DEVELOPMENT OF A POTENTIAL DEFENSE R&D COMPLEX

R&D STUDY SERIES

R & D STUDIES SERIES

THE DEVELOPMENT OF A POTENTIAL DEFENSE R & D COMPLEX

A Study of Minneapolis-Saint Paul

July 1966

STANFORD RESEARCH INSTITUTE
SRI
MENLO PARK
CALIFORNIA

KIRK DRAHEIM
RICHARD P. HOWELL
ALBERT SHAPERO

R & D
STUDIES
SERIES

THE DEVELOPMENT OF A POTENTIAL DEFENSE R & D COMPLEX

A Study of Minneapolis-Saint Paul

July 1966

TECHNOLOGY
MANAGEMENT
PROGRAM

SRI Project No. IMU-4370

Prepared by:

KIRK DRAHEIM
RICHARD P. HOWELL
ALBERT SHAPERO

STANFORD
RESEARCH
INSTITUTE

MENLO PARK
CALIFORNIA

Prepared for:

ASSISTANT DIRECTOR (ENGINEERING MANAGEMENT)
DIRECTORATE OF DEFENSE RESEARCH AND ENGINEERING
OFFICE OF THE SECRETARY OF DEFENSE

Contract No. SD-158

Other publications in the R&D STUDIES SERIES

ADAPTATIONS OF SCIENTISTS IN FIVE ORGANIZATIONS: A COMPARATIVE ANALYSIS
By: H. M. Vollmer, T. R. LaPorte, W. C. Pedersen, and P. A. Langton
* AD 619 525 May 1964

AN EXPLORATORY STUDY OF THE STRUCTURE AND DYNAMICS OF THE R&D INDUSTRY
By: Albert Shapero, Richard P. Howell, and James R. Tombaugh
* AD 447 118 June 1964

THE UTILIZATION OF SPACE-DERIVED TECHNOLOGY IN NON-SPACE APPLICATIONS
Part I: Liquid Hydrogen
By: John G. Meitner
October 1964

APPLICATIONS OF THE BEHAVIORAL SCIENCES TO RESEARCH MANAGEMENT:
AN INITIAL STUDY IN THE OFFICE OF AEROSPACE RESEARCH
By: Howard M. Vollmer
* AD 609 356 November 1964

WORK ACTIVITIES AND ATTITUDES OF SCIENTISTS AND RESEARCH MANAGERS:
DATA FROM A NATIONAL SURVEY
By: Howard M. Vollmer
* AD 620 376 May 1965

THE STRUCTURE AND DYNAMICS OF THE DEFENSE R&D INDUSTRY:
THE LOS ANGELES AND BOSTON COMPLEXES
By: Albert Shapero, Richard P. Howell, and James R. Tombaugh
* AD 652 232 November 1965

THE ROLE AND CAREER DEVELOPMENT OF THE SCIENTIFIC AND ENGINEERING OFFICER
IN THE AIR FORCE
By: Howard M. Vollmer and William C. Pedersen
December 1965

Price: $4.75 (In California add 4 percent sales tax).

* AVAILABLE FROM: CLEARINGHOUSE FOR FEDERAL SCIENTIFIC
and TECHNICAL INFORMATION, SPRINGFIELD, VIRGINIA 22151
HC $3.00/MF $0.65

PREFACE

This report is the third study of a series conducted since February 1963 for the Office of the Director of Defense Research and Engineering (ODDRE) of the Office of the Secretary of Defense (OSD), and performed under Contract No. SD-158 and directed by James E. Roach, Assistant Director, Engineering Management DDRE. The series had its origins in the continuing interest of ODDRE in (1) improving the quality and minimizing the costs of the research and development work for which it is responsible, (2) maintaining a strong and creative defense R&D industry, and (3) improving the positive effects and minimizing any deleterious effects of defense R&D on the general community, both at the local and national levels.

The research is being conducted by members of the Technology Management Programs of Stanford Research Institute and is part of its program of research on the Structure and Dynamics of the Research and Development industry. The Technology Management Programs include studies of: the structure, organization, and dynamics of the R&D industry; the economics of R&D; the social and economic impact; the organization and management of R&D; R&D technology utilization and transfer; technical manpower; science policy and the allocation of scientific and technical resources; and the development of systems analysis and other analytical methods useful in carrying out the above listed studies.

The research team is indebted to many individuals, both in the Department of Defense and in the companies and communities studied, for their active support and interest. We are indebted to James E. Roach and Lt. Col. Albert Wiegand of ODDRE for their support, encouragement, and practical help in assisting the study team's entry into defense R&D establishments. The research team would like to pay special tribute to the late J. Cameron Thomson, who was director of the Upper Midwest R&D Council at the time this study was made. Through his active help and support, the study effort was aided significantly. Also, a special acknowledgment must be made to the many individuals who not only helped in compiling the necessary data but also took a personal interest in the study.

Finally, we wish to thank our colleagues at Sta ford Research Institute for their support, aid, comments, and criticisms. We wish to thank Dr. Stewart P. Blake for his support; Jean Waters for her data processing and computer programming support; Wesley Tennant for his technical advice and personal contributions to this report; and Nancy Lawry, Gerrie Carpenter, Judy French, and Lynne Norris for their research assistance and secretarial support.

CONTENTS

CONTENTS

CONTENTS

ILLUSTRATIONS

BLANK PAGE

TABLES

TABLES

TABLES

TABLES

I INTRODUCTION

Purpose of the Defense R&D Study Series

The overall purpose of these studies is to develop a body of knowledge about the structure, organization, and dynamics of the defense R&D industry in the United States as an aid to the Office of the Director of Defense Research and Engineering (ODDRE). The body of knowledge is intended to provide a basis for improving ODDRE's ability to:

1. Set and modify Department of Defense (DOD) Research Development Test and Evaluation (RDTE) objectives, as they relate to nontechnological factors affecting the performance of defense RDTE either directly or through the environment in which such work is performed.

2. Supervise the achievement of these objectives.

3. Encourage improvement of the defense R&D industry's capability and efficiency in meeting DOD's needs (and other national needs).

4. Modify or mitigate the deleterious effects of shifts in defense R&D procurement.

Though sponsored by ODDRE, the studies are proving to be useful to many governmental and private organizations. For instance, the development of a systematic body of knowledge on the qualitative, quantitative, and structural characteristics of the defense R&D industry is helping to provide a basis for local defense-oriented communities to clarify the current and potential relationships between this new industry and their home environments.

Relation of This Study to Previous Studies in the Series

This is the third study of the series planned to develop a body of knowledge about the structure and dynamics of the defense R&D industry. The studies have proceeded in three phases:

Phase I

An exploratory study with the objective of seeking out patterns and relationships in the defense R&D industry to use as a basis for developing inferences and hypotheses concerning the structure and dynamics of the defense R&D industry.

The study, completed early in 1964, was published as: "An Exploratory Study of the Structure and Dynamics of the R&D Industry" (referred to in the following pages as reference 1).

<u>Phase II</u>

A study designed to test and validate or modify the inferences formulated in Phase I. The study, completed in 1965, was published as: "The Structure and Dynamics of the Defense R&D Industry: The Los Angeles and Boston Complexes" (referred to in the following pages as reference 2).

<u>Phase III</u>

A study designed to further test and validate the inferences developed in the foregoing studies; and to examine in detail the defense R&D industry in the Minneapolis-St. Paul (Twin Cities) area for a twofold purpose: (1) to identify variables affecting the transformation of an area into a defense R&D complex, and (2) to identify factors that may positively or negatively influence the growth of a defense R&D industry in the Midwest. This study has been recently completed, and is the subject reported herein.

<u>Method of Approach</u>

The method of approach throughout has attempted to achieve a balance between localization and generalization--between emphasis on selected communities and emphasis on the overall U.S. defense R&D industry. In each phase, individual defense R&D centers were selected as case studies, and were then compared with the total U.S. industry and with other selected centers for which data were available. In Phase I, the selection of Denver, Tucson, and Orlando was based on the consideration that they were not major defense R&D complexes but were communities dominated by a single, large, recently established defense R&D industrial facility, and hence the factors influencing the growth of the industry would be more discernible and capable of isolation. In Phase II, two major defense R&D complexes were selected--Los Angeles and Boston--to test, in such established complexes, the inferences drawn in Phase I.

In Phase III, the present study, the method of approach included:

1. Selecting a community as a case study on the basis of its geographic location (Midwest) and the extent of development of its defense R&D industry.

2. Measuring several dimensions of the defense R&D industry in the selected community, and comparing these with the data and findings in the preceding phases.

3. Tracing the historical development of the defense R&D industry in the selected community.

4. Examining the results of the comparative and historical analyses of the selected community in the light of the inferences drawn in the previous studies.[1,2]

5. Using the new data to develop inferences concerning factors affecting the transformation of an area into a defense R&D complex, and concerning the growth of defense R&D industry in the Midwest.

The Twin Cities community was selected after a preliminary survey indicated that it was well suited to provide the data relevant to the questions about growth factors for defense R&D complexes in general, and for the Midwest in particular.

The suitability of the Twin Cities for providing information on the general question was shown by its number of defense R&D contractors, which places the community somewhere between the Phase I case studies (defense R&D dominated by one major establishment in Denver, Tucson, and Orlando) and the Phase II case studies (major defense R&D complexes in Los Angeles and Boston). Moreover, the preliminary survey showed that the Twin Cities contained several defense R&D contractors in different industry classifications, and that there had been substantial activity in the generation of new technical companies over the past decade.

The Data

Scope and Sources

The data collected in the Twin Cities included information concerned with manpower, materiel procurement, industry-community interactions, financing, and R&D company formation and survival. These data were obtained from records of defense R&D contractors, the University of Minnesota, financial institutions, offices of the State of Minnesota, published sources, and interviews with representatives of industry, academic institutions, public agencies, and the press. For purposes of comparison, the extensive data collected in the previous studies were also used, e.g., manpower data on more than 30,000 engineers and scientists in Los Angeles and Boston.

Relationship of This Report to Previous Ones

Although this report is part of an integrated study series, it has been designed to be read independently of the two previous reports. Where specifically applicable, data from previous studies are included.

Textual vs Appendix Material

Because the data obtained have been voluminous and many-faceted, this report has been made synoptic in treatment, with the more detailed data and analyses included in appendixes. For readers wishing to probe more deeply into the textual content, these appendixes provide a greater focus on individual portions of the Twin Cities phase of the defense R&D study.

Appendix A - Regression analysis study of population and workforce migrations concerning the Twin Cities area.

Appendix B - History of the Twin Cities defense R&D industry.

Appendix C - Detailed tables on Twin Cities engineer/scientist characteristics. These tables carry the data to more specific levels than their summarized counterparts in the text.

Appendix D - Background material for Chapter IV (Factors Affecting the Development of the Twin Cities Defense R&D Industry).

II SUMMARY

The objectives of this study can be stated as two questions:

How does a defense R&D complex develop?

Considering its industrial and education capabilities, why has not a larger defense R&D industry developed in the Midwest?

Interrelationship of Growth Factors

Throughout this series of studies of the defense R&D industry, it has become increasingly evident that no factor can be singled out as being necessary and sufficient by itself to develop a defense R&D complex. This conclusion was drawn from the findings of the first study of Denver, Tucson, and Orlando, and it has been strengthened by the present study of the Twin Cities defense R&D industry. Hence, a strategy for developing a R&D complex must include consideration of several factors and must provide a flexibility which permits a shift in the emphasis from one factor to another as the local industry develops.

Characteristics of a Defense R&D Complex

The major defense R&D complexes are characterized by:

1. A relatively large and diverse defense R&D capability.

2. Economies of scale, which provide competitive advantages in the performance of defense R&D.

3. A resilience and regenerative ability enabling the complex to attract existing technical capabilities as well as to grow new ones, thus renewing and strengthening the local industry's ability to perform defense R&D despite the occurrence of cutbacks in overall market demand or shifts in defense technology.

These characteristics are useful in ranking communities as defense R&D centers--in a progression moving from communities with no defense R&D industry, to communities dominated by one major defense R&D establishment, to the potential defense R&D complex, and finally to the major defense R&D complex. In this progression, Denver, Tucson, and Orlando are ranked as areas dominated by one contractor; the Twin Cities area, as a potential complex; and Los Angeles and Boston, as established complexes.

A defense R&D complex is especially distinguished by its ability to cope successfully with the uncertainties of the defense R&D market, which include significant changes in the size of the market (both individual programs and total defense expenditures) or major shifts in technology. Useful measures of this resilience include the number of formations of companies with relevant capabilities; the ability of these companies to survive; and the ability of the community to attract relevant companies from other areas. Study of these measures, in Chapters IV and V and in a previous phase, identifies distinct differences between the potential complex (Twin Cities) and the communities with a single dominating contractor (Denver, Tucson, Orlando). The Twin Cities are characterized by a large number of relevant company formations, by a high survival rate for these companies, and by the ability to attract local investment. Conversely, the three other communities, as of 1963, had experienced few relevant company formations, had a relatively low survival rate, and although attracting some investment from companies outside the community, later experienced withdrawal of these same companies.

As for the major defense R&D complexes--Los Angeles and Boston--they have generated a high number of new, relevant companies, and these companies have experienced a high survival rate. In addition, a number of companies have moved, or considered moving, from other areas to Boston and Los Angeles for a variety of reasons, many of them associated with operational efficiencies.

Measures and Processes of Growth

The most commonly used measures of defense R&D industrial growth are the increase in total defense R&D dollars and the increase in the percentage of total defense R&D dollars awarded to a community. Such measures, used alone, often mask rather than depict the actual development of a community as a defense R&D complex. A series of awards to one contractor over a period of years can give an appearance of local growth that can quickly disappear with the completion of a major project. Even from an experience period of three years (as shown in Chapter III, Table 5), it is evident that an R&D center dominated by one contractor can experience sharp fluctuations in dollars received when the contractor experiences the "project piston"* effect that characterizes defense R&D contracting. In a community with a single dominant contractor, the downstroke of a major project piston, actuated by the cancellation or completion of a major contract, causes not only lay-offs but also out-migration of the technical workforce. Usually, the displaced employees enter the general migratory streams, never to return.

---

* "The project-contract nature of the defense R&D business is probably the largest single factor affecting the turnover of personnel. The manpower demand of a major defense R&D project, particularly the demand for professional technical manpower, acts in the manner of a large piston; pulling in large numbers on the 'upstroke' and pushing them out on the 'downstroke.'" From reference 1.

Several nondollar measures can be considered simultaneously with the dollar measures to obtain more useful indications of growth as well as to suggest some of the processes that may be essential to the achievement of such growth. The results of this study suggested that:*

1. An essential process in the transformation of a community into a defense R&D complex is an increase in the number of local contractors, with or without a parallel increase in the dollars awarded, to provide a multiplicity of potential growth points.

2. Consideration should be given not only to prime contractors but to the total number of local establishments engaged in defense R&D work. The total number of establishments includes defense subcontractors as well as nondefense (but defense-related) subcontractors who work for such agencies as NASA and AEC. A larger number of prime contractors means a larger number of managements making technical decisions from independent viewpoints, thereby increasing the probability of achieving technical variety. The presence of a large, locally dominant defense R&D establishment does not provide the conditions required for an increase in the number of local prime contractors. Domination by one organization may even be considered a negative factor.

3. A growing R&D community specializes in new technical fields in which there are greater chances to compete successfully and to develop competitive advantages over well-established complexes. This is reflected in a workforce that is more specialized in new technical fields, and is younger, on the average, than the workforce in the older complexes. As the community becomes established in its specialty, the aggregate of the community's technical capabilities should be deepened and broadened. The increase in the number of local prime contractors may be an aid in this process.

4. Aside from new technical fields, a growing R&D community gradually broadens and deepens its scope in existing fields by including more of the capabilities needed for specialized fields and for defense R&D in general. This is reflected by a workforce with a higher percentage of advanced degrees in the locally developed fields of specialization and by the gradual inclusion of a broader range of degree specialties. This part of the process tends to keep the average age of the workforce low since the process is still concentrated on new technology and newly produced advanced degrees.

---

* The results summarized here in the eight numbered paragraphs can be considered to be strong inferences concerning the development of defense R&D complexes.

5. A growing R&D community gradually achieves a capability to perform and to compete in all technologies of defense R&D against established complexes. The deeper involvement of a community's industry in defense R&D is reflected by a workforce that has a wide range of degree specialties and levels as well as a wide range of defense R&D experience, and an average age that is closer to the average age found in the older complexes.

6. A measure of the extent to which a community has developed a relevant workforce of the required magnitude is the percentage of engineers/scientists (E/S's) that the community hires from outside its home area. At the outset, if the percentage is large, the community's potential is limited. If the percentage is small, or continues to decrease over time, the community has the potential labor pool necessary to develop a defense R&D complex.

7. Further measures related to manpower are: salary levels for different age groups; proportion of E/S's hired directly after graduation from universities; proportion of E/S hires that were trained by local universities; turnover of E/S's; and average seniority of E/S's. These factors show that a growing R&D community will increase the quantity and variety of job options for E/S's as a consequence of the increase in companies and projects in the community. High turnover rates for E/S's, or increasing turnover rates, reveal the project-piston effect. Other factors related to the project-piston effect are: decrease in average seniority of E/S's, and an increase in the overall salary structure.

8. A growing R&D community can measure the breadth and depth of its R&D capabilities by the amount of materiel and services that must be procured from outside areas. This capability can be measured by the percentage of defense R&D prime contract dollars received locally that remain with the prime contractor or are subcontracted within the local area. A related measure of capability is the amount of subcontract dollars received from other areas.

Elements of the Growth Process

On the basis of the foregoing, it is suggested that the elements of the process for sustained growth in a potential R&D complex are:

1. A continuing effort to develop multiple points of potential growth until the local industry achieves a self-sustained momentum.

2. A technical specialization aimed at achieving competitive advantage, followed by a deliberate effort to deepen, broaden, and strengthen the fields of specialty.

Suggested Actions for Development of a Defense R&D Complex

Development of Multiple Growth Points

This includes the development of R&D-oriented entrepreneurs and a financial community with the know-how and interest in providing financial support to new and small companies. The financial support must be in terms of initial, working, and growth capital. Other support includes: policies by universities for encouraging engineering and science faculties to undertake entrepreneurial activity; support for technical ventures in the form of rent-free facilities; joint marketing aids; referral services for financial aid; consulting by community panels; and other local support.

Throughout the analytical comparisons of the Twin Cities with areas of greater and lesser development, it has become obvious that the local achievements of many small and medium size companies hold out the greatest potential for development. This point must be emphasized because the several thousands of regional and local development agencies in the United States are currently oriented toward attracting one or more of the small number of relocating divisions of major corporations. All of the evidence in this series of studies suggests that attracting corporation divisions does not provide the most effective or desirable path to development. On the contrary, establishment of a number of small and medium size technical companies is the most effective way to provide for the development of a complex. The existence of many companies provides a means for many independent decisions based on differing assumptions, thereby providing a flexible response to the unknown. A development program based on a number of small companies as opposed to a large establishment, even one having more sales dollars and manpower, permits a less volatile and more stable labor market, with a consequent development of the kind of growing labor pool that typifies a defense R&D complex. Such an approach helps to overcome the high degree of uncertainty that is inherent in the defense market.

Technical Specialization

Since new entrepreneurs and small companies are usually at a relative disadvantage in the marketplace, concentration on a specialty is a natural solution. A community that wishes to develop an R&D complex is, indeed, in the same position as that of a small company undertaking to compete with a large corporation. The probability of successfully entering the marketplace is raised by concentration on a small but growing segment of the total field. Once established, this segment can be used to support expansion to other specialties. The final goal of this process is to broaden out and achieve the full status of a major defense R&D complex.

To develop specialization, a community can consciously provide selected support to local enterprises successful in new technological fields. Support can include measures to encourage the local formation or location of other new ventures in the same or related fields, as well as measures to provide subsidiary functions that aid the technical companies in the selected specialized field. Once a specialty has obtained an economic foothold, the community can deliberately attempt to attract and support companies and services that would strengthen the capability of the specialized companies in the community.

The Midwest and the Defense R&D Industry

The data collected in the Twin Cities defense R&D study show that there are no regional factors precluding the development of defense R&D industry in the Midwest. However, these data and the data from previous studies suggest that the question of why a larger defense R&D industry has not grown in the Midwest must be considered in terms of climate, national migration patterns, resources, history, economic alternatives, and difficulties in competing with existing complexes.

Of these factors, the last two seem to play a major role. For example, in the Midwest after World War II, in Detroit, the decision was made to leave the aircraft field (and the consequent aerospace industry) to resume the automobile business. Since then, despite efforts to interest Midwest concerns in bidding on defense R&D subcontracts, there has been relatively little response, according to procurement personnel from major defense R&D companies.

As for the difficulties of competition, existing complexes have a great advantage, and consequently, many of those Midwest-based companies that have entered the defense R&D field have not chosen to compete from the Midwest. Rather, they conceded the advantages of the existing complexes by operating from inside the complexes--by acquisition, by moving, or by starting divisions there.

The Twin Cities area has gone contrary to the general Midwest pattern: it has responded to defense R&D needs, it has gained local support, it has attracted E/S's from elsewhere, and it has overcome whatever disadvantages its climate may have imposed.

III THE STRUCTURE AND DYNAMICS OF THE DEFENSE R&D INDUSTRY IN THE TWIN CITIES AREA

"Defense R&D industry," as used here, is a convenient classification of those firms and institutions that contract with the U.S. defense establishment for work defined in the RDTE program categories of the defense budget. Most of the firms so classified are not engaged solely in selling defense R&D; production of hardware is usually carried out by the same companies. However, unlike firms that perform R&D only for hardware, defense R&D firms also sell R&D as a product.

Composition of the Defense R&D Industry

The Twin Cities defense R&D industry, as defined, includes 17 surviving establishments that have received RDTE prime contract awards in the past 10 years. These plus the Electronics Division of General Mills, Inc., and Electro-Nuclear System Corporation, which are no longer operating, are listed in Table 1.

During the ten year period--fiscal years (FY) 1956 through 1965--approximately $500 million of R&D prime contract awards have been received by establishments in Minnesota. With two minor exceptions,* Minnesota's defense R&D industry is located in the Twin Cities, and consequently, the statewide data on R&D contract awards pertain almost exclusively to the Twin Cities.

The defense R&D prime contract awards received by Minnesota establishments accounted for 0.9-1.3% of the total defense R&D dollars awarded (see Table 2) by DOD in the period FY 1958-1965. Table 2 also shows Minnesota awards as percentages of U.S. Census region and division level: 10-14% of awards to the North Central region, and 35-62% of awards to the West North Central division.

---

* The two exceptions are: (1) G.T. Schjeldahl Company (about 40 miles from the Twin Cities) which accounted for $600,000 in defense R&D prime contract awards during the past ten years; and (2) the University of Minnesota's campus in Duluth, where contract work of less than $100,000 was performed.

