior, University of Michigan, Human Factors in Research Administration, Report of a Seminar conducted by the Foundation on Human Behavior, November 17-18 and December 1-2, 1955, Ann Arbor, 1955.

Perucci, Robert, W.K. LeBold, and W.E. Howland, The Engineer in Industry and Government, Goals of Engineering Education, Purdue University, Lafayette, Indiana, 1966.

Proceedings of the Midwest Conference on Reducing Obsolescence of Engineering Skills, sponsored by the Illinois Institute of Technology, March 26 and 27, 1963, IIT, Chicago 16, Illinois.

Continuing Education: A Stimulus for Engineering and Science; Proceedings of the Conference Sponsored by the New York State Advisory Council for the Advancement of Industrial Research and Development, in Cooperation with Columbia University, November 7 and 8, 1963. School of Engineering and Applied Science, Columbia University, New York, N.Y. 10027.

French, E.B., Personnel Problems in Industrial Research and Development, New York State School of Industrial and Labor Relations, Cornell University, 1963.

Haefele, J.W., Creativity and Innovation, McGraw-Hill, 1962.

Lehman, H.C., Age and Achievement, Princeton University Press, 1953.

Kornhauser, W., Scientists in Industry, University of California Press, Berkeley, 1963.

Marcson, S., The Scientist in American Industry, Harper & Row, 1960.

Raudsepp, E., Managing Creative Scientists and Engineers, Macmillan, 1963.

Strauss, A.L., and L. Rainwater, The Professional Scientist: A Study of American Chemists, Aldine Publishing Co., Chicago, 1962.

Allison, D., "Educating the Engineer," _International Science and Technology_, June, 1963, pp. 26-38.

Boehm, G., "Bringing Engineers Up to Date," _Fortune_, May, 1963, pp. 120-122, 180.

Brown, G.S., "Closing the Engineering Gap," _Electrical Engineering_, July, 1963, pp. 456-460.

Committee on Evaluation of Engineering Education, "Report of the Committee on Evaluation of Engineering Education," _Journal of Engineering Education_, September, 1955, pp. 26-59.

Grinter, L.E., "A Survey of Current Changes that Are Modernizing Engineering Education," _Journal of Engineering Education_, March, 1959, pp. 559-572.

Kriegel, M.W., "Updating the Training of Research and Development Personnel," _IEEE Transactions on Education_, December, 1963, pp. 51-56.

Pelz, D.C., "The 'Creative Years' and the Research Environment," _IEEE Transactions on Engineering Management_, March, 1964, pp. 23-29.

Princeton Creative Research, Inc., (E. Raudsepp, President) "Engineers Talk About Obsolescence," _Machine Design_, June 18, 1964, pp. 148-151; "Who Pays for Technical Retooling," _op. cit._, July 2, 1964, pp. 92-95; "Attitudes on Education," _op. cit._, July 16, 1964, pp. 124-127.

Torpey, W., "Company Investment in Continuing Education for Scientists and Engineers," Educational Record, Fall, 1964.

Weber, E., "Life Span of an Engineering Degree," _Electronic News_, November 29, 1965, p. 18.

"Firms Stress Quality in Technical Hiring," _Aviation Week and Space Technology_, September 21, 1964, pp. 103-106.

"New Hope for Rusty Researchers," _Chemical Week_, March 2, 1963, pp. 66-70.

Mooney, Joseph D. Displaced Engineers and Scientists: An Analysis of the Labor Market Adjustment of Professional Personnel. (Ph.D. dissertation - unpublished) Massachusetts Institute of Technology, Cambridge, Mass. , 1965.

Shapero, Albert, R.P. Howell, and J.R. Tombaugh, The Structure and Dynamics of the Defense Research and Development Industry: The Los Angeles and Boston Complexes, Stanford Research Institute, Menlo Park, California, 1966.

Ferdinand, T.N., "On the Obsolescence of Scientists and Engineers," American Scientist, January, 1966.

Parker, J.E., "Interactions of External and Internal Labor Markets for Engineers and Scientists," Proceedings of the Eighteenth Annual Winter Meeting of the Industrial Relations Research Association, December 28 and 29, 1965.

Survey of Continuing Education at Colleges and Universities in the United States (mimeographed), American Institute of Chemical Engineers, New York, N.Y., 1963.