Table 1

TWIN CITIES ESTABLISHMENTS RECEIVING DEFENSE
R&D PRIME CONTRACT AWARDS OVER $10,000
FY 1956-1965

Contractor (ranked by dollars received in period)	Prime Contract Awards (millions of dollars) 1956-1962	1963	1964	1965	10-Year Total
Univac Div., Sperry Rand Corp.	$141.6*	$21.5	$17.2	$15.6	$195.9*
Honeywell, Inc.	76.7*	17.1	11.4	11.0	116.2*
Electronics Div., General Mills, Inc.†	39.1	5.8	1.7		46.6
Control Data Corp.	21.4*	8.6	6.8	3.6	40.4*
Northern Ordnance Div., FMC Corp.	22.6	0.7	5.6	1.8	30.7
University of Minnesota	17.6	1.9	1.8	1.8	23.1
Western Electric Co.			7.1	10.1	17.2
Minnesota Mining & Mfg. Co.	10.3		2.1	0.9	13.3
Applied Research Div., Litton Industries†			1.5	2.7	4.2
Winzen Research, Inc.	3.0				3.0
Maico Electronics	2.4				2.4
Research, Inc.	1.7				1.7
Fluidyne Engineering Corp.	0.5		0.3	0.6	1.4
Donaldson Co.			0.5	0.5	1.0
Data Display Corp.‡		0.6		0.4	1.0
Lightning and Transients Research, Inc.		0.6	0.1	0.1	0.8
Viron Div., GCA Corp.			0.4	0.3	0.7
Electro-Nuclear System Corp.§	0.6				0.6
Archer-Daniels-Midland Co.				0.4	0.4
Total Twin Cities awards	$337.5	$56.8	$56.5	$49.8	$500.6
Annual average for 1956-1962	48.2				

* Estimates based upon relationship between total corporate R&D prime contract awards and the portion performed in Minnesota for the period 1963-65.
† Electronics Division of General Mills, Inc., succeeded by Applied Research Division, Litton Industries.
‡ Became subsidiary of Control Data Corporation in 1965.
§ Operations terminated in 1963.

Source: <u>500 Contractors Listed According to Net Value of Military Prime Contract Awards for Experimental, Developmental, Test and Research Work</u>, Office of the Secretary of Defense, reports for fiscal years 1956 through 1956.

Table 2

MINNESOTA DEFENSE R&D PRIME CONTRACT AWARDS
AS GEOGRAPHICAL PERCENTAGES
Fiscal Years 1958-1965

Fiscal Year	Percentage of U.S. Awards	Percentage of North Central Region Awards	Percentage of West North Central Division Awards
1958	1.3%	12.8%	53.8%
1959	1.3	11.8	50.1
1960	1.1	11.2	56.9
1961	0.9	10.7	61.9
1962	0.9	12.0	61.7
1963	1.0	14.0	57.0
1964	1.0	12.1	35.2
1965	1.1	10.8	46.0

Source: Office of the Secretary of Defense, The Changing Patterns of Defense Procurement, 1962; and Military Prime Contract Awards by Region and State, FY 1962-1965.

A distribution of contract awards for FY 1965 by R&D category in Table 3 shows that over 40% of the dollars awarded to Twin Cities defense R&D contractors were for engineering development and that the Twin Cities distribution was close to or higher than the national distribution in the first four categories of research.

Twin Cities organizations received defense R&D contract awards in 30 of the 33 technology areas that were used to code RDTE contracts. Of the R&D dollars awarded to Twin Cities organizations in this period, work identified by technology as "guided missiles" and "electronics and electronic equipment" received 58% (see Table 4). Other major contract award areas were "ordnance" (16.1%), "research and research equipment" (6.8%), and "chemical warfare equipment and materials" (4.3%).

Ranking of Twin Cities

To qualify as a major defense R&D complex, an area must receive a relatively large dollar value of defense R&D awards; have a relatively large number of defense R&D prime contractors; and be relatively free of domination by a single contractor.

Table 3

DISTRIBUTION OF DEFENSE R&D PRIME CONTRACT AWARD DOLLARS BY CATEGORY OF R&D FOR SELECTED AREAS FY 1965

	Category*						Total	
	1	2	3	4	5	6		
	Research	Exploratory Development	Advanced Develop-ment	Engineering Development	Operational System Development	Manage-ment and Support	Percent	Dollars Awarded
Total RDTE prime contract dollars awarded†	9.3%	14.0%	19.5%	21.5%	27.3%	8.3%	99.9%	$4,708,267
R&D category as % of dollars awarded to:								
Twin Cities	10.5	21.2	21.0	40.3	6.7	0.3	100.0	49,991
Los Angeles	6.5	12.5	19.7	17.6	32.7	10.9	99.9	822,304
Boston	11.1	16.5	15.7	14.3	11.0	31.4	100.0	313,093
Orlando	13.5	1.8	0.4	83.8	0.3	0.2	100.0	88,793
Denver	1.7	3.3	1.6	73.7	19.7	0.1	100.1	136,658
Tucson‡								

* The categories listed here are those used by DOD in its RDTE Program.
† Based on RDTE prime contract award data for FY 1965 covering contract actions exceeding $10,000.
‡ The amount of RDTE dollars awarded to Tucson in FY 1965 was too small for reasonable comparisons to be made.

Source: Stanford Research Institute.

Table 4

DISTRIBUTION OF DEFENSE R&D PRIME CONTRACT AWARD DOLLARS
BY TECHNOLOGY OF RESEARCH FOR AREAS STUDIED
FY 1965

Technology*	Total RDTE Awards	Twin Cities	Los Angeles	Boston	Orlando	Denver
	Percent of Award Dollars by Area					
Aircraft and flight equipment	13.6%	3.4%	8.4%	0.9%	0.0%	0.1%
Astronomy, geophysics and geography	1.0	†	0.7	1.7	0.1	0.2
Chemical warfare equipment and materials	0.9	4.3	1.3	0.4	0.0	0.1
Chemistry	0.4	0.0	0.2	0.7	0.0	†
Communications	3.3	0.7	2.1	1.2	2.4	†
Detection	3.3	0.6	2.3	3.7	0.4	1.7
Electrical equipment	1.5	0.6	1.2	0.7	0.0	†
Electronics and electronics equipment	12.4	28.1	13.6	52.6	0.6	0.2
Fluid mechanics	0.5	0.6	0.1	0.2	0.1	0.0
Fuels and combustion	0.6	0.6	0.5	0.3	0.0	0.2
Ground transportation and equipment	0.2	0.2	†	0.1	0.0	0.1
Guided missiles	39.3	29.9	53.7	21.0	95.4	94.2
Installations and construction	0.1	0.2	0.1	0.1	0.0	0.0
Materials (nonmetallic)	0.6	0.5	0.3	0.4	0.0	0.1
Mathematics	0.2	0.2	0.1	0.1	0.0	†
Medical sciences	0.9	0.6	0.5	0.6	†	0.2
Metallurgy	0.9	0.5	0.4	1.5	†	0.9
Military sciences and operations	1.8	0.6	2.8	0.5	0.0	†
Navigation	0.5	1.1	0.4	1.2	0.0	0.0
Nuclear physics and nuclear chemistry	0.6	1.8	0.3	1.4	0.2	0.0
Nuclear propulsion	0.8	0.6	†	0.0	0.0	0.0
Ordnance	2.5	16.1	1.9	1.1	0.4	0.2
Personnel and training	0.3	0.1	0.2	0.2	0.0	0.0
Photography and other reproductive processes	0.3	0.1	0.3	0.4	0.0	0.0
Physics	0.9	0.8	0.3	2.3	0.1	0.8
Production and management	0.1	0.0	†	†	0.0	0.0
Propulsion systems	5.5	0.4	3.8	0.8	†	0.6
Psychology and human engineering	0.2	0.2	0.1	0.2	0.0	0.0
Quartermaster equipment and supplies	0.1	0.4	0.1	†	0.0	†
Research and research equipment	5.5	6.8	4.1	5.2	0.4	0.3
Ships and marine equipment	0.6	†	0.1	0.3	0.0	0.0
Miscellaneous arts and sciences	0.2	†	†	0.1	0.0	0.0
Transportation	†	0.0	0.0	†	0.0	0.0
Total	99.6%	100.0%	99.9%	99.9%	100.1%	99.9%

Note: Columns may not add to 100 0% because of rounding.

* Based on service codes.

† Less than 0.05%

Source: Stanford Research Institute.

As can be seen in Table 5, in FY 1965 Los Angeles contractors included in the first 500 contractors* were awarded $790.8 million in defense R&D prime contracts and numbered 98 (139 establishments), but the largest contractor received only 22% of the local awards. Similarly, Boston received $308.2 million and had 59 contractors, while the largest contractor received only 39% of the local awards.

When compared in these quantitative terms with 19 other Midwest centers, the Twin Cities can well be considered as a potential defense R&D complex. In FY 1965, the Twin Cities ranked third in total defense R&D dollars awarded, third in number of defense R&D contractors receiving awards, and third in terms of nondomination by the largest local contractor. (The largest local contractor, the Univac Division of Sperry Rand, received 31% of the Twin Cities contract dollars awarded in FY 1965.) Only Detroit and Cincinnati received more dollars, only Dayton and Chicago had a larger number of defense R&D contractors, and only Dayton and Cleveland showed less domination by the largest contractor, while Chicago equalled the Twin Cities.

Fifteen of the 20 Midwest centers analyzed were dominated by a local contractor that received over 50% of all the local defense R&D dollars awarded in FY 1965; eight of these 20 had a local contractor that received over 90% of the dollars awarded. In FY 1963, 14 of these centers were dominated by a large contractor that received over 50% of the local awards, and ten of the centers had a contractor receiving over 90% of the awards.

Table 6 relates Minnesota's defense R&D to total defense dollars, since FY 1958, in two ways: (1) from a national standpoint, Minnesota's share of all defense dollars has been 0.6-1.3%, and its share of defense R&D has been almost the same--0.9-1.3%; and (2) from a local standpoint, Minnesota's proportion of defense R&D to its own total defense awards has been 19-34%, or a 24.5% annual average.

The defense R&D prime contract dollars awarded to Twin Cities establishments in FY 1963-1965 represent 3-4% of the total combined sales generated in Minnesota during these years by the 13 Twin Cities companies receiving defense R&D prime contracts. If Minnesota Mining and Manufacturing and Archer-Daniels-Midland are excluded, the figure increases to 6-7% of total combined sales. For six of the companies--Fluidyne, Lightning and Transients Research, Litton, Univac, Viron, and Western Electric--defense R&D prime contract awards accounted for 12% to 50% of their total Twin Cities sales. Yet these R&D awards take on more significance, because

---

* Based on RDTE awards of over $10,000 to the top 500 contractors, Directorate of Statistical Services, Office of Secretary of Defense. If all contractors receiving over $10,000 are considered, Los Angeles had 347 prime contractors receiving $822 million; Boston 207 contractors receiving $313 million; Twin Cities 40 contractors receiving $50 million; Denver 21 contractors receiving $137 million; and Orlando nine contractors receiving $89 million.

Table 5

COMPARISON OF SELECTED METROPOLITAN AREAS BY NUMBER OF DEFENSE R&D CONTRACTORS INCLUDED IN FIRST 500, VALUE OF AWARDS, AND PERCENT TO LARGEST CONTRACTOR FY 1963-1965

	Number of Defense R&D Contractors			Value of Defense R&D Awards (millions of dollars)			Percent of Area Awards to Largest Contractor			Largest Contractor in Area
	1963	1964	1965	1963	1964	1965	1963	1964	1965	
Complexes										
Los Angeles	92	86	98	$1,006.3	$1,114.9	$790.8	38%	49%	22%	North American
Boston	56	65	59	255.0	282.4	308.2	28	35	39	MIT
Midwest centers										
Twin Cities	8	12	13	56.8	56.4	49.7	38	30	31	Sperry-Rand-Univac Division
Detroit	14	12	12	28.7	47.4	69.0	23	81	72	Ling-Temco-Vought
Milwaukee	3	3	3	58.1	37.4	13.8	99	98	87	General Motors
Cincinnati	5	4	6	14.1	13.0	52.4	85	79	95	GE-Flight Propulsion
Chicago	19	18	20	35.6	29.1	28.7	33	26	31	IIT
Ann Arbor	6	5	3	24.8	26.7	33.1	41	65	42	(1963 & 1965) Bendix Systems Division (1964) Univ. of Michigan
Columbus	5	5	6	10.8	19.5	35.5	45	46	54	(1963 & 1964) Battelle (1965) N. American
Cleveland	11	10	10	25.8	15.0	16.3	66	51	28	Gen. Motors 1963-64, Clevite 1965
St. Louis	5	5	8	10.8	15.2	25.2	79	64	56	McDonnell Aircraft
Indianapolis	4	3	3	6.4	20.5	24.2	95	98	99	General Motors - Allison
Akron	4	3	3	18.9	10.5	4.0	92	86	60	Goodyear-Aerospace
South Bend	2	2	3	11.8	21.5	2.8	95	98	80	Bendix Mishawaka & Aerospace Divs.
Wichita	3	2	1	11.0	9.1	13.3	79	30	100	Boeing
Dayton	13	14	21	8.9	10.6	12.2	25	24	25	Dayton University
Urbana	3	2	3	8.0	7.1	7.5	94	95	78	University of Illinois
Kansas City, Mo.	1	2	2	2.6	1.6	2.3	100	98	98	Midwest Research Institute
Madison	1	2	2	1.7	2.2	2.3	100	95	95	University of Wisconsin
Cedar Rapids	1	1	1	2.6	0.5	0.7	100	100	100	Collins Radio
Sioux Falls	1	1	1	0.5	0.2	0.5	100	100	100	Raven Industries
Omaha	1	0	1	0.1	0.0	0.1	100	0	100	ITT 1963, IBM 1965
Other centers										
Denver	9	7	6	249.0	218.0	136.1	97	98	96	Martin
Orlando	3	2	2	17.8	74.2	88.7	86	94	84	Martin 1963, Western Electric 1964-65
Tucson	6	9	4	125.6	19.9	1.4	91	48	60	Martin 1963, Pan American Airways 1964 University of Arizona 1965

Source: Office of the Secretary of Defense, 500 Contractors Listed According to Net Value of Military Prime Contract Awards for RDTE Work, FY 1963, 1964, and 1965.

Table 6

PRIME CONTRACT DEFENSE AWARDS TO MINNESOTA, R&D AND ALL OTHER, AS A PERCENT OF TOTAL U.S. AWARDS FY 1958-1965*
(Millions of Dollars)

	1958	1959	1960	1961	1962	1963	1964	1965
Value of defense R&D awards								
Total U.S. awards	$16,953	$16,770	$14,886	$16,085	$18,926	$19,034	$18,652	$18,561
Minnesota awards	103	173	133	138	245	215	161	209
Minnesota as percent of U.S. awards	0.6%	1.0%	0.9%	0.9%	1.3%	1.1%	0.9%	1.1%
Value of all other defense procurement awards								
Total U.S. awards	$ 4,056	$ 5,207	$ 5,521	$ 6,027	$ 6,113	$ 6,199	$ 5,765	$ 4,707
Minnesota awards	53	65	60	51	52	59	57	50
Minnesota as percent of U.S. awards	1.3%	1.3%	1.1%	0.9%	0.9%	1.0%	1.0%	1.1%

* Exclusive of classified contracts.

Source: Office of the Secretary of Defense, The Changing Patterns of Defense Procurement (1962), and Military Prime Contract Awards by Region and State, FY 1962-63-64-65.

they represent industrial classifications that have a high technical content and are nationally significant to defense. Table 7 reveals that the Twin Cities are particularly specialized in two very valuable industry groups--automatic controls and measuring instruments; and computing and related machines. In both categories, the Twin Cities accounted for an estimated 14% of the value of total U.S. shipments for 1963. The Twin Cities area is specialized to a lesser extent in the production of surgical and medical instruments (5% of the value of total U.S. shipments); industrial electrical equipment (4%); and ordnance and accessories (2%).

In terms of total manufacturing industry in the Twin Cities, the 142 establishments in the defense-related industrial groups represented about 5.5% of the 2,599 manufacturing establishments in the Twin Cities, but accounted for 28% of all manufacturing employment in the area.

Manpower: The Industry's Engineer/Scientist Workforce

The engineer/scientist (E/S) workforce of the defense R&D industry is its principal "production" factor. This workforce accounts for the largest portion of R&D costs and is essentially the technical capability that the companies and institutions in the industry "sell" to DOD. Therefore, a study of the E/S workforce in the Twin Cities should shed some light on the questions motivating our research: how can a defense R&D complex be developed, and what factors deter the Midwest from becoming such a complex?

Besides using data from the earlier studies, the research team obtained data in July-August 1965 from the personnel records of four large Twin Cities establishments. These records include data on a total of 1,966 E/S's performing defense R&D contract work in the Twin Cities. The sample obtained is estimated to represent over 90% of the total Twin Cities defense R&D prime contract workforce. As in the earlier studies,[1,2] the data on individual E/S employees were drawn from the employment application forms and payroll records of each participating establishment.*

Educational Composition of the E/S Workforce

The educational profile of the Twin Cities E/S workforce studied is shown in Table 8. Also shown are the educational characteristics of similar workforces in the major defense R&D industry complexes of Los Angeles and Boston, and in the single-establishment dominated defense R&D centers of Denver, Tucson, and Orlando.

---

* Throughout the discussion of manpower, the total number (N) of E/S's considered may vary slightly from table to table. This variation is caused by occasional omissions in the data available (as when an applicant has failed to enter marital status on the employment application form).

Table 7

COMPARISON OF TWIN CITIES DEFENSE R&D INDUSTRY WITH ALL DEFENSE-RELATED AND MANUFACTURING INDUSTRY LOCALLY AND NATIONALLY
1963

Industry	Number of Estab-lishments	Employees in Twin Cities	Value of Shipments (millions of dollars) Twin Cities	U.S.	Twin Cities Percent of U.S.
All manufacturing industry	2,559	166,600	$1,972	$417,300	0.5%
Defense-related industry					
Automatic controls and measuring instruments	24	18,000	375	2,746	14
Computing machines and related equipment	10	13,000	250	1,854	14
Surgical and medical instruments	16	700	15	286	5
Industrial electrical and electronic equipment	16	2,950	77	2,072	4
Ordnance and accessories	3	5,500	75	3,539	2
Electronic components	24	2,500	40	3,813	1
Radio, TV, tape recorder equipment	11	900	12	2,292	1
Other high technology industry	10	1,850	34	n.a.*	n.a.*
Total	142	46,500	$890		
Defense R&D industry	14	5,000	$54†	$5,557†	1%

* n.a. = not available.
† Annual average of FY 1963-65 prime contract defense R&D awards.

Sources: Stanford Research Institute and 1963 Census of Manufacturing.

Table 8

EDUCATIONAL PROFILE OF THE DEFENSE
R&D ENGINEER/SCIENTIST WORKFORCE
Selected Metropolitan Areas
(Total Sample N = 34,015; Twin Cities Sample N = 1,966)

	Percent of E/S's with a Degree at Time of Hire				
	Bachelor's Degree	Master's Degree	Doctor's Degree	Total with Degree	No Degree
Los Angeles*	57.3%	12.1%	3.0%	72.4%	27.6%
Boston*	58.7	16.7	4.8	80.2	19.8
Denver, Tucson and Orlando†	53.0	8.2	0.8	62.0	38.0
Twin Cities	73.3	12.3	1.2	86.8	13.2

* From reference 2.
† From reference 1.

In terms of degreed vs nondegreed technical professionals, the Twin Cities workforce has the highest percentage of degreed E/S's (86.8%). This is a distinctly higher percentage (7 to 15 percentage points) than found in the Los Angeles and Boston defense R&D complexes, and substantially higher (almost 25 percentage points) than found in the communities dominated by one establishment. The E/S's in the Twin Cities defense R&D workforce have a smaller percentage of graduate degrees (13.5%) compared with Los Angeles (15.1%) and Boston (21.5%), and a larger percentage compared with Denver, Tucson, and Orlando (9.0%). Although the Twin Cities workforce has a slightly larger percentage of E/S's having a master's degree, compared with the Los Angeles workforce, it has a smaller percentage of E/S's with doctorates. Boston leads the Twin Cities in both graduate degree categories, and the Twin Cities similarly lead the centers of Denver, Tucson, and Orlando, dominated by one establishment.

Data on the various degree specialties found in the Twin Cities E/S workforce are shown in Table 9, along with similar data from Los Angeles and Boston; 66.6% of the Twin Cities E/S's have engineering degrees, of which 43.5% are in electrical and electronic engineering.

E/S's with degrees in electrical and electronic engineering, together with those holding degrees in mathematics and statistics, make up nearly 57% of the total Twin Cities E/S workforce. This compares with 40% in Boston and 31% in Los Angeles for the same specialties. The heavy specialization in electrical and electronic engineering, mathematics, and statistics reflects the computer and control orientation of the Twin Cities.

Table 9

CURRENT WORKFORCE SPECIALTIES
Percent of E/S's at Time of Hire
Twin Cities, Los Angeles, and
Boston Defense R&D Centers

Specialty	Twin Cities	Los Angeles	Boston
Mechanical engineering	15.3%	18.7%	13.7%
Aeronautical engineering	5.2	12.4	4.8
Electrical engineering*	43.5	23.4	34.8
General engineering	1.3	8.4	2.9
Civil engineering	0.4	2.0	1.1
Industrial & management engineering	0.8	1.1	3.3
Other engineering†	0.1	1.4	0.7
Physics‡	6.8	7.1	10.3
Chemistry & biochemistry	1.9	5.4	3.4
Mathematics & statistics	13.3	7.5	9.0
Other technical specialties	3.6	7.0	6.8
Nontechnical specialties	2.7	3.3	2.7
Unknown	5.3	2.1	6.3
Total	100.2%§	99.8%	99.8%

* Includes telecommunications, radio communications, electronics.
† Includes structural, tool, industrial design, nuclear engineering.
‡ Includes astrophysics, engineering physics, geophysics.
§ Figures do not total 100% because of rounding.

Source: Appendix Table C-1.

Although the range of degree specialties in the Twin Cities workforce has broadened to a limited extent in the past 15 years, the Twin Cities workforce remains somewhat specialized.

Age Composition

The average age of E/S's in the Twin Cities R&D workforce is 34.8 years. This is approximately equal to the average age of the E/S's in the Boston workforce (34.3 years in 1964), and younger than the average age of Los Angeles E/S's (37.1 in 1964). The younger workforces in Boston and the Twin Cities reflect the newer nature of the defense R&D industry in these two areas, compared with the older industry in Los Angeles, and this newness also reflects the higher concentration of skills in new industrial fields (e.g., computers).

Sex and Marital Status

Slightly more than 1% of the defense R&D E/S's in the Twin Cities were women--a finding which parallels the data from Los Angeles and Boston. At the time of hire into the current workforce, 69.3% of the male E/S's in the Twin Cities were married, compared with 70.9% in Los Angeles and Boston, again reflecting the higher average age of the Los Angeles workforce. Less than 1% of the E/S's in the Twin Cities were divorced or separated at time of hire, compared with 1.8% in Boston and Los Angeles. At time of hire, 29.7% of the Twin Cities E/S's were single males, compared with 27.3% in Los Angeles and Boston.

Job Mobility

The E/S's employed in the Twin Cities R&D establishments were analyzed for geographic and establishment mobility. Geographic mobility means the movement of E/S's between Census regions, Census divisions, states, and selected intrastate areas. Establishment mobility means the movement of E/S's between industries, types of organizations (e.g., academic, industrial, governmental), and companies within the defense R&D industry.

The raw data for the analysis, obtained from employment applications, consisted of the identity and location of each of the three most recent organizations for which an E/S had worked before joining the workforce of the contractor participating in the study (no intra-company transfers were included). In order to avoid double-counting of individuals, the primary analysis made use of current workforce information only.

Comparisons were made between the mobility data of the Twin Cities workforce and similar data for the E/S workforce previously studied in Los Angeles, Boston, Denver, Tucson, and Orlando. To measure geographic and establishment mobility, the source of an E/S was taken to be his location and employer just before he was hired by one of the contractors participating in the study.

Geographic Mobility. It was concluded in an earlier study of this series that ". . . the geographic source of the largest single fraction of the E/S's in the defense R&D workforce of a given area is the home state and region."[a] This conclusion was borne out once more in the present analysis of geographic mobility (see Table 10). The majority of the E/S's in the Twin Cities defense R&D industry were drawn from the "home" Census region, "home" Census division, and the "home" state. The North Central region was the source of 73.6% of the Twin Cities E/S's; the West North Central division, 56.0%; and the state of Minnesota, 42.3%. The importance of the "home" areas as sources of E/S's was also seen in Los Angeles and Boston. In the latter two complexes, however, larger percentages of the current workforce were hired from the "home" state than was found to be the case in the Twin Cities. This reflects, in part, the existence of larger, specialized labor pools in the two major complexes, thus alleviating reliance on the "import" of E/S's from elsewhere.

Table 10

GEOGRAPHIC SOURCE OF ENGINEERS AND SCIENTISTS AT TIME OF HIRE
Percent of E/S's from Various Census Regions and Divisions, Twin Cities, Los Angeles, and Boston Defense R&D Industry

Census Region and Division	Twin Cities (N = 1,935)	Los Angeles (N = 26,342)	Boston (N = 2,911)
Northeast region	7.8%	14.5%	80.7%
North Central region	73.6	15.5	6.7
Southern region	5.9	9.3	7.0
Western region	12.7	60.8	5.6
Total	100.0%	100.1%	100.0%

Note: Columns may not add to 100% because of rounding.

Source: Appendix Table C-2.

Figure 1 shows how the home area as a source of E/S's for the Twin Cities workforce has varied over the years. The Twin Cities' dependence on out-of-area hires has shown a steady increase over time, rising from 11% in 1935 to 70% in 1965. In a previous study, it was found that in the large, well-established complex of Los Angeles, the percentage of E/S's hired from outside the Southern California area varied directly with the rise and fall of the total U.S. defense R&D industry market. In the younger and smaller Boston complex, there was a steady increase in the percentage of hires from outside Massachusetts between 1940 to 1959, followed by a slight drop during the 1960-1964 period.

An examination of the geographic sources of the most recent degree received indicated, as shown in Table 11, that 83.2% of the Twin Cities E/S's received their most recent degree from institutions in the North Central region, the "home" region of the Twin Cities. This compares closely with the Boston data which show that 82.3% of its E/S's received their degrees in Boston's "home" region, the Northeast. In both Boston and the Twin Cities, the "home" region has played a much greater role in the education of local E/S's than was the case in Los Angeles. The data from the Los Angeles defense R&D industry, with its much greater pool of E/S's, indicate that less than 25% of them received their most recent degree from institutions in the Western region.

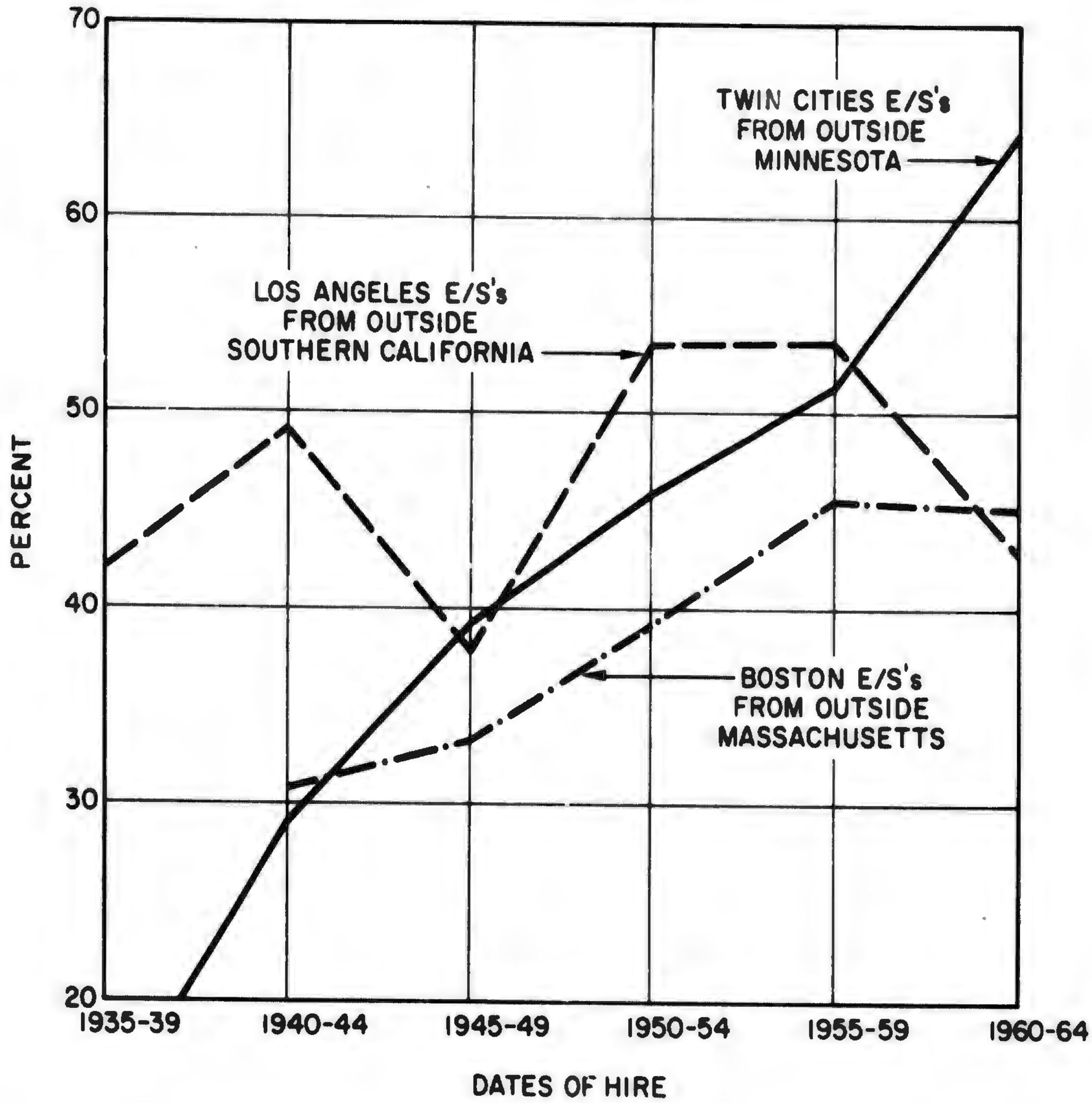


FIG. I ENGINEER/SCIENTIST HIRES FROM OUTSIDE THE HOME AREA
Twin Cities, Los Angeles, and Boston Defense R & D Establishments

Table 11

GEOGRAPHIC SOURCE OF MOST RECENT UNIVERSITY DEGREE
OF ENGINEERS AND SCIENTISTS
Percent of Current E/S's Receiving Degree from Census Regions
Twin Cities, Los Angeles, and Boston Defense R&D Establishments

Census Region	Twin Cities (N = 1,693)	Los Angeles (N = 24,149)	Boston (N = 2,803)	Ex-Minnesotans in Los Angeles (N = 214)
Northeast	8.9%	33.3%	82.3%	4.2%
North Central	83.2	27.7	9.6	90.7
Southern	4.4	14.3	6.5	1.9
Western	3.5	24.8	1.6	3.3
Total	100.0%	100.1%	100.0%	100.1%

Note: Figures do not add to 100.0% because of rounding.

Source: Appendix Table C-3.

As in the earlier studies, an analysis was made of the relationship of the geographic flow of the E/S's in the Twin Cities establishments to the migration patterns of the general Twin Cities population.

This analysis was made by means of a regression analysis (see Appendix A). The results reinforce the conclusion reached in the earlier studies that there is a high correlation between the migration pattern of the industry's E/S's and those of the general population during the 1950-1960 Census period. The mobility of Twin Cities E/S's appears to be part of a major U.S. demographic movement to the large metropolitan areas from the less urban areas, particularly from areas adjacent to the metropolitan area.*

Establishment Mobility. The largest single percentage (40.7%) of the E/S's in the Twin Cities workforce studied came to the current workforce of the Twin Cities directly from completion of university work. In Table 12, the data on the Boston and Los Angeles workforces show a much smaller percentage (23.9%) of E/S's coming to the current workforce directly after graduation from a college or university. In other respects, the E/S pattern of flow from various institutional sources to the current Twin Cities workforce is similar to the patterns found in Los Angeles and Boston.

* See C. Taeuber, and I. B. Taeuber, The Changing Population of the United States, Wiley, New York, 1958.

Table 12

INSTITUTIONAL SOURCES OF ENGINEERS AND SCIENTISTS
Twin Cities and Los Angeles-Boston Defense R&D Establishments

Type of Institution	Percent Hired: Twin Cities	Percent Hired: Los Angeles-Boston
Among 500 top defense R&D prime contractors FY 1955-1963	33.2%	42.9%
Armed services (military)	.4	1.1
Armed services and DOD (civilian)	.9	1.3
Other U.S. government	.2	.3
State government	2.0	.8
College and university (faculty)	1.8	2.2
College and university (student)	40.7	23.9
Self-employment	.9	1.6
Companies not among top 500 defense R&D prime contractors	18.6	24.6
Unknown*	1.4	1.3

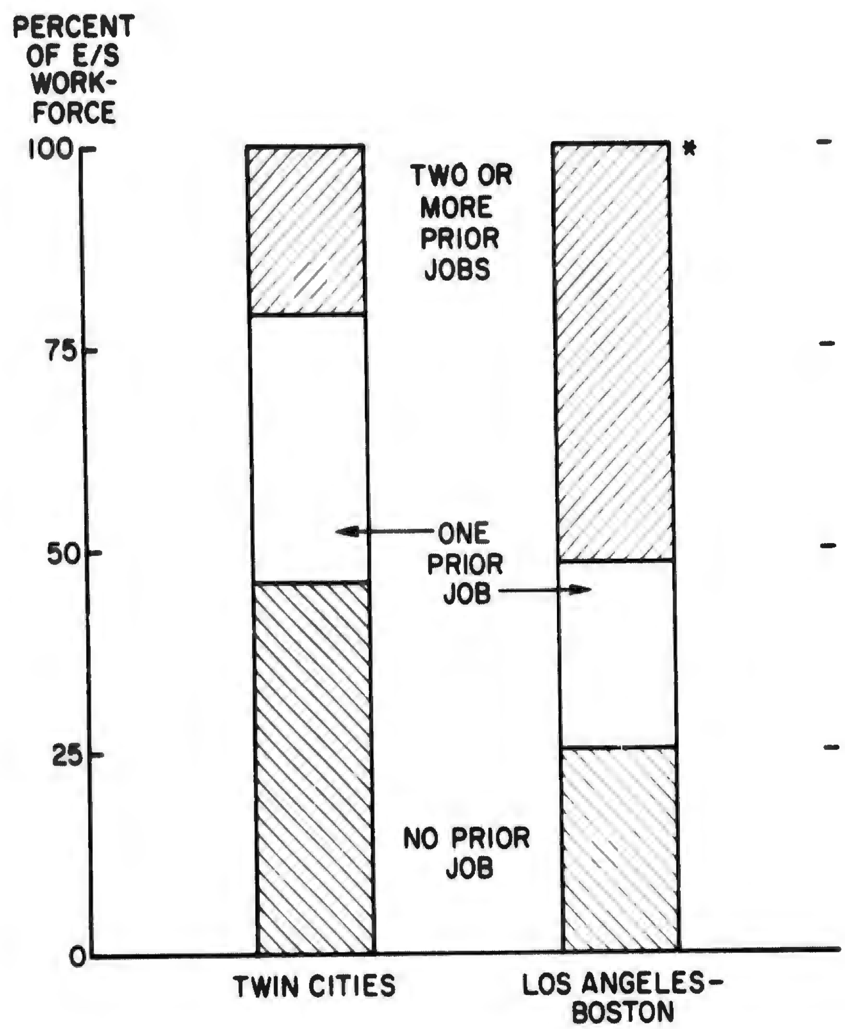
* These are new hires without prior experience or university level education.

Other major sources are defense R&D prime contractors, the armed services and the government.

Turnover and Retention

Not all of the Twin Cities establishments studied kept records of the rate of turnover of their E/S's separate from the overall workforce. During Twin Cities interviews, however, personnel managers stated that the rate of E/S turnover in the Twin Cities was very low compared with that found in other areas of the United States. Two analyses--one relating to the number of prior jobs held, the other to average seniority--support this opinion.

As shown in Figure 2, over 41% of the Twin Cities E/S's have held no previous position, compared with 25% in Los Angeles and Boston. Furthermore, over 50% of the Los Angeles-Boston E/S workforce have held more than two prior jobs, compared with less than 25% of the E/S's in the Twin Cities. Of those E/S's in Los Angeles and Boston that had held two or more jobs, nearly half had held four or more jobs.



*IN LOS ANGELES AND BOSTON, NEARLY 24% HAD HELD FOUR OR MORE PRIOR JOBS

FIG. 2 NUMBER OF PRIOR JOBS HELD BY ENGINEERS AND SCIENTISTS IN THE TWIN CITIES AND LOS ANGELES-BOSTON DEFENSE R & D ESTABLISHMENTS

Figure 3 shows the average seniority of the Twin Cities E/S's compared with Los Angeles and Boston E/S's. It is evident that for any given age, on the average, Twin Cities E/S's have been with their present employer longer than have Los Angeles or Boston E/S's. A regression analysis of Twin Cities E/S's relating seniority to age indicates a significant relationship.*

As was found previously in the Los Angeles and Boston study, the average number of years that Twin Cities E/S's had been with their present employers was inversely related to the number of prior jobs held (see Table 13). However, the average number of years on the present job was found to be higher in the Twin Cities than in the Los Angeles and Boston complexes, indicating a lower turnover rate for the Twin Cities establishments.

Table 13

AVERAGE YEARS OF CURRENT ENGINEERS/SCIENTISTS ON PRESENT JOBS
AS RELATED TO NUMBER OF PRIOR JOBS AT TIME OF HIRE
Twin Cities and Los Angeles-Boston Defense R&D Establishments

Number of Jobs Prior to Present One	Twin Cities Number	Twin Cities Percent	Twin Cities Average Years on Present Job	Los Angeles-Boston Number	Los Angeles-Boston Present	Los Angeles-Boston Average Years on Present Job
0	816	41.5%	6.5	7,461	24.7%	6.1
1	589	30.0	6.0	6,398	21.3	5.8
2 or more	561	28.5	6.0	16,302	54.0	5.8
Total	1,966	100.0%	6.2	30,161	100.0%	5.9

Salary Characteristics

The salary data obtained from the defense R&D establishments studied in the Twin Cities were analyzed in terms of average monthly salary of E/S's and the average annual increase in monthly salary. The first of these measures provides a means for obtaining some idea of the relative valuation placed on various characteristics of the E/S's in the industry, while the second provides a means for obtaining some idea of the dynamics in that valuation. These data were compared with those obtained in the Boston and Los Angeles complexes.

---

* The equation has a correlation coefficient of 0.95 and takes the form: Seniority = 0.568 (Age - 23).

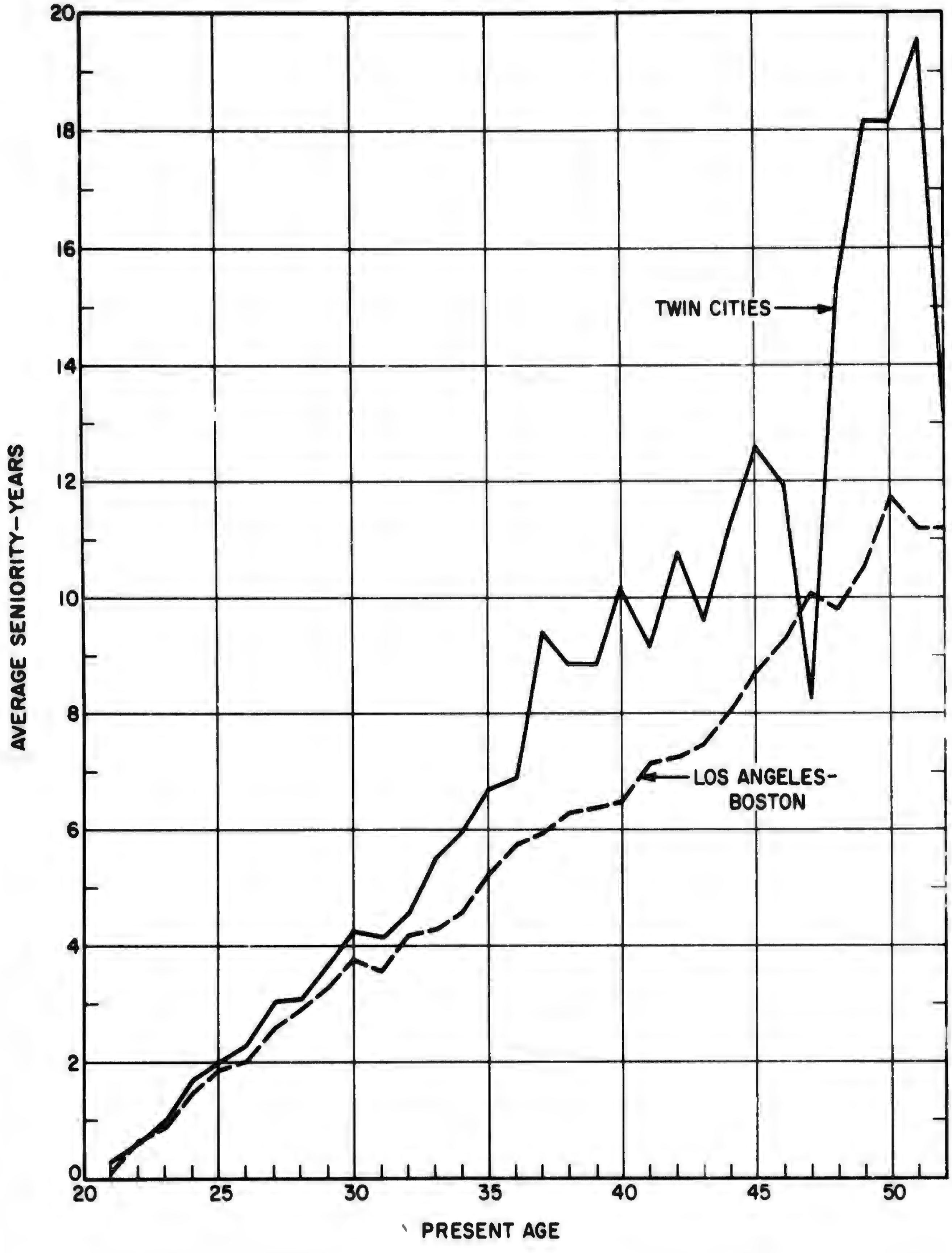


FIG. 3 AGE—SENIORITY COMPARISONS OF ENGINEERS AND SCIENTISTS: TWIN CITIES VERSUS LOS ANGELES-BOSTON DEFENSE R & D ESTABLISHMENTS

In mid-1965, the average monthly salary of the Twin Cities E/S's studied was $984, compared with $1,004 for the Boston E/S's and $1,104 for Los Angeles E/S's studied in mid-1964. These variations are accounted for by: (1) the differentials in age of the workforces (average age of E/S's in Twin Cities is 34.8 years; in Boston, 34.3 years; and in Los Angeles, 37.1 years); (2) the differences in degree level and degree specialty composition; and (3) the interregional salary structure differentials. Figure 4 shows the difference in average monthly salary by age for E/S's with a bachelor's degree in the Twin Cities, and in Los Angeles and Boston. The general pattern of higher salary being related to higher educational level is similar for all of the areas studied, although the Twin Cities salary levels are lower than those found in Los Angeles and Boston for all degree levels.

The extent of the average annual increase in monthly salary of Twin Cities E/S's appears to be related to degree level, specialty, age, and type of last organizational affiliation. The average annual increase in monthly salary for various fields of specialty is shown in Table 14. There appears to be little interregional consistency in the amounts of the increases given or in the ranking of increases by specialty. Average annual increases in monthly salary for Twin Cities E/S's ranged from a high of $90.00 for meteorology to a low of $40.00 for tool engineering and ceramics. For Los Angeles and Boston, the range was from a high of $84.29 for biochemistry to a low of $54.63 for industrial design. E/S's with degrees in geophysics ranked second in both the Twin Cities ($87.50) and Los Angeles-Boston ($82.50). With some exceptions (biology, geophysics, industrial engineering, mathematics/statistics, meteorology, social sciences other than economics, and telecommunications/radio engineering), the average monthly increase per year was higher in Los Angeles-Boston. E/S's with degrees in the social sciences (excluding economics) received increases that were third in rank in the Twin Cities, but lower in Los Angeles-Boston. Similarly, E/S's with degrees in ceramics received increases that were third in rank in the two major complexes but lowest in the Twin Cities.

As noted below, Twin Cities E/S's in the 20-34 age group have received higher average annual increases in monthly salary than older E/S's. This pattern of increases differs between E/S's in the Twin Cities and the Los Angeles-Boston complexes. In the two major complexes, the amount of the average monthly increase went up with age until age 35-39. This differential may be explained by the increasing tendency for Twin Cities establishments to compete for younger E/S's from locations outside Minnesota. This explanation is supported by data which show an increasing percentage of E/S's being hired from outside Minnesota, and a high percentage of these being hired directly upon graduation from universities.

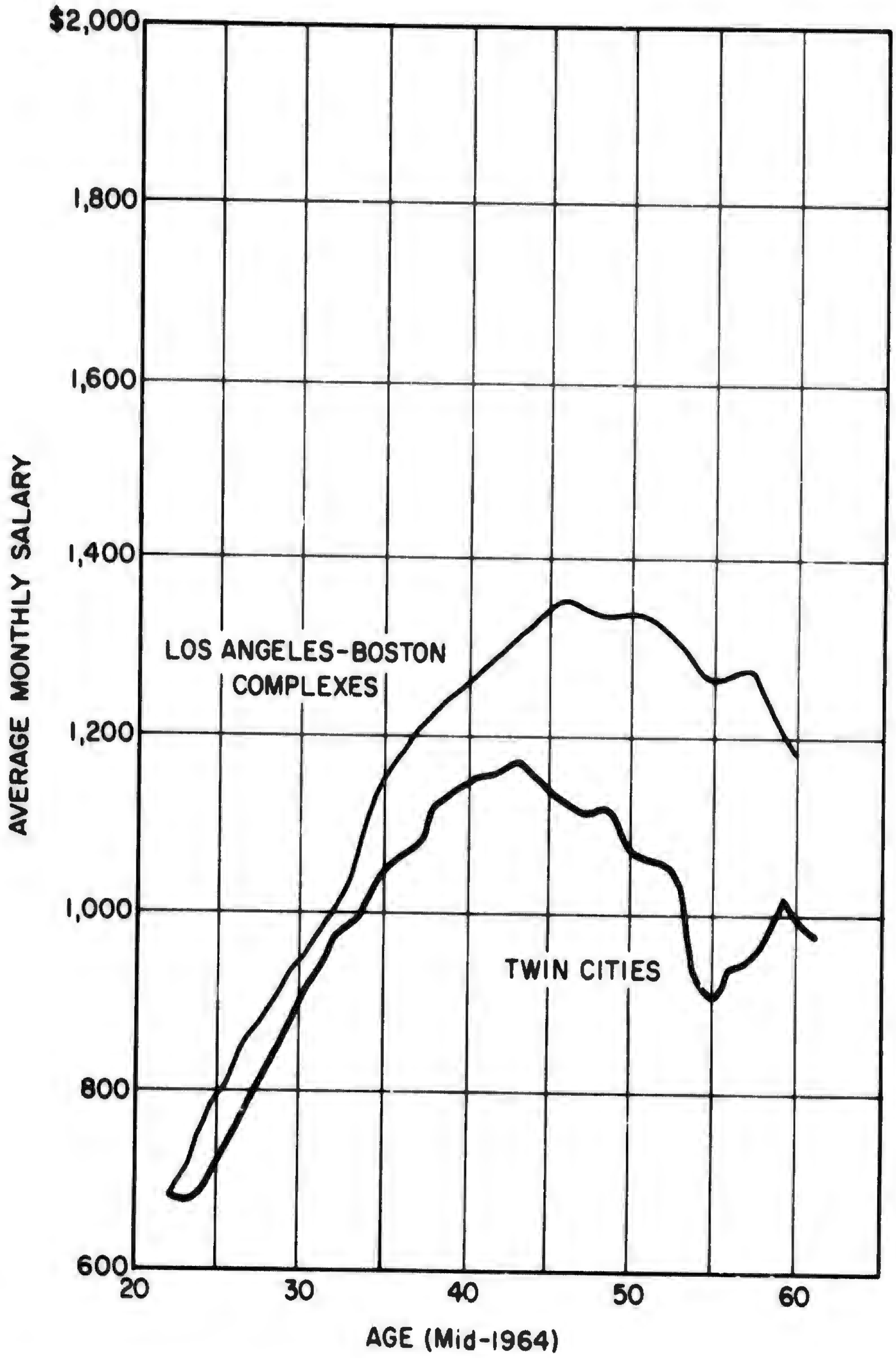


FIG. 4 AVERAGE MONTHLY SALARY OF ENGINEERS AND SCIENTISTS WITH BACHELOR'S DEGREES, BY AGE—in Twin Cities and Los Angeles-Boston Defense R & D Establishments

Five Year Averages Weighted Binomially

Table 14

AVERAGE ANNUAL INCREASE IN MONTHLY SALARY OF ENGINEERS AND SCIENTISTS VS FIELD OF SPECIALTY (BACHELOR'S DEGREE LEVEL)
Twin Cities and Los Angeles-Boston Defense R&D Establishments

Specialty	Twin Cities (N = 1,751)	Los Angeles and Boston (N = 13,418)
Aeronautical engineering	$60.98	$67.49
Astrophysics	--	65.71
Biochemistry	--	84.29
Biology	65.00	55.56
Business administration, commerce	64.74	65.10
Ceramics	40.00	81.25
Chemistry, chemical eng., physical chem.	65.63	68.81
Civil engineering	57.14	72.58
Economics	60.00	77.93
Electrical engineering	71.54	74.44
Electronics	62.57	70.48
Engineering, general	73.33	75.60
Engineering physics	67.00	74.09
Geophysics	87.50	82.50
General science	52.50	70.22
Industrial design	--	54.63
Industrial eng., management eng., production eng.	64.00	62.31
Mathematics, statistics	72.31	72.25
Mechanics, mechanical engineering	62.[illegible]1	71.52
Medicine	--	72.50
Metallurgy	60.00	68.40
Meteorology	90.00	76.67
Military sciences	60.00	61.70
Music, fine arts	61.67	76.95
Other physical science	60.71	64.44
Other social science specialty	67.14	67.72
Physics	69.17	75.87
Physiology	--	78.00
Psychology	55.20	72.04
Social science (except economics)	86.67	66.00
Structural engineering	50.00	57.84
Telecommunications, radio engineering	83.33	62.42
Tool engineering	40.00	63.33

AVERAGE ANNUAL INCREASE
IN MONTHLY SALARY OF ENGINEERS AND SCIENTISTS BY AGE
Twin Cities and Los Angeles-Boston Defense R&D Establishments

Age Group	Monthly Salary Increase: Twin Cities	Los Angeles-Boston
20-24	$72.14	$62.15
25-29	71.09	71.08
30-34	72.83	73.27
35-39	68.44	75.46
40-44	57.95	72.09
45-49	53.52	67.23
50-54	44.06	60.54
55-59	39.45	57.92
60-65	43.33	55.09

In terms of type of last organizational affiliation, Twin Cities E/S's who were self-employed before entering the current workforce have received the highest average annual increases in salary; next highest are those who came from university teaching, while those whose last job was with the state government have received the lowest average annual increases. By comparison, Los Angeles and Boston E/S's whose last job was with a college or university faculty received the highest average annual increases, while those who were self-employed received the lowest.

AVERAGE ANNUAL INCREASE IN E/S MONTHLY SALARY BY TYPE
OF LAST ORGANIZATION AFFILIATION
Twin Cities and Los Angeles-Boston Defense R&D Establishments

Last Affiliation	Twin Cities	Los Angeles-Boston
College and university (faculty)	$ 67.10	$ 80.59
Nondefense U.S. government	63.33	78.18
Armed services (civilian)	57.65	75.49
Defense companies	63.83	73.46
Armed services (military)	60.00	73.18
State government	54.19	71.92
College and university (student)	71.94	69.79
Nondefense companies	62.94	67.22
Self-employed	108.00	65.50
Unknown	55.26	61.63

Twin Cities E/S's Vs Ex-Minnesota E/S's in Los Angeles

It was possible to make a comparison of some of the characteristics of E/S's in the current Twin Cities workforce with those of 250 E/S's in the Los Angeles workforce who had migrated from Minnesota.

As shown below, a higher percentage of the Minnesota E/S's in Los Angeles are nondegreed than in the current Twin Cities workforce. The same is true of the E/S's with doctorates.

	Level of Education			
	Bachelor's Degree	Master's Degree	Doctor's Degree	No Degree
Twin Cities E/S's (N = 1,966)	73.3%	12.3%	1.2%	13.3%
Ex-Minnesota E/S's in LA (N = 250)	68.0	12.4	2.8	16.8

In terms of age, the E/S's that migrated from Minnesota to Los Angeles tend to be older than the E/S's in the Twin Cities workforce. Of the former Twin Cities E/S's in Los Angeles, 42.4% were age 40 and over, compared with 24.4% for the Twin Cities E/S workforce.

Table 15

AGES OF CURRENT TWIN CITIES ENGINEERS AND SCIENTISTS VS AGES OF THOSE WHO HAVE MIGRATED FROM MINNESOTA TO LOS ANGELES

Age	E/S's in Twin Cities		Ex-Minnesota E/S's in Los Angeles Complex	
	N	%	N	%
60-64	10	0.7	0	0
55-59	24	1.3	6	2.4
50-54	42	2.3	14	5.6
45-59	122	6.1	32	12.8
40-44	274	14.0	54	21.6
35-39	410	20.9	47	18.8
30-34	586	29.8	44	17.6
25-29	412	20.9	52	20.8
20-24	86	4.4	1	0.4

The ex-Minnesota E/S's in the Los Angeles workforce receive salaries that are close to the Los Angeles averages for all E/S's at given degree levels and ages. That is, the ex-Minnesota E/S's in Los Angeles receive higher average salaries for given degree levels and ages than the E/S's in the Twin Cities workforce (see Figure 5).

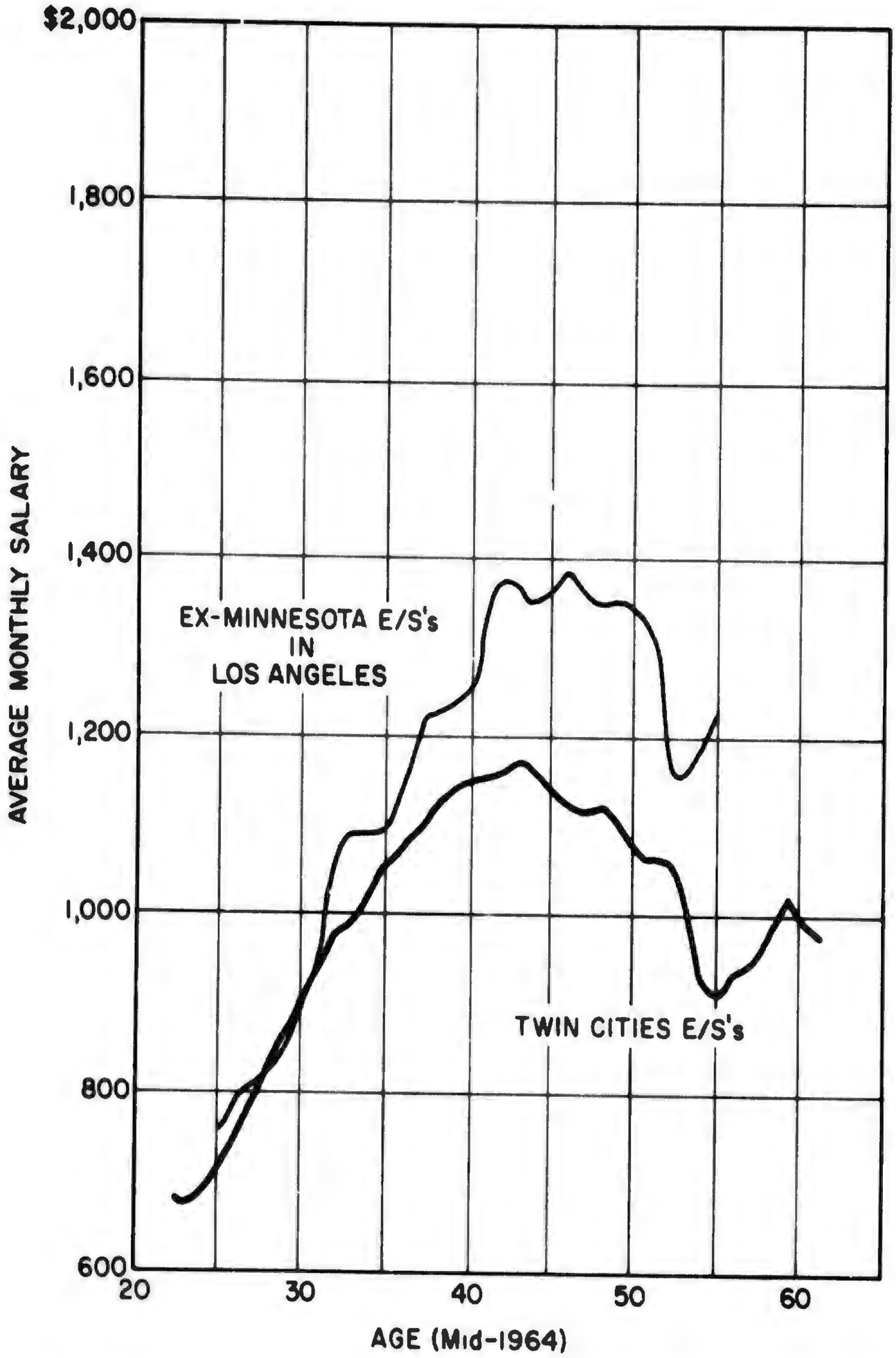


FIG. 5 AVERAGE MONTHLY SALARY OF ENGINEERS AND SCIENTISTS WITH BACHELOR'S DEGREES, BY AGE—Twin Cities E/S's versus Minnesota E/S's Who Migrated to Los Angeles

Five Year Averages Weighted Binomially

Materiel Procurement

In the areas studied, certain characteristics of the defense R&D industries were identified and evaluated by analyzing the sources of the goods and services procured outside the R&D centers and by analyzing the variation in this procurement with time. "Materiel" is used here to include all goods and services purchased outside.

In the previous studies of this series, materiel procurement data from many contractors covered both R&D and production activities. As was pointed out in the study of the Los Angeles and Boston:[2]

> "The extent to which the data collected were contaminated by the inclusion of non-R&D procurement cannot be precisely specified; however, it is believed that in no case did the contamination invalidate the general conclusions of the analysis."

Part of this contamination resulted from the methods by which establishments summarize their materiel purchases--by vendor, by type of establishment, by geography, but not by contract. Consequently, R&D procurement could not be completely separated from other procurement included in the summarized data.

It was decided, therefore, to attempt to obtain data by R&D contract rather than by company summarization that consolidated all procurements. It was believed that this approach would permit a limited check to be made on the procurement patterns that had been identified in previous studies. Advantage was taken of a parallel effort to measure the economic impact of defense R&D expenditures, and a limited amount of data was obtained on materiel procurements for 415 defense R&D contracts awarded in 1965. The data used were for R&D prime contracts awarded to companies in the Twin Cities, Los Angeles, Boston, and Charlotte, N.C. The latter was included to obtain some comparison with a community having a defense R&D industry dominated by one establishment. Since the sample was limited, any inferences drawn must be considered to be similarly limited.

As shown below, in the sample of R&D contracts studied, the percentage of total defense contract dollars expended for purchased materiel was 16.9% for Twin Cities contractors, compared with about 25% for Los Angeles, about 36% for Boston, and about 43% for Charlotte, N.C. contractors.

Location	Contracts in Sample		Purchases as a Percent of Total Contract Amount
	Number	Amount	
Twin Cities	59	$ 4,329,000	16.9%
Los Angeles	221	43,228,000	24.7
Boston	132	88,601,000	36.3
Charlotte	3	934,000	43.2

The 43% compares with an average of 45.2% of total defense contract dollars for purchases by contractors in the defense R&D centers of Denver, Tucson, and Orlando,[a] which, like Charlotte, are examples of centers dominated by single establishments.

Table 16 shows the regional distribution of the materiel procurements for the sample of contracts analyzed in this study. (A more detailed table is Table C-4 in Appendix C.)

Table 16

GEOGRAPHIC LOCATION OF PROCUREMENT BY R&D PRIME CONTRACTORS IN SELECTED AREAS

Location of Vendor	Percent Purchased by Prime Contractor Located in the R&D Centers Below			
	Twin Cities	Los Angeles	Boston	Charlotte
Northeast region	18.8%	26.0%	66.4%	10.8%
North Central region	59.0	4.4	7.4	9.7
Southern region	9.0	7.3	6.5	23.6
Western region	9.6	60.4	13.4	28.6
National & otherwise nondistributable	3.4	1.9	6.3	27.2
Total	99.8%	100.0%	100.0%	99.9%

Note: Figures do not add to 100.0% because of rounding.

Source: Appendix Table C-4.

The geographic distribution of the Los Angeles and Boston R&D contracts parallels the data developed in the previous study of these two R&D complexes.[a] The Western and Northeast regions were the major sources--accounting for 86.4% of the dollar value of the Los Angeles materiel procurements and 79.8% in the case of Boston. The "home" region was the source of 60.4% of the procurement for Los Angeles and 66.4% for Boston. For Twin Cities contractors, the Northeast and Western regions combined supplied only 28.4% of the dollar value of their materiel procurements while the "home" (North Central) region supplied 59.0%. The geographic distribution of the Charlotte data is not as meaningful as would be desired since 27.2% of the purchases are unidentified as to geographic source; these included many overhead items as well as air travel and other undistributed "national" costs.

Table 17 presents the classification of materiel bought by Twin Cities R&D prime contractors from other areas, and bought by prime contractors in other complexes from Twin Cities suppliers. On the basis of this limited sample, it is seen that the Twin Cities companies purchase electronic components from Los Angeles and Boston suppliers, and that contractors in Los Angeles and Boston purchase computing and related machines from Twin Cities suppliers.

Although the sample of R&D contracts studied was limited, differences can be noted between the major defense R&D complexes, the centers dominated by one company, and the Twin Cities potential complex. The single-company dominated centers and the establishments in the major complexes appear to expend a larger percentage of their contract dollars for outside procurement than do defense contractors in the Twin Cities. Also, based upon the sample, the establishments in the complexes purchased a larger percentage of their materiel from suppliers in their "home" region than the contractors in the other centers. Defense contractors in the single-company dominated center appear to be dependent on the major complexes to a much greater degree than are the contractors in a developing complex such as the Twin Cities.

Table 17

MATERIEL PROCUREMENT BY AND FROM TWIN CITIES FIRMS FOR DEFENSE R&D CONTRACTS

	Purchases					
	From Twin Cities by: †			By Twin Cities from: ‡		
SIC Classification of Procurement*	Los Angeles Firms	San Francisco Firms	Boston Firms	Los Angeles Firms	San Francisco Firms	Boston Firms
1929 Ammunition, not elsewhere classified	$ 28,129	$	$	$	$	$3,000
2818 Industrial and organic chemicals			100			
2819 Industrial and organic chemicals			200			
3571 Computing and accounting machines	300	143,700	377,600			
3591 Machine shops, jobbing, and repairs	16,898		7,000	22,100		
3611 Electric measuring instruments and test equipment	60,500	2,200				
3613 Switch gears and switchboard apparatus			100			
3662 Radio and TV transmitting, signaling, and detection equipment	100	31,800	4,000			
3679 Electronic components not elsewhere classified				13,300	4,200	3,800
3692 Primary batteries				1,600		
7391 Research, development, and testing labs	51,071					
7392 Research, development, and testing labs		1,000			21,100	
Total	$156,998	$481,700	$389,000	$37,000	$28,300	$6,800

* Standard Industrial Classification Code.
† Of total purchase amounting to $94,867,500 (Los Angeles = $18,038,300; San Francisco = $44,034,800; Boston = $32,794,400).
‡ Of total purchase amounting to $486,200.

Source: R. Howell, W. Breswick, and E. Wenrick, An Exploratory Study of the Economic Impact of Defense R&D Expenditures in Terms of Value Added and Employment Generated, unpublished report, Stanford Research Institute, February 1966.

IV FACTORS AFFECTING THE DEVELOPMENT OF THE TWIN CITIES DEFENSE R&D INDUSTRY

Introduction

This portion of the research on the Twin Cities involved identification and analysis of the factors that might be considered essential to the transformation of a community into a defense R&D complex. From the earlier study on Denver, Tucson, and Orlando[1], the results indicated that no factor could be singled out as all-important, but that two factors had some importance: (1) the presence of R&D-oriented entrepreneurs in the community (or their attraction to it), and (2) the availability of financial support in the form of initial, working, and growth capital for companies engaged in defense R&D. Our research was intended to reexamine these factors in the light of data obtained about the Twin Cities area, keeping in mind that the earlier study involved the community having a single large defense R&D establishment, whereas the Twin Cities contained a cluster of co-located defense R&D companies. In addition, other factors contributing to the development of a defense R&D industry appeared deserving of analysis: the historical pattern of industrial growth and decline, as seen in company formations, failures, and spin-offs; and the contribution of higher education. Accordingly, the scope of the research reported in this chapter includes:

1. Company formations, failures, and spin-offs
2. The role of the financial community
3. The role of the R&D-oriented entrepreneur
4. The role of the local university

Company Formations, Failures, and Spin-offs

Company Formations

In 1966, there were 142 Twin Cities establishments in the broad group of high technology companies that comprise the local defense R&D industry base. Table 18 summarizes the chronology of the formation of these 142 surviving establishments. Appendix B presents the history of the Twin Cities defense R&D industry in greater detail, from the 19th century to the present.

The formation rate of these surviving Twin Cities companies (or their predecessors) was low until the 1940s. At the rate of less than one new company every two years, only 22 of these 142 companies (or their successors) were formed during the 45-year period between 1895 and 1940.

Table 18

CHRONOLOGY OF SURVIVING TWIN CITIES HIGH TECHNOLOGY COMPANY FORMATIONS

Period	Automatic Controls & Measuring Instruments	Medical & Surgical Devices & Apparatus	Electrical & Electronic Equipment	Computers & Data Proc.	Ordnance & Accessories	Other High Technology Establishments	Supporting Industries & Services	Total Formations
Pre-1905	1		2				1	4
1905-1914	1		1				1	3
1915-1924	2		4		1	1		8
1925-1934	2	1	2			1		6
1935-1939		1						1
1940-1944		3	3	1	1	1	1	10
1945-1949	3	3	5		1	2	5	19
1950-1954	5		11				3	19
1955-1959	4	3	11	3		2	8	31
1960-1965	6	4	10	5		2	9	36
n.a.	—	1	3	—	—	1	—	5
Totals	24	16	52	9	3	10	28	142

n.a. = not available.

Source: Stanford Research Institute.

But during the decade of the 1940s, 29 technical establishments were formed. A few of these, such as Northern Ordnance, Inc., and the Mechanical Division of General Mills, were formed in response to the military requirements of World War II, but the great majority (70%) of these company formations of the 1940s occurred after World War II. Among the historical factors contributing to this acceleration in company formations were lay-offs from defense plants and the return to the Twin Cities of men with new technical and supervisory skills acquired in military service.

This increased rate of successful company formation, which began after World War II, continued through the decade of the 1950s, a period in which 69 successful companies were formed. Beginning with the establishment of a segment of the U.S. computer industry in the Twin Cities in 1946, the industry has flourished and has fostered the formation of a number of supplier and computer "software" companies in the area. During five years (1957-1962) of this period, another important influence on the rate of formation of technical companies in the Twin Cities was the development of the local over-the-counter stock market. This Twin Cities phenomenon, which is referred to as the "dollar stock market," provided a period of easy equity financing, and prompted a number of entrepreneurs to "make the jump" and form their own companies.

Also contributing to the high rate of formation of technical companies in the Twin Cities since 1950 have been the perceived pressures, whether real or assumed, of threats to job security. A number of "spin-off" companies were formed during a period of differences in objectives between local operating managers and absentee corporate management. Other spin-off companies were formed at times when the firms employing these entrepreneurs were being acquired by other firms. Often, some of these company formations followed mergers which resulted in lesser responsibilities or a less important job for a key individual.

Company Failures

The data obtained on failures of technical companies in the Twin Cities are limited to failures that occurred in the 1950s and 1960s. See Table 19. Of a total of 111 technical companies formed during this 15-year period, 26 companies, or 24% of the company formations, have failed or no longer operate in the Twin Cities. Twenty of the companies which failed were formed during the period 1959 through 1962, and at least 19 of the 26 companies raised their initial capital in the Twin Cities "dollar stock market."

Compared with the experience of the Small Business Investment Companies (SBICs) specializing in high technology investments, and the experience of company failures in other high technology areas of the country, the Twin Cities' failure rate of 24% for technical companies is not high.

Table 19 indicates that since 1950, the highest failure rate (57%) in the Twin Cities has occurred in companies formed to develop and produce

Table 19

TWIN CITIES TECHNICAL COMPANY FAILURES, 1950-1961
(No Record of Company Failures for 1962-1965)

Industrial Category of Company*	Company Formations	Company Failures	Failures as % of Formations
Automatic controls & measuring instruments	17	3	18%
Medical-surgical devices & apparatus	14	8	57
Electrical-electronic equipment	44	12	27
Computers & data processing machinery	11	2	18
Other high technology	4	0	0
Supporting industries & services	21	1	5
Total	111	26	24%

* Ordnance material category omitted because no companies were formed in this period.

medical and surgical devices and apparatus. The second highest failure rate (27%) has been for companies formed to produce electrical and electronic products.

Company Spin-offs

The term "spin-off" is used here to denote a company formed by principals whose most recent affiliation was with an existing company in the same field as the new company, or in an associated field. By this definition, a department store formed by scientists leaving a missile company would not be considered a spin-off, but a metallurgical laboratory set up by these scientists would be. An indication of the Twin Cities experience with spin-offs was obtained from an analysis of the prior company affiliations of the principal officers of 166 technical companies formed in the Twin Cities. At least 36 of these formations were spin-offs from other Twin Cities companies.

As indicated by Table 20, those organizations from which the greatest number of new technical companies were formed are: the Univac Division of Sperry Rand Corporation--13 spin-offs; Honeywell, Inc.--nine; the Electronics Division and its predecessor, the Mechanical Division of General Mills, Inc.--eight; and the University of Minnesota--six. The Twin Cities hearing aid companies, as a group, have been a good source of spin-offs, since four companies have provided entrepreneurs for at least eight new technical companies.

There have been a number of "spin-offs from spin-offs," some within a period of relatively few years. One of the longest of such chains, all within a seven-year period, involved four companies which originated from Engineering Research Associates (ERA). This series of spin-offs is shown in Figure 6.

Table 20 shows the survival rate of the 36 company formations from the four principal spin-off sources. The 82% survival rate (30 companies) from these four Twin Cities companies is close to the 76% survival rate of the 111 technical company formations since 1950, mentioned earlier. Included in the 30 surviving establishments remaining in the Twin Cities area are two which have been acquired by larger companies. All of the six companies no longer operating in the Twin Cities (last column of Table 20--"Failed or Moved") were formed during the period 1959 through 1961, and all took advantage of the local "dollar stock market" to raise initial capital.

The Role of the Twin Cities Financial Community

An indication of the emergence of the Twin Cities as a strong regional financial center is that this area is now headquarters for the following financial establishments: 48 banks; three banking corporations that own the controlling stock in hundreds of independently managed banks and branches in the surrounding region; 15 savings and loan associations (including the nation's second largest); 75 insurance companies which have over $24 billion of life insurance in force; seven Small Business Investment Corporations (including one of the first two SBICs to be licensed in the country and the first to go "public"); and six organizations sponsoring mutual funds (including the largest in the world).

Characteristics of Research-Based Industry

Because of the unique characteristics of research-based or high technology companies, their financial requirements and the evaluation of these requirements by financial organizations differ considerably compared with most manufacturing industries. Among the characteristics of high technology companies that differentiate them from other kinds of companies are the following:

Table 20

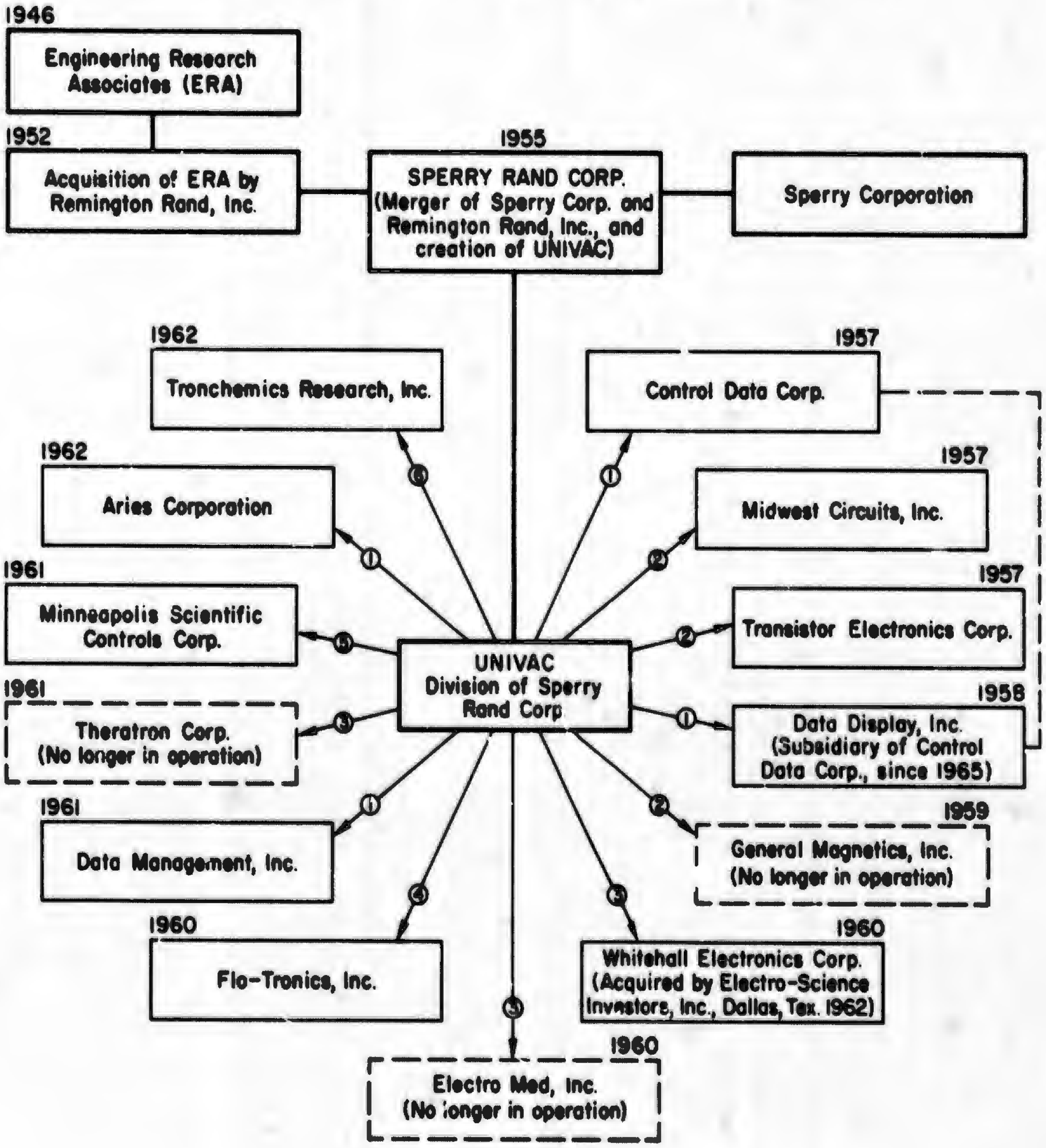
PRINCIPAL SOURCES OF TWIN CITIES TECHNICAL COMPANY SPIN-OFFS
1944-1965

Year	Sperry Rand Corp. No. of Spin-offs	Sperry Rand Corp. Failed or Moved	Honeywell, Inc. No. of Spin-offs	Honeywell, Inc. Failed or Moved	General Mills, Inc. No. of Spin-offs	General Mills, Inc. Failed or Moved	Univ. of Minn. No. of Spin-offs	Univ. of Minn. Failed or Moved	Totals of Establishments No. of Spin-offs	Totals of Establishments Failed or Moved
1944			1						1	
1945			1						1	
1946							1		1	
1947									0	
1948					1				1	
1949									0	
1950			1		1				2	
1951					1		1		2	
1952			1				1		2	
1953									0	
1954									0	
1955									0	
1956			1				1		2	
1957	3				1				4	
1958	1								1	
1959	1	1	1		1				3	1
1960	3	2	1				1		5	2
1961	3	1	2	1	2		1	1	8	3
1962	2				1				3	
1963-65*										
Total	13	4	9	1	8	0	6	1	36	6

* No spin-offs recorded in this period.

Source: Stanford Research Institute.

Figure 6 EXAMPLE OF TECHNICAL COMPANY FORMATIONS, SPIN-OFFS, AND MERGERS ORIGINATING WITH ENGINEERING RESEARCH ASSOCIATES (ERA)*



Industrial Categories	Table Ref.
1 Computers and Data Processing	B-7
2 Electrical and Electronic Components	B-6
3 Medical and Surgical Devices	B-2
4 Misc. Electrical and Electronic Equipment	B-5
5 Industrial Electrical Equipment	B-3
6 Data Processing, Process Control, Chemical and Food Processing	

*This example depicts only the first line of spin-offs subsequent to the formation of UNIVAC. A number of spin-offs from spin-offs have occurred and are continuing to occur.

1. They are R&D-oriented.
   Often they are trying to accomplish what has not been done before, and consequently, the elapsed time between R&D and a marketable product is often long, without benefit of either revenue or profits. Thus the R&D companies require substantial working capital to finance the relatively costly labor inputs normally involved in successful R&D. The problem of working capital is not confined to innovative research; similar continuing expenditures are often required for product improvement where there is a high rate of product obsolescence due to changes in technology.

2. They are usually formed by technically trained entrepreneurs. Most of these entrepreneurs have not had previous business experience other than the management of research projects or programs. It is one thing when the technical entrepreneurs are aware of their need for financial advice, but it is another when some technical people are of the opinion that any intelligent person can understand business matters. The question, "If you had it to do over again (i.e., establish your company), would you do anything different?" was asked of several presidents of small Twin Cities technical companies. The most frequent reply related to methods of financing. The financial lessons had eventually been learned but often too late, and often at a rather high price to the company and stockholders.

3. Technical professional manpower is indispensable and tends to become a relatively fixed overhead cost.
   This inelasticity of the cost of technical manpower poses financial problems similar to those resulting from semi-fixed general and administrative overheads under conditions of declining sales volume. The number of R&D personnel in most technical companies cannot be regulated with fluctuating sales as in the case of production workers.

Stages of Financing

The financing of successful technological companies is discussed by phases: (1) initial, (2) interim, and (3) growth. The sources of financing for the different phases vary considerably.

Initial Financing. In the initial phase of operations, there is often no marketable product, working model, mock-up, or prototype, and there may not even be a design or any product specifications. The principal asset may consist of a new theory or idea that must be proved, tested for feasibility, and applied in the form of a product which not only is needed but also can be sold at a reasonable price in relation to the performance capabilities--i.e., cost-effectiveness--of the product.

Except for the five-year period between 1957 and 1962, new technical companies formed in the Twin Cities, as in other communities, obtained most of their "seed" capital from the founders of the company, relatives, friends, or well-to-do persons with an interest in the new venture. Often, to conserve funds, Twin Cities operations were started in the basement of a man's home, as in the case of the Telex Corporation, or on a part-time basis, such as Fabri-Tek, Inc.

Normally, new companies do not obtain their initial financing from a public stock issue, since experience has shown that initial overcapitalization fosters inefficiencies which may affect the company's longer range operations, including its ability to obtain future financing. However, in the five-year period between 1957 and 1962, a number of new R&D-based companies in the Twin Cities obtained their initial financing from public stock issues. More than $50 million in capital was raised during this period by these Twin Cities companies, but for some of them, this "easy money" in relatively substantial amounts was not sufficient to prevent failure.

Retained earnings, if any, for a new R&D-based company are seldom sufficient for prolonged growth of any magnitude, because the length of time required from initial research to a marketable product places heavy financial demands on a struggling company. The experience of new technical companies in the Twin Cities has been no exception; since 1950, at least 26 Twin Cities technical companies have gone out of business or left the area.

Interim Financing. Typically, the interim phase begins with the use of short term credit. For some R&D-based companies in the Twin Cities, short term financing combined with retention of earnings has been sufficient for a slow and steady growth. Few companies, however, are able to undertake large scale manufacture, establish effective marketing organizations, advertise on a national basis, and initiate R&D programs for new products without a sizable infusion of long term capital. Most of these companies in this phase are not self-regenerative--i.e., they do not have the ability to generate sufficient internal capital for the development, manufacture, and marketing of products in sufficient volume to guarantee growth or assure their continued existence.

It has been during their interim phase that a number of Twin Cities R&D-based companies have supplemented bank financing with assistance from other establishments including Small Business Investment Companies (SBICs), the Small Business Administration (SBA), venture capital firms, and investment firms.

Various means have been used to bring together Twin Cities R&D-based companies and potential investors. In many cases, a local banking relationship led to another source of funds if the bank itself was unable to handle the requirement. Since 1959, SBICs have been a frequent source. Of the eleven SBICs which have been licensed in the Twin Cities area, five have been affiliated with banks, bank sponsorship ranging from 2.5% to 100% of capital.

For interim financing, some of the small R&D-based companies in the Twin Cities have used more than one outside source of funds. One company, whose 1964 sales were between $2 million and $3 million, has used at least four different outside sources of funds for interim financing at various times--banks, a public stock issue, an SBIC, and a major supplier.

Growth Financing. In the typical growth pattern of a successful R&D-based company, the third major financing stage begins when the company is in a financial and operating position to successfully issue stock to the public. Normally, this position occurs after a company has been in existence at least five years, when sales have exceeded $1 million, and when there have been some profitable years of operation.

Some Twin Cities R&D-based companies, even though they have been in a sound enough position to make a public stock offering, have chosen not to do so. In most of these cases, this was because of a strong preference for maintaining control within the original investing group, and a decision to grow from earnings.

A factor which fast-growing companies do not always take into consideration is that outside financing may be required every two or three years. When a public stock issue is used in the early years of growth and the stock is selling below the original offering price, it is practically impossible to go back to the public for additional financing. A number of Twin Cities R&D-based companies that raised capital prematurely by public underwritings in the 1958-1962 period experienced difficulties in obtaining needed additional funds. Consequently, some companies were forced into mergers or bankruptcy.

Other Twin Cities companies found that "going public" was just the beginning of a very difficult period. Until the public stock issue, the entrepreneurs had relative freedom of action, subject primarily to the approval of the initial and interim investors. Yet when these companies became partly owned by other individuals, the fortunes of the company were followed by the "public" owners, and actions of the entrepreneurs were subject to question at stockholder meetings and by mail or telephone. When these "public partners" are technically unsophisticated, as most are, they often do not realize the need and nature of R&D expenditures, which can be described as "patient money." As a result, their behavior as investors has often adversely affected the credit rating of some Twin Cities companies. The experiences of the early 1960s, not only in the Twin Cities but nationally, illustrate what can happen. The stock prices of many technical companies rose during 1960 and 1961 with little relationship to fundamental values, only to fall in 1962 to levels significantly below these values. As a consequence, after May 1962, a number of technological companies experienced financing difficulties which would have been less critical had their capital stock been evaluated by investors having experience with technical companies.

Some of the sources of financing that have been available to Twin Cities R&D-based companies have included: a special Twin Cities over-the-counter stock market during the five years between 1957 and 1962; financial assistance sponsored by the Federal government; assistance through merger with another company; and assistance from local banks, insurance companies, and investment companies.

The "Dollar Stock Market"

The late 1950s and early 1960s were marked by a great popular interest in the issuance and purchase of the capital stock of R&D-based companies--the so-called "glamour stocks." With the exception of New York, Los Angeles, and possibly Boston and San Francisco, no metropolitan area in the country had such a rash of new stock issues by technical companies as did the Twin Cities.

During the five-year period from mid-1957 to mid-1962, 129 new public stocks valued at over $60 million were issued by Minnesota technical companies, all but a few located in the Twin Cities area. These issues included stocks of companies engaged in nondefense R&D and manufacturing, such as chemical and related products. As shown in Table 21, most of these stock issues came to market during 1960 and 1961, and there were practically none after the national collapse of the stock market in May 1962.

The stock offerings of Twin Cities technical companies during this period had the following characteristics:

1. They were local over-the-counter stocks not listed on either the New York or American stock exchanges. (A few subsequently qualified for exchange listing.)

2. Most were initially sold intrastate, and hence were not subject to Securities and Exchange Commission (SEC) registration and review.

3. Selling prices were usually $1.00 or $1.15 per share, the 15 cents representing the commission for selling the stock when an underwriter was used (hence, the expression "dollar stock market").

4. The majority of the new issues were quickly over-subscribed or completely sold.

5. "Instant profits" could be expected if the stocks were not held too long, because of the demand for most of the stocks at the time of issue.

The Twin Cities over-the-counter stock market was not confined to offerings by technical companies. During the same five-year period, there were 94 new issues by nontechnical companies. For nontechnical company stocks, it was less of a "dollar stock market" than for technical companies.

Table 21

STOCK OFFERINGS BY MINNESOTA TECHNICAL COMPANIES
1957-1962

	Number of Issues by Offering Price ($) per Share					Total Value
Year	$0- $1.15	$1.16- $2.50	$ 2.51- $10.00	Over $10.00	Total	of Offerings ($ million)
1957	1	0	1	4	6	$ 0.8
1958	3	1	0	0	4	0.5
1959	6	4	3	4	17	18.9
1960	22	3	16	2	43	17.3
1961	42	2	7	0	51	21.5
1962	7	1	0	0	8	1.7
Total	81	11	27	10	129	$60.7

Source: Developed by SRI from stock prospectuses.

For technical company issues, 63% (81 out of 129) were sold at $1.00 to $1.15 per share, whereas for nontechnical issues, only 35% (33 out of 94) were sold at that price.

There are several recorded indications of the magnitude of the somewhat unique local over-the-counter market which developed in the Twin Cities:

1. During the five-year period from fiscal 1957-58 through 1961-62, the Securities Division of the Minnesota Department of Commerce, with a total staff of nine or less, collected a total of $860,933 in registration and other fees, and expended only $305,097. Because of the volume of new issues and limited personnel, the approval of new stock issues during much of the 1957-62 period became practically automatic. Detailed by year, total fees collected and expenditures of the Minnesota State Securities Division (in thousands of dollars) were:

Fiscal Year	Total Fees Collected	Expenditures	No. on Staff
1957-58	$103.2	$53.9	8
1958-59	133.3	58.8	8
1959-60	149.5	59.5	9
1960-61	238.2	65.5	9
1961-62	236.8	67.6	9

2. Interest ran so high that the region had its own stock market publication (a monthly magazine called The Upper Midwest Investor--later renamed Mid-American Investor), which was published from April 1961 through December 1963.

3. The increase in the formation of companies and new stock issues in the Twin Cities was responsible for the establishment of at least six new brokerage firms--a 20% increase. All of the new brokerage organizations concentrated at that time on low-priced, unlisted, local issues. One of them had more than 30 employees. Some of these firms are still functioning, and at least one of them now specializes in high grade securities.

4. The Twin Cities over-the-counter securities market was considered sufficiently newsworthy in the early 1960s to be the subject for a two-hour NBC-TV "Today" program. In addition to coverage by Twin Cities and other Minnesota newspapers, articles on the Twin Cities over-the-counter stock market were published in The Detroit News and Business Week magazine.

Causes of the "Dollar Stock Market." What brought about this large local over-the-counter market in the Twin Cities? In addition to the general nationwide appeal for technological "glamour" stocks during the late 1950s and early 1960s, there were particular Twin Cities developments which accelerated the local situation.

Probably the most important factor was the formation of Control Data Corporation and the public issue of 600,000 shares of its common stock in August 1957. The founders and first employees were "pros" in the computer field--some with as much as fifteen years of experience.

Despite the fact that the founders and first employees had this wealth of computer technology background, the Minnesota Securities Division lacked experience with this type of venture, and local investment firms were not receptive to handling the underwriting. After much effort, the registration of the stock with the Minnesota Securities Division was accomplished, and the stock was sold to around 300 "venturesome" individuals, not through an underwriter but by CD employees.

The success of Control Data's public stock issue is indicated by its rise in price from $1 to $10 a share within a year's time. This in itself, however, was not enough to cause the flurry of company formations and new public stock issues that were to follow. It took another company formation and a public stock issue this time, not by well-established "pros" but by young entrepreneurs who had been at the project engineer and technical staff level. This second experience (1) convinced the great number of "would-be" entrepreneurs and promoters that "if they can do it, so can we," and (2) further stimulated the interest of investors.

The company that confirmed the success of technical company stock issues was Data Display, Inc., incorporated in October 1958 by employees of the Univac Division of Sperry Rand; and Data Display was primarily financed by an offering of 150,000 shares of common stock at $1 a share to residents of Minnesota, again without the services of an underwriter. Much of this stock was literally sold out of the glove compartments of the founders' autos. By January 1961, the bid price of the stock was in the range of $7.50 to $10.75 per share, and a high of $23.25 per share was reached in April of the same year.

The business of Data Display was the design, development, and manufacture of visual display equipment for computer systems. The company's first unit was sold in 1960 to Control Data, which continued to be an important customer up to the time it acquired Data Display as a wholly owned subsidiary in January 1965.

As indicated previously in this report, a number of the R&D-based companies formed during the late 1950s and early 1960s to take advantage of the "dollar stock market" subsequently failed. In terms of the local economy, financial losses have been experienced by many of the local purchasers of stock. On the other hand, the number of surviving companies has served to broaden considerably the technological base of the Twin Cities. As a measure of the latter result, 19 of the technical companies which were founded in the 1957-1962 period and obtained capital in the Twin Cities "dollar stock market" now employ a combined total of approximately 7,500 persons in the Twin Cities and generate annual sales of over $180 million.

Effect of the "Dollar Stock Market." What has been the effect of the "dollar stock market" on the subsequent public financing of Twin Cities R&D-based companies? For some time after the May 1962 nationwide market slump, it was difficult to sell any new over-the-counter stock issues in Minnesota. As an example, it is reported that it took Jansen Electronics Mfg., Inc., from September 1961 until January 1964 to sell out its issue of 100,000 shares at $1 a share.

Beginning in July 1964, the situation began to change, when Fabri-Tek, Inc., producers of computer memory devices and systems, offered the public 100,000 shares at $11.50 a share. The stock was traded at around $33 before the end of the year. Subsequently split at 2-1/2 shares for one, the stock reached a high of $28.50 (equivalent to $71.25 before the split) in 1965. Another company, Aries Corp., which provided data processing services, went "public" in June 1965, offering 50,000 shares at $3 a share. The stock more than doubled in price within a few months. Aries had originally planned to go "public" in 1962, and was within a week of the date of the offering when the market collapsed. The issue was cancelled, and Aries lived on its original capital--$100,000 provided by the incorporators and another $100,000 from Minnesota Capital Corp., a Small Business Investment Company (discussed later in this chapter).

On the basis of the Fabri-Tek and Aries experiences, it appears that new technical companies have no difficulty selling stock to the public in Minnesota as long as they can demonstrate their capabilities. Of special interest here is the fact that demonstration of capabilities is now being made to a financial community which gained considerable experience in evaluating technical companies in the days of the "dollar stock market."

Small Business Administration Loans

The Small Business Administration (SBA) was established in 1953 to render financial assistance to small businesses by supplying needed credit not otherwise available on reasonable terms. (See Appendix D for details.) Through 1964, a national total of 40,754 direct and participation loans, having a value of $2.4 billion, were approved.

During the five-year period from 1960 through 1964, SBA loans, both direct and participation, to firms in the Twin Cities area totaled $12.2 million. Of this amount, only 6.1% were loans made to technical companies. This is considerably below the experience of Twin Cities Small Business Investment Companies (SBICs) for the same period (see next section). Financial assistance by Twin Cities SBICs to technical companies has accounted for approximately 25% of their approximately $11 million in loans and investments since 1959.

Total SBA loans to Twin Cities R&D-based companies, as indicated by SBA reports, were:

Year	No. of Loans	Amount of Loans (thousands of dollars)
1956	1	$ 20
1957	2	200
1958	1	15
1959	1	10
1960	1	100
1961	0	0
1962	7	539
1963	3	165
1964	10	328
Total	26	$1,377

It will be noted that 75% of the SBA loans to Twin Cities technical companies have been made since 1962, after the decline of the "dollar stock market." Five of the 26 loans, totaling $130,000, have been direct loans. These have ranged in size from $10,000 to $65,000 and have averaged $26,000. The 21 participation loans totaling $1,247,000 have ranged in size from $10,000 to $200,000 and have averaged $59,000. SBA participation has ranged from 60 to 90% and has averaged 76%.

Small Business Investment Companies

Since 1958, when the Small Business Investment Act was passed to provide for the establishment of Small Business Investment Companies (SBICs), the Twin Cities have had 11 licensed SBICs, and seven were still operating on March 31, 1965. Their combined capital and surplus was about $6 million, with other reserves (matching funds from the SBA) of $3.8 million. Of these total available resources, approximately 70% was loaned or committed in 1965--a considerable increase over the 44% at December 31, 1962 (which paralleled the 43% commitment of total available resources of $843 million by 639 active U.S. SBICs in 1962). See Appendix D.

As shown in Table 22, the Twin Cities shared 13th rank among U.S. metropolitan areas* in the total number of SBICs licensed as of December 31, 1963. Among Midwestern metropolitan areas, only Chicago and Cleveland had more SBICs than the Twin Cities. As recently as December 31, 1963, five of the country's 65 SBICs with capital and surplus in excess of $1 million were located in the Twin Cities. Only New York City and Chicago had as many of these large SBICs as the Twin Cities.

In the Twin Cities, commercial banks--and to a lesser extent, finance and investment companies--have played an important part in the formation and operation of local SBICs. No less than eight of the 11 SBICs licensed in the Twin Cities have had either bank or finance and investment company affiliation or sponsorship. In only three other metropolitan areas--New York City, Chicago, and Boston--has the financial community been as influential in the establishment of SBICs.

With one exception, all Twin Cities SBICs will invest in new businesses and businesses with growth potential, including R&D-based companies. One Twin Cities SBIC has had a special interest in companies operating in medical and scientific fields. Another originally intended to invest only in electronics and scientifically oriented companies, but later broadened its policy to invest in any type of company.

Of the total financial assistance provided by Twin Cities SBICs, approximately 30% has been given to 16 companies considered to be technically oriented (i.e., having R&D expenditures greater than 3.4% of sales, the average for all U.S. manufacturing industries).

As shown in Table 23, Twin Cities SBIC transactions do not parallel national experience in loans and debentures, but do parallel national experience in capital stock investment (equity financing). There has been little differentiation between financial assistance to Twin Cities technical companies and assistance to all Twin Cities companies.

---

* These are the Standard Metropolitan Statistical Areas (SMSA) designated by the U.S. Census Bureau, but for brevity, this report uses "standard metropolitan area" or simply "metropolitan area."

Table 22

NUMBER OF SBIC'S LICENSED
IN STANDARD METROPOLITAN AREAS

Standard Metropolitan Areas	Number of SBICs
Areas with most SBICs (by rank order)	
New York	105
San Francisco-Oakland	53
Boston*	42
Los Angeles-Long Beach*	32
Chicago	23
Philadelphia	22
Oklahoma City	21
Dallas	20
Washington, D.C.	19
Cleveland	12
Houston	11
Tampa-St. Petersburg	11
Atlanta	10
Minneapolis-St. Paul	10
Denver*	8
Milwaukee	8
Selected Midwestern areas	
Columbus	5
Detroit	5
Indianapolis	4
Kansas City	4
Cedar Rapids	2
Cincinnati	2
Madison	2
St. Louis	2
Omaha	1
Urbana	1
Wichita	1
Akron	0
Ann Arbor	0
Dayton	0
Sioux Falls	0
South Bend	0
Other areas	
Tucson*	1
Orlando*	1

* Previously studied by SRI.

Source: The SBIC National Director, 1963, and 1964 Supplement.

Table 23

PROPORTION OF SBIC FINANCIAL ASSISTANCE--
TWIN CITIES AND UNITED STATES

Form of Assistance	Percent of Dollar Value of SBIC Financing: Twin Cities Technical Companies	Twin Cities All Companies	U.S. All Companies
Loans	10%	11%	38%
Debentures	76	76	51
Capital stock	14	13	11
Total	100%	100%	100%

Source: Appendix Table D-3.

Most capital supplied by Twin Cities SBICs has been for periods ranging from five to ten years. The size of loans and investments made to all companies has ranged from $11,000 to $500,000, compared with a range of $15,000 to $380,000 for financial assistance to technical companies. The average loan by Twin Cities SBICs to all companies has been $63,000, which is the same as the average for SBICs nationally. Based on a very limited sample, loans by Twin Cities SBICs to technical companies have averaged $79,000. The average equity investment by Twin Cities SBICs has been $103,000 for all companies and $94,000 for technical companies. These figures compare with a national SBIC average of $146,000. The maximum legal financial commitment for Twin Cities SBICs ranges from $60,000 (20% of minimum capital of $300,000) to $500,000. There is only one known investment of $500,000 by a Twin Cities SBIC, and this was to a nontechnical company.

Twin Cities SBIC interest rates for technical companies have been 6-8%, considerably lower than those obtained by all U.S. SBICs (Appendix D).

The extent of financial assistance to technical companies by Twin Cities SBICs has been influenced considerably by the fact that during the early 1960s, small technical companies in the area had little difficulty in obtaining equity capital in the "dollar stock market." After the precipitous drop in the stock market in May 1962, the decline in the demand for stocks of technical companies was paralleled by a decline in the number of technical companies seeking financial assistance. In recent years, however, technical companies have shown increased interest in obtaining financial assistance from Twin Cities SBICs. Also, one SBIC official stated that SBICs are more interested in these companies: "Technical companies today seeking SBIC financial assistance have more substance today than they did during the early 1960s."

The experience of Twin Cities SBICs with financial assistance to technical companies has been varied. The results have ranged from complete failure of companies to highly successful operations. Executives of some of the Twin Cities SBICs indicate that with no other type of company have they taken such a degree of risk as they have with technical companies. Although there have been occasional spectacular successes, Twin Cities SBIC experience with technical companies, as a whole, has not been as favorable as with other types of companies. However, SBIC executives believe that their experience with technical companies will improve.

Mergers

A significant source of financing for Twin Cities R&D-based companies has been the larger company interested in acquiring talented individuals or acquiring products with a growth potential through merger. Merger with a larger company is not usually advantageous to the R&D-based company in the early stages of growth, because at that time the smaller company is normally not in a position to negotiate from strength. However, resistance to merger (or acquisition) weakens if the small company seeking capital for survival or expansion has been unsuccessful in obtaining the necessary financing. The second or third time around for interim financing has set the stage for many of the mergers of Twin Cities R&D-based companies. In some cases, the high cost of continuous technical product development was responsible for merger. As shown in Table 24, at least 35 Twin Cities technical companies have been merged or have sold a substantial block of their capital stock to other firms. In some cases, particularly since 1960, there is evidence that the choice was between merger and dissolution.

Local Banks, Insurance Companies, and Other Institutional Investors

The principal type of financial assistance rendered by the Twin Cities banks to local R&D-based industry has been loans for working capital. Interviews with officers of eight Twin Cities technological companies formed since 1952, having annual sales ranging from $200,000 to $16 million, indicated no particular difficulty in obtaining commercial bank financing for working capital requirements.

The capital needs of some Twin Cities R&D-based companies were financed by equipment and building loans from commercial banks and insurance companies. Generally, maturities under 7 years were required for such loans by commercial banks, and under 12 to 15 years for term loans by life insurance companies. To accommodate smaller companies, the minimum commitment level of at least one Twin Cities life insurance

Table 24

MERGERS AND CAPITAL STOCK PURCHASES OF TWIN CITIES TECHNICAL COMPANIES 1952-1965

Date Formed	Technical Company	Parent or Stockholder Company	Date of Transactions
1955	ADC Products, Inc. (Donlan Mfg. Co.)	Magnetic Controls Co.	1965
1961	Advanced Scientific Instruments, Inc.	Electro-Mechanical Research, Inc. (Sarasota, Fla.)	1963
1950	Amer. Monarch Corp. (Amer. Electronics, Inc.)	Minneapolis Scientific Controls Corp.	1965
n.a.	Becks, Inc.	Control Data Corp.	1962
n.a.	Cedar Engineering	Control Data Corp.	1957
1930	Control Corp.	Control Data Corp.	1960
1949	Dahlberg Co.*	Motorola, Inc. (Franklin Park, Ill.)	1959
1956	Data Display, Inc.	Control Data Corp.	1965
1921	Electric Machinery Mfg. Co.	Worthington Corp. (Harrison, N.J.)	1944
n.a.	Electric Service Systems, Inc.†	Flo-tronics, Inc.	1960
1960	Electro-Craft Corp.	Napco Industries, Inc.	1963
1960	Electro-Med, Inc.	Knapic Electro-Physics, Inc. (Palo Alto, Calif.)	1962
1960	Electronic Medical Systems, Inc.	Medtronic, Inc.	1962
1946	Engineering Research Assoc.	Sperry Rand Corp.	1952
1952	Fluidyne Engineering Corp.	Chicago Bridge & Iron Co., Chicago (50% stock)	1959
1955	Geophysical Specialties Co.	Minnetech Laboratories, Inc.	1964
n.a.	Heights Precision Products, Inc.	Miniature Instruments, Inc.	1958
1945	Hoffman Engineering Corp.	Federal Cartridge Corp.	1964
n.a.	K&M Electronics Co	Miratel Electronics, Inc.	1961
1936	Maico Electronics, Inc.	Sheaffer Pen Co. (Ft. Madison, Iowa)	1958
n.a.	Miniature Mechanisms, Inc.	Miniature Instruments, Inc.	1958
1948	Minnesota Engineering Co.	General Electronic Control, Inc.	1960
n.a.	Miratel, Inc.	Miratel Electronics, Inc.	1961
1960	Northern Electronics, Inc.	Minneapolis Scientific Controls Corp.	1962
1942	Northern Ordnance, Inc.	FMC Corp. (San Jose, Calif.)	1964
n.a.	D. W. Onan & Sons, Inc.	Studebaker Corp. (South Bend, Ind.)	1960
n.a.	Precision, Inc.	Electro-Med, Inc.†	1961
n.a.	Precision Industries, Inc.†	Research, Inc.	1960
n.a.	Qualitone Hearing Aid Co.	Seeburg Corp. (Chicago)	1961
1959	Scientific Computers, Inc.	Control Data Corp. (25% stock)	1961
1953	Seco Electronics, Inc.*	Diacro Corp. (Lake City, Minn.)	1961
1961	Telostat Corp.†	Bachrach Instruments Co. (Pittsburgh)	1962
1953	Tenlo Research Corp.	Rosemount Engineering Co.	1961
n.a	Viron Division	GCA Corp.	1960
1960	Whitehall Electronics Corp.	Electro-Science Investors, Inc. (Richardson, Tex.)	1962

n.a. = not available.

* Operating independently again (as Dahlberg Electronics, Inc since 1963, and Seco Electronics, Inc. since 1965).
† Subsequently sold.

Source: Stanford Research Institute.

company was reduced from $250,000 to $100,000. Most of this type of lending has been mortgage lending. One of the Twin Cities insurance companies established a commercial and industrial loan department whose primary function has been to assist small and medium size companies by making loans which are not secured primarily by the pledge of real property. In general, loans of less than $100,000 are precluded because of the cost of investigating and servicing.

A combination of borrowing from both banks and life insurance companies has been used by some Twin Cities R&D-based companies. Thus, under a plant construction program, the bank carries a construction loan for about two years, and then an insurance company mortgage loan, or sale and lease-back, is applied.

The amount of investment in local technical companies by Twin Cities insurance companies has been limited. Of the 75 insurance companies in the Twin Cities, the Northwest National Life Insurance Company is reported to have had one of the more aggressive programs.

At the beginning of 1965, six organizations in the Twin Cities were sponsoring mutual funds: General Securities, Inc.; Imperial Financial Services, Inc.; Invested Dollars Fund, Inc.; Investors Group Funds; Liberty Fund; and Mairs and Power Funds. The largest of these, and also the largest in the world, is the Investors Group Fund with total net assets of $4.6 billion at the beginning of 1965.

During the "dollar stock market" period, some investment companies were formed in the Twin Cities to invest in scientific and technological "growth" companies. Two of the more familiar investment companies were the Midwest Technical Development Corporation and Search Investments Corporation. Appendix D presents additional financial information.

The Role of the Entrepreneur

The community with a defense R&D complex is differentiated from other areas by its large number and variety of enterprises that have a demonstrable capability for performing or supporting defense R&D. This diversity provides the basis for the defense R&D, and for the complex's relative efficiencies and its consequent ability to nurture and attract additional resources, thus continuing its relative advantage. The diversity also provides the resilience shown by a complex in the face of market changes. Therefore, an understanding of how a defense R&D complex develops must consider the manner in which the number of relevant enterprises within the area is increased--particularly the enterprises that are most likely to add to the development and growth process.

The number of relevant enterprises in an area is increased by: (1) formation of new companies and formation of new divisions of existing companies, (2) in-migration of enterprises from other areas, and (3) conversion of other kinds of local enterprises to defense R&D. Item (1) is of greatest interest here, since it appears to be the way in which the growth of a defense R&D complex might be most positively affected.

Entrepreneurship and Twin Cities Defense R&D Base

The development of the Twin Cities defense R&D industry base has roots that, in some cases, go back to the 19th century (see Appendix B). Throughout its development, the Twin Cities industry has been marked by entrepreneurs, entrepreneurship, and new company formation. Since World War II, at least 135 companies have been formed in the local industry, of which over 111 were still operating (in one form or another) in late 1965.

Unlike other communities with a defense R&D industry, the Twin Cities have contained very few relevant establishments which were begun by an in-migrant division of an outside company. Although there are divisions of non-Minnesota companies in the Twin Cities today, they are primarily the results of the acquisition or merger of a locally established company by a non-Minnesota corporation. With the notable exception of the men who formed Engineering Research Associates and its later offshoots, the Twin Cities industry has been primarily founded by men raised or educated in the local region.

The majority of the entrepreneurs who formed companies in the local industry can be considered to be R&D-oriented or technically oriented entrepreneurs, because they were men who had been trained as engineers or technicians and had usually worked in high technology companies. There is also some evidence of the influence of a small group of financial entrepreneurs who assumed the initiative in forming technical companies to take advantage of the "dollar stock market" of the late 1950s and early 1960s.

Conditions Associated with Twin Cities Technical Company Formations

From interviews with company principals and other key local figures, and from historical data, it was possible to identify a number of factors or conditions that, alone or in combination, were associated in some way with the formation and early survival of companies in the Twin Cities defense R&D industry.

First, in every case of a company formation studied, there appeared to be one individual who, more than the others, had been the chief initiator in launching the process by which the company was finally formed. Many of these individuals had long had the intention of going into business.

Second, there appeared to be a pre-formation period in which some combination of "pulls" and "pushes," or positive and negative conditions, operated to make the company founder or founders "more ready" for the decisive action. For example, in the post-World War II period of formation of many companies, the easy initial financing provided by the local "dollar stock market" (1959-61) was a strong "pull." Another positive pull was the guaranteed initial market for some companies--an R&D contract, or an order for a service or product. On the other hand, negative "push" appeared as a precondition more often than positive pull in the cases studied. The type of push most often identified in the company formations was some form of external threat--the threat of a cutback in business or personnel of the organization in which the potential entrepreneurs were employed; or the threat of arbitrary or unpopular decisions by an absentee management.

Third, certain kinds of environments and organizations appeared to be more highly associated with subsequent company formations than others. For example, four companies were formed by personnel from the University of Minnesota Aeronautical Laboratory; and several companies were formed from Engineering Research Associates. See the previous discussion of spin-offs.

Fourth, there appeared to be a conditioning psychological factor: the perception by the entrepreneur of the credibility of forming his own company. This feeling of confidence appears to depend on the entrepreneur's observation or knowledge of other entrepreneurs who have formed companies.

The Entrepreneur and Company Formation

In summary, on the basis of the data obtained on entrepreneurs and Twin Cities company formation, it appears that the formation of a technical company, as an idea, may take many months to gestate, but the actual company formation is usually a "triggered" act. It may be triggered by a single major event, or it may, like a capacitor, build up a charge that is triggered by minor events.

Aside from the actual financial and technical barriers of entry into a given business field, there is often a perceptual barrier facing the would-be entrepreneur that must be overcome before the company formation will actually be undertaken.

The entrepreneur is a man in whom there is the desire and intent to start a company. This intent is strengthened by both positive and negative events, including threats to job security or social position, frustrations on the job, encouragement by example, encouragement by colleagues and potential backers, and particularly, the lessening of financial risk in the form of available low-cost financing.

As various events occur--that strengthen the individual's drive to start a company, that diminish the perceptual barrier to credibility, that overcome the actual economic barriers to the formation of a company--the potential for company formation increases until the act is triggered.

Combinations of these factors can be found in the formation of almost all of the technical company formations studied in the Twin Cities. In some cases, the "dollar stock market" diminished the actual economic barrier and acted as a positive pull on the potential entrepreneur who already had the intention of forming a company "sometime." The triggering act occasionally was a difference of opinion between an engineer and management over the potential of a new product design, or the cajoling arguments of an entrepreneur-minded stock underwriter, or the threat of closing down an organization. In other cases, the observation of former associates, "no more qualified than yourself," succeeding in a new company made the company formation act quite credible. When combined with a negative push resulting from a job situation, the offer of a contract or an order became the triggering event.

The Role of the Local University

In the development of local defense R&D industry, universities have been called on to serve in many ways:

1. To perform defense R&D. In this case, they provide part of the local defense R&D capability--sometimes even the major part.

2. To supply engineers and scientists as a basic input to the technical capabilities of the R&D industry.

3. To provide continuing education, which updates and upgrades technical capabilities and also attracts technical-professional personnel to the local defense R&D workforce.

4. To provide advice, consultation, and technical services.

5. To function as sources of new R&D companies, and as a means for attracting R&D companies into an area.

For the Twin Cities study, the University of Minnesota is the subject of the following analysis, because in relation to the 30 other institutions of higher learning in Minnesota, the University of Minnesota, for the period 1961-62:

1. Was the only one producing Ph.D.'s.

2. Produced over two-thirds of the master's degrees.

3. Was the only one producing engineers at all three degree levels.

4. Produced 47 of the 133 bachelors of physics.

5. Produced 20 out of 21 master's degrees in physics.

6. Produced the only degrees in statistics, all Ph.D.'s, although

17 institutions produced bachelor's degrees in mathematics.

7. Produced 23 of the 26 master's degrees in mathematics.

Performance of Defense R&D

During the period 1940-1965, sponsored research performed by the University of Minnesota increased from less than $1 million to $28 million. This compares with a national growth in sponsored research in universities from approximately $50 million in 1940 to $1.8 billion in 1965.* Sponsorship of the $28 million of research at the University of Minnesota in fiscal year 1964-1965 was:

Sponsor	Percent 1964-65 Research Expenditures	
Defense agencies	10.0%	
U.S. Public Health Service	54.6	
National Science Foundation	13.5	
NASA	5.5	
AEC	5.2	
U.S. Office of Education	2.1	
Total federal agencies		90.9%
Foundations	4.9	
Business and industry	2.0	
Individuals and others	1.6	
Endowments	0.6	
Total nonfederal agencies		9.1%
		100.0%

The 90.9% of 1964-65 federally sponsored research at the University of Minnesota compares with an average of 68% federally sponsored research at 164 colleges and universities reported in the 1966 survey of Industrial Research magazine.† In recent years, the University's research for defense agencies has annually involved about 100 senior researchers, in addition to graduate students and supporting personnel. Table 25 compares Minnesota with other states in terms of defense R&D prime contract awards to schools.

* National Science Foundation.

† Danilov, Victor S.,"The Academic Marketplace," Industrial Research, April 1966.

Table 25

R&D DEFENSE PRIME CONTRACT AWARDS TO SCHOOLS IN TOP 20 STATES
1961 and 1965
(Millions of Dollars)

State	1961 Amount	1961 % of Total	1965 Amount	1965 % of Total	5-year Total Amount	5-year Total % of Total
Massachusetts	$119.4	36.6%	$134.9	36.5%	$ 636.0	34.1%
Maryland	45.8	14.0	51.2	13.8	274.5	14.7
California	38.5	11.8	29.3	7.9	214.0	11.5
New York	25.3	7.8	29.3	7.9	151.4	8.1
Illinois	18.8	5.8	14.0	3.8	110.2	5.9
Michigan	14.2	4.4	16.2	4.4	70.9	3.8
Pennsylvania	9.5	2.9	18.2	4.9	65.2	3.5
Ohio	7.2	2.2	6.5	1.8	37.9	2.0
Washington, D.C.	4.2	1.3	10.1	2.7	36.4	2.0
Texas	4.4	1.3	6.3	1.7	27.2	1.5
New Jersey	5.5	1.7	5.9	1.6	24.1	1.3
Colorado	2.9	0.9	5.4	1.5	23.4	1.3
Washington	3.5	1.1	4.4	1.2	19.7	1.1
Rhode Island	4.7	1.4	3.1	0.8	17.5	0.9
North Carolina	1.4	0.4	3.3	0.9	17.4	0.9
New Mexico	2.6	0.8	3.6	1.0	17.1	0.9
Indiana	1.9	0.6	2.5	0.7	14.3	0.8
Florida	2.3	0.7	3.0	0.8	12.8	0.7
MINNESOTA	2.4	0.7	1.8*	0.5*	10.0	0.5
Utah	1.2	0.4	2.1	0.6	9.2	0.5
Subtotal	$315.7	97.1%	$351.1	95.0%	$1,789.2	96.0%
Total for all schools	326.3	100.0	369.9	100.0	1,866.2	100.0

* Minnesota replaced by Wisconsin ($2.2 million and 0.6%) in top 20 for 1965.

Source: Appendix Table D-5.

Approximately one-third of the University of Minnesota's $28 million of research for the academic year 1964-65 was for work by its Institute of Technology. The Institute's research volume has grown from $46,000 in 1940-41 to $7.4 million in 1963-64, with about 88% sponsored by the federal government.

The University as a Source of E/S's

Relevant technical professionals are broadly defined here as engineers, physicists, mathematicians, and statisticians. From Table 9 (Chapter III) and data in previous studies, the following comparison is made for three defense R&D establishments, in terms of percent of E/S's holding degrees in engineering, or degrees in engineering, physics, mathematics, or statistics.

Defense R&D Establishment	% E/S's with Degrees in Eng.	% E/S's with Degrees in Eng., Phys., Math., or Stat.
Twin Cities	66.6%	86.7%
Los Angeles	67.4	82.0
Boston	61.3	80.6

In the 1962-63 school year, universities and colleges in Minnesota accounted for 1.7% of the 54,264 bachelor's degrees conferred nationally in the relevant fields, 1.1% of the relevant master's degrees, and 1.8% of the relevant doctorates. For the six academic years 1960 through 1965, the University of Minnesota's Institute of Technology conferred a total of 2,419 bachelor's degrees. Of those departments particularly related to high technology industry, the University of Minnesota has produced the following percentages of U.S. bachelor's degrees: aeronautical engineering 1.7%; chemical engineering 1.1%; electrical engineering 1.1%; metallurgy and mining engineering 1.0%; mechanical and industrial engineering 0.9%; physics 0.5%; and chemistry 0.3%.

From the experience of the past five years, it appears that Twin Cities industries absorb about 100 engineering and science bachelor degree graduates annually from the University of Minnesota, out of about 400 annual graduates in these fields. As can be seen in Table 26, since 1960, establishments in nine states account for over 85% of the "first job" hiring of University of Minnesota technology bachelor degree graduates. Over two-thirds of the University of Minnesota technology bachelor degree graduates remain in the Midwest for their first job. From the data in Table 26, the following observations are pertinent:

1. The proportion of University of Minnesota technology bachelor degree graduates taking positions in California varies considerably. From 1960 through 1963, the percentage of graduates accepting positions with California establishments increased

from 6.1% to 22.3% of the total. In 1964 and 1965, the out-migration to California decreased considerably--to 7.6% and 9.0% of the total.

2. Since 1960, the percentage of graduates remaining in the Midwest on their first position has ranged from 60.1% in 1961 to 74.7% in 1960.

3. Only in 1965 did the nine states of Minnesota, California, Wisconsin, New York, Washington, Illinois, Ohio, Iowa, and Michigan account for less than approximately 85% of the University of Minnesota technology bachelor degree graduates accepting full-time positions. The "space center" states of Texas, Alabama, and Florida have increased their percentage "take" from nothing in 1962 to 3.4% of the total in 1965. Also showing increases in recent years have been the Northeastern states of New Jersey, Massachusetts, and Connecticut. Combined, these states show an increase from 0.8% of the total in 1963 to 4.3% in 1965.

Table 26

LOCATION OF FIRST JOB OF UNIVERSITY OF MINNESOTA INSTITUTE OF TECHNOLOGY BACHELOR DEGREE GRADUATES 1960-1965 (Percent of Total)

Year	Minn.	Calif.	Wisc.	N.Y.	Wash.	Ill.	Ohio	Iowa	Mich.	All Other Locations
1960	51.2	6.8	6.1	6.1	1.4	2.7	4.4	3.8	2.7	14.8
1961	43.1	13.3	5.5	5.0	7.8	4.6	3.7	0.9	0.9	15.2
1962	52.1	16.6	6.6	3.1	3.9	1.9	3.1	1.9	1.5	9.3
1963	45.1	22.3	3.9	3.4	2.6	3.4	0.9	3.4	1.3	13.7
1964	54.6	7.6	5.2	4.1	2.9	2.3	2.9	4.1	1.7	14.6
1965	45.1	9.0	3.9	3.0	6.4	4.3	3.9	1.3	4.3	18.8
Weighted Average	48.5	12.6	5.3	4.2	4.0	3.2	3.2	2.6	2.1	14.3

Source: University of Minnesota.

The University as a Source of Continuing Education

In response to the needs of local industry, the University of Minnesota has established a number of programs and seminars in both technical and management subjects: evening graduate programs in electrical engineering and business administration; engineering-technician certificate programs; technology seminars; correspondence courses; and other Extension Division evening and special classes.

Evening Graduate Programs. These programs enable employees of technical companies to complete the requirements for a master's degree in electrical engineering or business administration in three years by attending evening classes. Over the years 1960-65, 382 students were enrolled in the electrical engineering classes, and 477 in the business administration classes. Of the business students, two-thirds of those enrolled for 1964-65 had engineering or science undergraduate bachelor's degrees.

Engineering-Technician Certificate Programs. The current Engineering Science and Technician Certificate Programs, established in 1959, are an outgrowth of similar programs originating in 1923. The present programs, following meetings of industrial and academic representatives, have been designed particularly for the part-time student who has the ability to carry college-level courses leading to a career at either the professional engineer or the engineering technician level. Although certificates are granted by the General Extension Division, bachelor's degrees in engineering are granted only by the Institute of Technology.

Course work in the Basic Engineering Science Certificate Program is the same as required for first year engineering students in the Institute of Technology. All courses in the Basic and the Senior Engineering Science Certificate Programs carry degree credit and are transferable to the Institute of Technology when admission requirements are satisfied. Most of the classes in the four Senior Engineering Technician Certificate Programs also carry degree credits and are transferable. As of 1966, the total enrollment in these programs was 472.

Seminars. In the summer of 1965, the Institute of Technology and the Center for Continuation Study of the University of Minnesota presented a series of one-day and two-day seminars on engineering and scientific topics, which are listed in Appendix D.

Other Courses. The General Extension Division of the University also offers evening degree-credit classes in engineering and the physical and technical sciences. In 1964-65, 51 undergraduate and 18 graduate courses were offered.

To determine the extent to which employees of Twin Cities technical companies participated in this program, 22 undergraduate and 14 graduate courses offered during 1964-65 were analyzed. For the undergraduate courses, there were 600 registrations, with 507 (85%) completing the course. For the 14 graduate courses, there were 760 registrations, with 681 (90%) completing the course. Twin Cities technical companies supplied 61% of the registrations in the undergraduate courses, and 60% of the registrations in the graduate courses. Five well-known companies also supplied evening instructors during 1964-65. Of the 22 undergraduate courses analyzed, 12 had industry instructors, and of the 14 graduate courses analyzed, two had industry instructors.

The University as a Source of Advice, Consultation, and Services

Consulting Services. From 1959 to 1965, 211 Institute of Technology faculty consulting agreements were approved by the University Board of Regents. The number of such agreements made annually has increased from 22 approved in 1959 to 46 in 1964. Of the total, 84 agreements were made with Twin Cities establishments and 127 with establishments located elsewhere. Approximately 60% of the agreements were with establishments having substantial participation in defense, space, or atomic energy activities. Departments with the largest number of consulting agreements during the six-year period were electrical engineering 49, physics 38, and mechanical engineering 36.

Consulting agreements were made with the following types of establishments:

Type of Establishment	No. of Establishments	No. of Consulting Agreements
Companies		
Twin Cities	31	77
Other locations	51	87
Government agencies		
Defense, space, and atomic	9	12
Other	7	12
Schools		
Government-funded laboratories	4	15
Other	3	3
Other nonprofit organizations	4	5
Total	109	211

The foregoing summary indicates that several of the establishments had more than one agreement with the University faculty. In many cases, the agreement was renewed on a year-to-year basis.

Membership on Company Boards of Directors. University of Minnesota faculty are permitted to serve on company boards of directors with the approval of the Board of Regents. A review of 69 stock prospectuses of Twin Cities technical companies and Board of Regents minutes of meetings since 1959 indicates that there have been at least 18 University of Minnesota faculty members on the boards of directors of Twin Cities technical companies during that period. The following University departments have been represented:

University of Minnesota Department	Faculty Members on Twin Cities Company Boards of Directors 1959-65
School of Medicine	9
Chemistry	2
Electrical Eng.	2
Chemical Eng.	1
Mechanical Eng.	1
Rosemount Aeronautical Laboratory	1
Physics	1
Institute of Technology Administration	1
	18

Company Use of University Facilities and Services. The University of Minnesota provides a variety of facilities and services which are available to outside companies. These are in addition to library facilities which are used by a number of the Twin Cities companies interviewed.

The University's Numerical Analysis Center was established in 1958. Its principal computing equipment consists of three Control Data Corporation units: a model 1604 computer system with 32K words of memory, a model 160 computer, and a model 8090 computer. Peripheral equipment for these computers includes: 12 magnetic tape handlers, two high speed card readers, a high speed line printer, two digital plotters, and paper tape reader and punch. The Center has also designed and built a linkage system between the 8090 computer and its Reeves Electronic Analog computer, permitting analog inputs to the digital computer under digital control. During 1966, the Center will acquire a Control Data 6600 computer and a much more sophisticated combined analog and digital computer system which will link a modern solid state analog computer to a control computer such as the Control Data 1700. The Center is also considering the possibility of extending this "hybrid" system to permit tying in a number of remotely located engineering laboratories on a time-shared basis.

According to its Director, the Numerical Analysis Center of the University of Minnesota makes its equipment available to companies on a fee basis, provided that such usage does not interfere with the educational and research programs of the University. The fee charged covers the rental of the equipment and the services ordinarily rendered by machine operators and similar personnel.

Since the establishment of the Center, usage by companies is indicated by the following yearly charges:

Year	Companies Served	Total Charges
1958-59	1	$ 2,400
1959-60	1	5,359
1960-61	4	1,710
1961-62	1	269
1962-63	2	1,472
1963-64	3	431
1964-65	1	193
Total		$11,834

Contributing to the low outside usage of the University's Numerical Analysis Center facilities has been the existence of one or more local commercial computer service bureaus since 1959.

University of Minnesota laboratory facilities are available on a fee basis, provided such services are not in competition with private industry. The usage of the University's laboratory facilities by local companies has more than doubled since the academic year 1959-60, based on a sample of ten of the larger Twin Cities defense R&D contractors. Despite this increase, total usage of University laboratory facilities by local companies was less than $60,000 for the academic year 1964-65. Two companies accounted for over $50,000 of this total.

With the help of a $100,000 appropriation from NASA and $30,000 from seven Minnesota companies, the University of Minnesota established a Technical Utilization Program during 1965. Twin Cities companies participating in underwriting the program include Control Data Corporation; Fabri-Tek, Inc.; Honeywell, Inc.; Applied Science Division of Litton Industries, Inc.; Minnesota Mining and Manufacturing Company; the Univac Division of Sperry Rand Corporation; and the Rochester (Minnesota) plant of IBM Corporation.

The objective of the Technical Utilization Program is to facilitate the flow to industry of information about the results of research projects being carried on at the University of Minnesota. The new program is related to a $3.5 million NASA grant for a Space Sciences Research Center at the University. NASA stipulated that data and results from such space research be used to help stimulate the economy. The Technical Utilization Program is an extension of this requirement to include all types of research carried on by the University of Minnesota.

V SPECULATIONS ON FACTORS RELATED TO THE DEVELOPMENT OF A DEFENSE R&D COMPLEX

The data that have been obtained in this and previous studies are reexamined in this chapter for insight into the central questions of this study:

How does a defense R&D complex develop?

Why has not a larger defense R&D industry developed in the Midwest, considering its industrial and educational capabilities?

This reexamination compares the Twin Cities with communities having both greater and less defense R&D capability, in order to identify processes that may be related to the transformation of a community into a full R&D complex. The results of this comparison are used as the basis for speculative answers to the two central questions.

Characteristics of a Defense R&D Complex

The major defense R&D complexes are characterized by:

1. A relatively large and diverse defense R&D capability
2. Economies of scale which provide competitive advantages
3. A resilience and regenerative ability enabling the complex to attract existing capabilities or to grow new capabilities, thus renewing and strengthening the local industry's ability to perform defense R&D, despite cutbacks in the overall market demand or shifts in defense technology.

These characteristics are highly interrelated and are useful for ranking communities as defense R&D industrial centers. Such a ranking will show a progression from communities with no defense R&D industry, to those dominated by one major defense R&D establishment, to the potential complex, and finally to the major defense R&D complex. Of the communities examined in this series of studies, Tucson, Orlando, and Denver would rank as communities dominated by one establishment; Los Angeles and Boston as full complexes; and the Twin Cities as a potential complex.

The three interrelated characteristics of a major defense R&D complex are also useful in identifying some dimensions or yardsticks that can be applied in measuring the progress of a community from a condition of "zero" defense R&D industry to that of possessing a defense R&D complex.

These dimensions include:

1. Size and growth in size as measured by: total defense R&D dollars received; percent of national defense R&D dollars received; and size of the defense R&D workforce.

2. Breadth and diversity as measured by: the amount of work done in each of the six R&D categories; the variety of technologies represented; the spectrum of specialties in the technical workforce; and the variety of supporting industries.

3. The demonstrated ability to attract subcontracts, workers, and companies from other communities.

4. The ability to stay abreast of market demands for new technologies.

5. The regenerative capability evidenced by the formation and attraction of new high technology enterprises.

In the following discussion, the Twin Cities are compared with other communities in terms of these and similar characteristics.

Progress toward a relatively large and diverse defense R&D capability can be measured in several ways. The most commonly used measure of such progress is the increase in total dollars awarded to industry in the community, or the increased percentage of total defense R&D dollars awarded to the community. In Tables 2 and 5 (Chapter III), it is seen that the absolute dollars of defense R&D awarded to Twin Cities organizations dropped during FY 1963-1965, but that the percentage of total defense R&D dollars awarded to the Twin Cities increased somewhat.

A close examination of the data in Table 5, however, casts doubt upon the value of "dollars" as the most useful growth measure of local defense R&D industry. Taken by themselves, such measures as "dollars awarded" and even "percent of total dollars awarded" often mask rather than depict the actual development of a community as a defense R&D complex. A series of awards to a single dominant contractor over a period of years can give an appearance of local growth that can disappear in one year with the completion of a major project. Even for the short period of three years covered in Table 5, it is evident that a dominant local contractor can be the source of sharp fluctuations in dollars received as the contractor experiences the "project piston" effect* that is part of the project-contract

---

* "The project-contract nature of the defense R&D business is probably the largest single factor affecting the turnover of personnel. The manpower demand of a major defense R&D project, particularly the demand for professional technical manpower, acts in the manner of a large piston; pulling in large numbers on the 'upstroke' and pushing them out on the 'downstroke.'" From reference 1.

nature of defense R&D. In a community with a single dominant establishment, the downstroke of a project piston actuated by the cancellation or completion of a major project not only causes lay-offs, but also causes out-migration of the technical workforce. Usually, the displaced E/S's enter the general migratory streams, never to return.

A better way to consider growth in local capability is to consider three nondollar factors simultaneously with relative growth in dollar awards--number of prime contractors, degree of nondependence on any single contractor, and the total number of local establishments in fields relevant to defense R&D (including defense subcontractors as well as many NASA and AEC prime and major subcontractors). Considered in this broader framework, the Twin Cities area appears to be progressing in its development as a defense R&D complex. During FY 1963-1965, its percentage of total U.S. defense R&D awards increased slightly, the number of prime contractors increased, and the percentage of awards to the largest local contractor was of the order found in the Los Angeles and Boston complexes. Other Midwest centers that had somewhat similar defense R&D characteristics during this period, though receiving less total dollars, were Dayton and Chicago. The foregoing suggests that an essential process in the transformation of a community into a defense R&D complex is an increase in the number of local prime contractors, with or without a parallel increase in the dollars awarded to them, to provide a multiplicity of potential growth points.

In Table 5, we can see that the existence of a large dominant local defense R&D contractor does not necessarily result in an increase in the number of local prime contractors for defense R&D, even after many years. Of the 20 Midwest centers listed in Table 5, four had only one defense R&D prime contractor in FY 1965, despite the fact that at least two of these centers have been in defense R&D work for over two decades. Twelve of the 20 Midwest centers listed had three or fewer prime contractors in FY 1965, and in 10 of these 12, the largest local contractor received over 75% of the dollars awarded to the community's industry. There is also some evidence from the previous study of Denver, Tucson, and Orlando that the presence of even a very large local defense R&D contractor does no necessarily result in the co-location or development of local subcontractors. In 1963-1964, not one surviving company was found in Denver, Tucson, and Orlando that had depended to a great extent on the single large local defense R&D prime contractor as a customer. These findings support the conclusion that the presence of a large locally dominant defense R&D establishment does not provide the conditions required for an increase in the number of local prime contractors.

Other dimensions of growth in local defense R&D capabilities are evidenced in Tables 3 and 4, which provide measures of the depth and diversity of the industry in the communities studied. A measure of the depth of the industry in a community is found in Table 3, which shows the percentage of FY 1965 defense R&D dollars awarded by DOD research category to the contractors in the areas studied. Essentially, the six categories used span the spectrum of R&D activities from Research (Category 1) through Operational Systems Development (Category 5) and Management (Category 6).

A reexamination of Table 3 shows a decrease in the concentration of defense R&D dollars awarded to any single category as a community develops into a defense R&D complex, and a narrowing range of percentages of dollars awarded to all categories. The largest single percentage of dollars awarded to a single R&D category in FY 1965 was 83.8% and 73.7% for Orlando and Denver, dropping to 40.3% for the Twin Cities and 31.4% and 32.7% for Boston and Los Angeles. Similarly, in both Orlando and Denver, four of the six R&D categories accounted for less than 10% of the dollars awarded, and one category accounted for less than 20%. In the Twin Cities, two categories received less than 10%, and three received between 10-21% compared with five categories receiving 10-20% in Boston and four categories receiving 10-20% in Los Angeles.

A measure of the technical breadth of a community's defense R&D industry is found in Table 4, which shows the distribution of FY 1965 defense R&D dollars awarded to the contractors in the areas studied by DOD technology code. An examination of Table 4 shows that as a community develops toward a defense R&D complex, the dollars awarded to local contractors become less concentrated in any single field of technology, and tend to spread out over a number of technological fields. Here again, as with the previous analysis of the distribution of dollars by research category, it is seen that in FY 1965, awards received by Orlando and Denver contractors were heavily concentrated in a single technology classification, 95.4% and 94.2%, respectively, dropping to 29.9% for the Twin Cities, and 52.6% and 53.7% for Boston and Los Angeles. The Orlando industry received no awards in 20 of the 33 technology codes, and less than 1% of the dollars awarded to the area was received for each of 11 of the technology codes. In Denver, 12 of the technology codes showed zero awards. In the Twin Cities, only three of the technology codes were blank, and Boston and Los Angeles each had only one technology code in which no awards were received. These results point up another essential process in the transformation of a community into a defense R&D complex--the deepening and broadening of the aggregate of its local technical capabilities. This also suggests that an increase in the number of local prime contractors may be an aid in this process. A larger number of prime contractors means a larger number of managements making technical decisions from independent viewpoints, thereby increasing the probability of achieving technical variety.

A defense R&D complex is distinguished by the characteristics of the E/S workforce it is able to attract and retain. Analysis of Tables 8 and 9 (Chapter III) provides some insights into the differences in E/S characteristics between communities at different stages in their development as defense R&D complexes. Denver, Tucson, and Orlando have workforces with the lowest percentage of degree-holding E/S's, and the lowest percentage of E/S's holding advanced degrees. The Twin Cities, a potential complex, have a higher percentage of degreed E/S's than do the Los Angeles and Boston workforces, but the Twin Cities have a smaller percentage of E/S's with advanced degrees.

The degree composition of the defense R&D industry's E/S workforce is steadily rising over time. The companies in the industry increasingly favor or require advanced degrees, and in general, E/S's with advanced degrees have relative freedom in choosing their place of work, given the existence or availability of appropriate work. Consequently, the percentage of E/S's with advanced degrees in a community's industry is one indicator of its ability to attract and retain qualified E/S's and to develop as a complex. Younger complexes will show an increasing demand for, and supply of, E/S's with advanced degrees. In the older complex, Los Angeles, the workforce contains a relatively larger proportion of older workers without advanced degrees or without any degree if hired before 1950. Over time, however, the percentage of E/S's with advanced degrees in the Los Angeles workforce is increasing rapidly.

The pull that a complex asserts on E/S's with advanced degrees is indicated by the data on the E/S's that have greatest relative freedom of choice--E/S's with a Ph.D. When the relative age of the Los Angeles complex is taken into account, it is seen that the percentage of E/S's with a Ph.D. in a community rises with its progress in developing as a complex.

In terms of degree specialties, the Twin Cities E/S workforce is more highly specialized than that of Boston, which in turn has a workforce that is more specialized than that of Los Angeles. An examination of Table 9 shows that with time, the Los Angeles and Boston defense R&D industries are tending to hire technical specialties in a way that makes their workforces more alike (e.g., over time, Los Angeles companies are hiring a higher percentage of electronics engineers; in Boston, this pattern is reversed).

In terms of age characteristics, the Twin Cities E/S workforce is similar to that of Boston, and both are distinctly younger than the E/S workforce in Los Angeles (see Chapter III). Ex-Minnesota E/S's identified in the Los Angeles workforce were similarly older, on the average, than the Twin Cities E/S's. These data and the data on degree specialties reflect the relative composite age of the defense R&D industry in Los Angeles as compared to Boston and the Twin Cities. The data reflect the heavy concentration of the Twin Cities defense R&D industry in the newer technologies (such as computers) which necessarily depend upon the more recent and younger products of our universities. A similar pattern has been evident in the development of the industry in Boston. The relative average age of the Twin Cities E/S's and the increase in hiring point to the increasing ability of the local industry to compete for younger E/S's.

The foregoing suggests that in the transformation into a defense R&D complex, the defense R&D industry of a community often (and perhaps necessarily) follows a process in which it:

1. Specializes in new technical fields where there are greater chances to compete successfully and to develop competitive advantages over other well-established complexes. This is reflected by a workforce that is more specialized in new technical fields and is younger, on the average, than the workforces in the older complexes.

2. Gradually broadens and deepens its scope to include more of the capabilities relevant to its specialized fields and to defense R&D in general. This is reflected by a workforce with a higher percentage of advanced degrees in the locally developed fields of specialization, and by the gradual inclusion of a broader range of degree specialties. This part of the process tends to keep the average age of the workforce low since it is still concentrated on new technology and newly produced advanced degrees.

3. Gradually achieves a capability to perform, and to compete for, the full spectrum of defense R&D against established complexes. The deeper involvement of a community's industry in defense R&D is reflected by a workforce that has a wide range of degree specialties and levels as well as a wide range of defense R&D experience, and an average age that is closer to that found in the older complexes.

A defense R&D complex is distinguished by the presence of a relevant workforce that is large enough to supply a large percentage of the local industry requirements under a variety of conditions of demand. One measure of the extent to which a community has developed a relevant workforce of the required magnitude is the percentage of E/S's that the community's industry hires from outside its home area. A reexamination of Figure 1 in this report and of Figure 4 in the report on Denver, Tucson, and Orlando[1] shows that:

1. The annual percentage of salaried workers (mostly E/S's) hired from outside their home areas by the single large establishments in Denver, Tucson, and Orlando remained close to 80% for eight years after start-up. Though there is evidence of a very slight downtrend in these percentages with time, the data from these three communities covered periods during which they had experienced no major project cutbacks. There is a high likelihood (considering the mobility patterns that have been found) that the out-of-area hire percentages will remain high, if not increase, when a major cutback is followed by an increase in activity.

2. The annual percentage of E/S's hired from outside the home area has been constantly rising in the Twin Cities, a pattern which existed in Boston until the period following 1960, when the percentage stayed constant.

The foregoing hiring patterns suggest that as a community with several defense R&D contractors develops as a defense R&D complex:

1. It outstrips the ability of the local labor pool and institutions to supply its needs.

2. It increasingly depends on other areas as sources of E/S's, until the local labor pool is large enough and distributed among enough

establishments that a sudden demand by one local defense R&D establishment can be substantially supplied by the E/S's made available by other local establishments with a slackened demand.

3. Once condition 2 is achieved, the percentage of imports from other areas and probably other industries tends to reflect the rise and drop in national defense and associated R&D expenditures.

Here again, the data suggest that the dominating, large, imported establishment does not by itself provide the necessary conditions for developing the kind of local E/S pool conducive to the development of a defense R&D complex. The workforce of the large establishment is far larger than the entire local labor supply. Any rise and fall in its demand for E/S's is completely beyond the marginal supply capacities of the local community.

The extent to which a local defense R&D industry hires inexperienced E/S's (those that are newly graduated), provides insights into an important aspect of the development of a defense R&D complex and the role which local universities might play in it. Measures of this hiring of inexperienced E/S's are provided by (1) the data on the percentage of local E/S's hired directly from universities upon completion of their education, and (2) the data on the geographic sources of the university education received by the E/S in each community workforce. Reexamination of Table 12 in this report and Table 11a in reference 1 shows that nearly 24% of E/S's in the Los Angeles and Boston workforces had been hired directly from universities upon completion of education, nearly 41% of the Twin Cities E/S's, and less than 8% of the salaried workers (including E/S's) in Denver, Tucson, and Orlando. Also, less than 21% of the Los Angeles E/S's had received their university education in California; in Boston, the percentage of local E/S's that had received their education in Massachusetts was about 55%; and in the Twin Cities, those with Minnesota educations were 35%.

In the Denver, Tucson, and Orlando instances, each is dominated by a single large establishment that is a division of a major corporation and therefore somewhat independent of local recruiting mechanisms and salary structures. In each of these cases, an experienced initial cadre and management were imported from other corporation establishments with a major project or projects in-hand. All of these conditions, especially in the first decade of operations, acted to bias hiring of E/S's with some minimum of training (i.e., the demand was for experienced personnel, rather than inexperienced new graduates).

The high percentage of E/S's coming directly from the university into the Twin Cities workforce, compared with the percentages found in established complexes, points to the relative inability of potential defense R&D communities to compete for experienced E/S's. This viewpoint is supported by a reexamination of the average monthly salaries of Twin Cities E/S's compared with those of Los Angeles and Boston E/S's (see Figure 4), or compared with those of ex-Minnesota E/S's in Los Angeles (see Figure 5). These figures show that the Twin Cities salary structure has been substantially lower than that found in the major complexes. These figures also show, however, that the salaries for E/S's below 32 years of age in the Twin Cities are much closer to, and therefore competitive with, those found in the complexes. This points to an increasing ability on the part of the Twin Cities to compete with the established complexes for E/S's, and provides another indication of the development of the Twin Cities as a complex.

The foregoing paragraphs suggest that in the transformation into a defense R&D complex, the defense R&D industry of a community generally follows a process in which it:

1. Initially depends on lower labor costs as one means to help it compete for work in the marketplace. Lower labor costs are made possible by (a) a workforce that contains a high percentage of E/S's who were hired directly from universities, and (b) a salary structure that is significantly lower than the structure found in the established complexes.

2. May initially be aided greatly by the presence of a local university as a source of E/S's who are attached to the local area by family and other social ties, and who therefore are attracted to local industry despite lower salaries. The aid of the university is indicated by the presence in the local workforce of a large percentage of E/S's who have received their educations locally or within the home region of the community.

3. Gradually achieves the ability to compete with the established complexes for E/S's newly produced by more remote universities, for E/S's with advanced degrees, and for experienced E/S's. This increasing competitiveness is evidenced as a diminishing gap between the salaries for younger E/S's in local industry and those in the major complexes, particularly for locally produced E/S's. The increasing competitiveness is also evidenced by an increase in the percentage of E/S's with advanced degrees, and by a diminishing percentage of hires coming directly from the universities.

In the case of the community dominated by a large in-migrant establishment, the process just described differs, because small companies are required to meet the salaries offered by the large establishment (as was found in the Denver, Tucson, and Orlando study), and cannot use lower labor costs as an aid in competing for markets. They therefore have to achieve early high efficiencies or fail.

Other manpower factors that mark the transition of a community to a defense R&D complex are the turnover of E/S's and the average seniority of E/S's. A reexamination of Figures 2 and 3 and Table 13 shows a clear differential between the Twin Cities and the established complexes, with the established complexes having a higher turnover as measured by average seniority and average number of jobs held by the local E/S's. These observations point to a crucial process in the development of a defense R&D

complex--the increase in the quantity and variety of job options for E/S's as a consequence of the increase in companies and projects in the community. The increase in the number of project pistons at work in the community is reflected by an increase in the local turnover rates for E/S's, a decrease in average seniority, and an increase in the overall salary structure. The increase in salaries and options also makes the area attractive to E/S's from other communities.

Another way to measure the breadth and depth of capabilities that distinguish a defense R&D complex is to measure its ability to provide a major portion of the materiel and services required for the accomplishment of a large variety of defense R&D projects. This ability can be measured by the percentage of locally received defense R&D prime contract dollars that remain with the prime contractor and that are awarded for materiel procurement within the local area. Another measure, of course, is the amount of subcontract dollars received from other areas. A reexamination of the data on materiel procurement in Chapter III and the study of Denver, Tucson, and Orlando shows that in the communities with a dominant in-migrant establishment, approximately 55% of the prime contract dollars remained with the prime contractors, and approximately 9% were awarded for materiel procurement to local companies, for a local total of 64% of the prime contract dollars. In the complexes of Boston and Los Angeles and in the potential complex of the Twin Cities, between 64% and 83% of the prime contract dollars remained with the prime contractors. Together with local procurement, between 80% and 90% were spent locally, with the highest total percentage being found in the Twin Cities.

Though the data are limited, they suggest the following process in the development of a community into a defense R&D complex:

1. Initially, the local companies procure a substantial proportion of the materiel required for their projects from the established complexes. This dependence is measured by the high percentage of out-of-house, out-of-area procurement on the part of local prime contractors, and by the percentage of the outside procurement that is of a high technology character--as was found in Denver, Tucson, and Orlando. In this case, the large local in-migrant establishments resembled displaced "fragments" of a major complex that were still connected to major centers and depended on them for materiel and manpower.

2. During periods when the overall defense R&D market is rising, local companies begin to include more functions within their own organizations, some of which are marginal in terms of profitability and efficiency. This limited form of vertical integration comes about as the result of a kind of make-or-buy decision process in which the local companies decide to gain control over critical inputs, even though they might be considered marginal from a profitability viewpoint. An example of this might be the inclusion of a printed circuitry section or a high-spec plating department in order to guarantee close and controllable services or products for an important project, despite the unprofitability of these functions for the company on a long term basis.

3. As local companies are formed that are responsive to the needs of several prime contractors, their prime contractors gradually begin to give up functions that are marginal from a profit or efficiency viewpoint, and to avoid increasing the capacity of other functions despite temporary peak needs. As projects phase out or as the overall defense R&D market turns down, thereby making the required functions more available throughout the country as well as cheaper, the make-or-buy decision is reversed. Marginal functions are eliminated from the organization, and increases in the capacity for other functions are decided against.

4. Suppliers of the marginal functions and suppliers of functions requiring additional capacity become established locally. As a local market for each function grows, it becomes feasible for supplier companies to establish themselves profitably within the community. If at this time, local companies give up their less efficient functions to the local suppliers, voluntarily or through spin-off, a sort of rationalization takes place that is accelerated by the insecure position of the inefficient function within the company, thereby providing a push to the potential entrepreneur in its ranks. At the same time, the function for which additional capacity is needed provides a positive incentive to the potential entrepreneurs in the company's ranks. A multiple company market is needed for such suppliers to succeed. A single large defense R&D establishment provides a market that is too volatile for a supplier to depend upon.

A defense R&D complex is especially distinguished by its ability to cope successfully with the uncertainties of the defense R&D market which include sharp changes in the size of the market and major shifts in technology. Useful measures of this ability include the number of formations of companies with relevant capabilities; the survival rate of these companies; and the ability of the community to attract relevant companies from other areas. Regarding these measures, a reexamination of the data in Chapters III and IV and of the information from the study of Denver, Tucson, and Orlando shows distinct differences between the potential complex and the communities with a single dominating establishment. The Twin Cities have been marked by a high number of relevant company formations, by a high survival rate, and by the ability to attract local investment from defense R&D companies in the major complexes. The other communities, as of 1963, had experienced few relevant company formations, a relatively low survival rate, and had attracted some outside company investments--but then had also experienced subsequent withdrawals of these outside companies.

Though data were not collected on these measures in the Boston and Los Angeles complexes, the work of Professor E. B. Roberts and his students at MIT shows that just considering the spin-offs from MIT, Boston has generated a high number of new relevant companies, and these companies have experienced a high survival rate. In addition, in the earlier studies in this series, a number of cases were found in which companies had moved, or were considering moving, from other areas to Los Angeles, to the San Francisco Bay Area, and to Boston for a variety of reasons associated with operational efficiencies.

One chief executive stated that he had moved his company from Ohio to Boston "in order to obtain financial support from bankers that understood the electronic business." One small company announced a move from Tucson to Palo Alto "in order to have access to a pool of specially skilled labor." The principals in a small Utah electronics company stated that they were contemplating a move to Los Angeles in order "to be near our major market." No such example was encountered in the Twin Cities. Many examples were found, of course, of small companies that were moved for a variety of personal reasons of the chief officers (e.g., "asthma in the family," "the fishing in Colorado, " etc.), but these fall outside the "operational efficiency" criterion. The Twin Cities experience and that of Boston very strongly suggest that in the development of a defense R&D complex, the local community undergoes a highly localized version (in terms of sector and region) of what Professor W. W. Rostow has called "takeoff into sustained growth." Elements of this process that are suggested by the data on company formations, survivals, and the attraction of enterprises include:

1. The attraction into the community of R&D oriented entrepreneurs. This is exemplified by the chance attraction to the Twin Cities of the men who formed Electronics Research Associates; by the attraction and development of R&D entrepreneurs in the Boston area as a result of the presence and policies of MIT; and by the similar experience in the San Francisco Bay Area. (This view is also supported by the negative experience in areas with excellent universities that did not have policies of permitting or encouraging entrepreneurial activity by their faculty.)

2. The development of a financial community with the know-how and interest to provide financial support to new and small R&D companies. The presence of such a financial community is one of the characteristics of all of the areas with defense R&D complexes or with developing complexes.

Speculations on a Strategy for Developing a Defense R&D Complex

Throughout this series of studies of the defense R&D industry, it has become increasingly apparent that no factor can be singled out as being necessary and sufficient by itself to develop a defense R&D complex. This major conclusion of the first study of Denver, Tucson, and Orlando has been underscored in this study of the development of the Twin Cities defense R&D industry. Hence, a strategy for developing a defense R&D complex must consider several factors and must include a policy that allows flexibility in shifting the emphasis from one factor to another as the local industry develops.

Two major strategic goals are indicated if an attempt is to be made to develop a defense R&D complex:

1. A continuing effort to develop multiple points of potential growth until the local industry achieves a self-sustaining momentum.

2. A technical specialization aimed at achieving a competitive advantage, followed by a deliberate effort to deepen, broaden, and strengthen the fields of specialty.

Multiple Points of Potential Growth

Throughout the analytical comparisons of the Twin Cities with areas of greater and lesser development, it has become obvious that many small and medium size companies hold the greatest potential for development. This point must be emphasized because the several thousands of regional and local development agencies in the United States are currently oriented toward the attraction of the small number of relocating divisions of major corporations. All of the evidence in this series of studies suggests that attracting corporation divisions does not provide the most effective path to development. On the contrary, establishment of a number of small and medium size technical companies is the most effective way to provide for the development of a complex. To have many companies is a means of providing for many independent decisions based on differing assumptions. A development program based on a number of small companies as opposed to a large establishment, even one with more dollars and manpower, permits a less volatile, more stable labor market, with a consequent development of the kind of growing labor pool that is essential to defense R&D. Such an approach overcomes the high degree of uncertainty that is inherent in the defense R&D market.

Technical Specialization

A community wishing to develop a defense R&D complex is in a position analogous to that of a small company undertaking to compete with a large corporation. The probability of its being able to successfully enter the marketplace is raised by concentration on a small but growing segment of the total field. Once established, this segment can be used to support expansion to other specialties. The final goal of this process is to broaden out and achieve the full status of a complex.

The data and the analytical results of this study and preceding studies suggest that to achieve the first of these two strategic goals, a community must have, or must help provide, conditions that are favorable for technical company formations and for the attraction of small and medium size technical companies. Conditions favorable to company formation include:

1. The presence of a financial community attuned to the financial needs of small and medium size technical companies in terms of initial investment, working capital, and growth capital.

2. An environment of positive encouragement to technically oriented entrepreneurs such as can be provided by university administrative policies that encourage entrepreneurial activity by their engineering and science faculties.

3. The provision of other forms of support for new technical ventures--i.e., the provision of rent-free facilities, joint marketing aids, referral services for financial aid, consulting by community supported panels, etc.

In addition to conditions favorable for company formation, a community must have, or provide for, conditions that are conducive to the survival and early growth of the new technical ventures. In the growth stage, financial support is still the primary need, followed by other kinds of support that can help the new ventures achieve operational efficiency. Important among the latter is a local university to serve as a source of supply of E/S's who will originally make up the majority of the local professional technical workforce. In some cases, an important factor will be improvement of access to national markets through an improvement in the local transportation linkage to other national centers.

To achieve the second strategic goal, a community can take steps to consciously provide selected support to local enterprises that succeed in new fields of technology. Support here can include measures to encourage the local formation or location of other new ventures in the same or related fields, as well as support functions that would aid the technical companies in these new fields. Once a specialty has obtained an economic foothold, the local community can undertake a deliberate effort to continue to deepen and strengthen its specialized capability by judicious attraction of, and support for, companies and services that would strengthen the capability of the other companies in the community.

The Midwest and the Defense R&D Industry

The data collected in this study of the Twin Cities defense R&D industry clearly demonstrate that there are no regional factors which preclude the development of defense R&D industry in the Midwest. However, these data and data from previous studies suggest that the question of why a larger defense R&D industry has not grown in the Midwest region must be considered in terms of climate, national migration patterns, resources, history, economic alternatives, and difficulties in competing with existing complexes.

Climate has affected the location and concentration of the defense R&D industry in different ways at different points in its history. Originally, according to many reference sources, the aircraft industry and its associated defense R&D located in California in order to take advantage of the much greater number of flying days provided by the climate. During World War II and during the Korean War, the increased demand for aircraft and aircraft R&D resulted in the buildup of the industry already located in California as well as elsewhere.

When a large growth in defense R&D took place during the period of missile buildup, climate and historic U.S. population migration patterns provided companies that had already located in such states as California and Florida with an advantage in competing for and obtaining E/S's from other areas of the country. During this period, a number of Midwestern companies established or moved divisions to the so-called "sunshine" states in order to attract or retain E/S's. Personnel department members of one Florida company stated that during this period, they received 60,000 out-of-state applications in response to advertisements for 3,000 positions.

As with all regional developments, historical actions and historical accidents have played a role in the location of the defense R&D industry. In the Twin Cities, a good example is the fortuitous location there of the Electronics Research Associates group, which played a large part in the development of that area's computer capabilities. Another example is the deliberate encouragement of defense R&D plant relocation during the period when there was an active strategic dispersal policy.

Local resources and the question of economic alternatives played a major role in diminishing the part that the Midwest has played in defense R&D. The strength that the Midwest has developed as a manufacturing area has acted to deter the region's development as a defense R&D producer. A good example of the manufacturing orientation is given by Thompson: "... Detroit could have carried on its World War II work in aircraft, at least in aircraft engines... But impatience to get back to the more lucrative automobile business was so great that airplane production was not even accorded a secondary place on Detroit's postwar industrial agenda."*

Interviews with a limited number of executives in Midwest manufacturing concerns supported this viewpoint with examples of similar decisions that had been made by their companies following the war. This viewpoint is further emphasized by the comments made by a number of procurement personnel from major defense R&D companies who stated that despite major efforts to interest Midwest concerns in bidding on defense subcontracts, there was little response.

Thompson further points out that Los Angeles did not have the established resources and the consequent attractive economic alternative available to Detroit. Therefore, Los Angeles fought to retain and develop its defense R&D and production, and succeeded in doing so.

Once major complexes became established, they rapidly began to gain competitive advantages over other areas, making it increasingly difficult for these other areas to successfully enter the field. For example, Los Angeles gained many competitive advantages such as a highly skilled labor

---

* Thompson, Wilbur R., A Preface to Urban Economics, published for Resources for the Future, Inc. by The Johns Hopkins Press, Baltimore, 1965.

force and a multiplicity of specialized supporting services (e.g., companies that specialize in packaging to military specification). Consequently, Midwest companies that have recently decided to enter the field have chosen to operate within the existing complexes--by acquiring an existing company, by moving into the complex, or by starting a division there--rather than to compete from the Midwest.

The Twin Cities case is seen to be an exception because despite the general Midwest experience:

1. Climate has certainly not prevented development of the Twin Cities defense R&D industry.

2. A historic U. S. migration pattern has operated to bring E/S's from other parts of the Upper Midwest region to the Twin Cities.

3. Historic accident, as pointed out above, helped assure it a place in the computer industry.

4. The Twin Cities industrial community chose to invest in and compete for defense R&D business, and local conditions supported their efforts.

BIBLIOGRAPHY

BOOKS AND STUDIES

Baty, Gordon, Initial Financing of the New Research-Based Enterprise in New England, master's thesis and Research Report No. 25 to Federal Reserve Bank of Boston, MIT, Cambridge, Mass., 1964

Beckhart, Benjamin H., Business Loans of American Commercial Banks, The Ronald Press, New York, N.Y., 1959

Boyden, George L., Jr., The Role of Venture Capital in New Enterprises, bachelor's thesis, MIT, Cambridge, Mass., 1951

Bureau of Business and Economic Research, San Diego State College, A Study of the Problems of Small Electronics Manufacturing Companies in Southern California, prepared for SBA, San Diego, Calif., 1962

Carson, Deane, The Effect of Tight Money on Small Business Financing, prepared for SBA, Brown University, Providence, R.I., 1963

Carter, C. F., and B. R. Williams, Industry and Technical Progress, Oxford University Press, London, England, 1957

Champlin, Herbert H., The Effects of Changes in the Internal Revenue Code on the Financing of New Research-Based Enterprises, bachelor's thesis, MIT, Cambridge, Mass., 1959

Child, John F., Long-Term Financing, Prentice-Hall, Inc., New York, N.Y., 1960

Christiansen, C. R., Management Succession in Small and Growing Enterprises, Graduate School of Business Administration, Harvard University, Boston, Mass., 1953

Cole, Arthur H., Business Enterprise in Its Social Setting, Harvard University Press, Cambridge, Mass., 1959

Collins, Orvis F., and David G. Moore, The Enterprising Man, prepared for SBA, Michigan State University, East Lansing, Mich., 1964

Draheim, Kirk P., Technological Industry in the Upper Midwest, Technical Paper No. 11, Upper Midwest Economic Study, Minneapolis, Minn., 1964

__________, Electronics in the Free World, Long Range Planning Research Report No. 179, Stanford Research Institute, Menlo Park, Calif., 1963

Draheim, Kirk P., Albert Shapero, et al., A Study of the Potential for Development of an Electronics Industry in Israel, prepared for AID (Agency for International Development), Stanford Research Institute, Menlo Park, Calif., 1962

Draheim, Kirk P., Albert Shapero, and Howard M. Vollmer, "Financial and Technical Profile of the Aerospace Industry," sections of a report, The Industry-Government Aerospace Relationship, prepared for Aerospace Industries Association of America, Inc., Stanford Research Institute, Menlo Park, Calif., 1963

Edwards, Ronald S. and Harry Townsend, Business Enterprise, Macmillan and Co., London, England, 1958

Finn, Gene L. The Availability of Credit to Wisconsin Small Business, prepared for SBA, University of Wisconsin, Madison, Wis., 1962

Flink, Solomon J., Equity Financing of Small Manufacturing Companies in New Jersey, prepared for SBA, Rutgers University, New Brunswick, N.J., 1962

__________, Equity Financing for Small Business, Simmons-Boardman Publishing Co., New York, N.Y., 1962

Friedland, Seymour, et al., The Financing of Manufacturing Activities in New Jersey, prepared for SBA, Rutgers University, New Brunswick, N.J., 1963

Friedmann, John, and William Alonso, Regional Development and Planning, a Reader, MIT, Cambridge, Mass., 1964

Gordon, Kenneth F., An Examination of Some Problems of Financing and Managing a New Research-Based Enterprise, master's thesis, MIT, Cambridge, Mass., 1960

Haggett, Peter, Locational Analysis in Human Geography, St. Martins Press, New York, N.Y., 1961

Harbison, Frederick, and Charles A. Myers, Management in the Industrial World, McGraw-Hill Book Co., New York, N.Y., 1959

Isard, Walter, and James Ganschow, Awards of Prime Military Contracts by County, State and Metropolitan Area of the United States, Fiscal Year 1960, Regional Science Research Institute, Philadelphia, Pa., 1960

Isard, Walter, and Gerald J. Karaska, Unclassified Defense Contracts: Awards by County, State and Metropolitan Area of the United States, Fiscal Year 1962, World Friends Research Center, Philadelphia, Pa., 1962

__________, Unclassified Defense and Space Contracts: Awards by County, State and Metropolitan Area, United States, Fiscal Year 1964, World Friends Research Center, Philadelphia, Pa., 1965

Kaplan, A.D.H., Small Business: Its Place and Problems, McGraw-Hill Book Co., New York, N.Y., 1948

Kelley, R. E., SBIC's in Action, Keyfax Publications, Los Angeles, Calif., 1965

__________, The SBIC's: Suppliers of Venture Capital, Keyfax Publications, Los Angeles, Calif., 1961

Litzinger, William David, Entrepreneurial Prototype in Bank Management: a Comparative Study of Branch Bank Managers, Ph.D. thesis, University of Southern Calif., Los Angeles, Calif., 1963

McClelland, David C., The Achieving Society, D. Van Nostrand Inc., Princeton, N.J., 1961

Mahar, James F., and Dean C. Coddington, The Financial Gap--Real or Imaginary?, for SBA, Denver Research Institute, Denver, Colo., 1962

Merwin, Charles L., Financing Small Corporations, National Bureau of Economic Research, New York, N.Y., 1943

Mills, James I., A Study of Small Business and Federal Government Programs to Assist Small Business, Ph.D. thesis, George Washington University, Washington, D.C., 1965

Munro, J. S., Jr., Commercial Banks and Venture Capital, bachelor's thesis, MIT, Cambridge, Mass., 1948

Nancy, Michael, Problems in Raising Short and Long Term Capital for Small Business, bachelor's thesis, MIT, Cambridge, Mass., 1952

Nessell, C. W., The Restless Spirit, (the story of Honeywell, Inc.), Minneapolis, Minnesota, 1963

Olson, Harold G., Bank Investment in a Small Business Investment Company Under the Small Business Investment Act of 1958, thesis for the Stonier Graduate School of Banking, Rutgers University, New Brunswick, N.J., 1961

Prochnow, Herbert V., Term Loans and Theories of Bank Liquidity, Prentice-Hall, Inc., Englewood Cliffs, N.J., 1950

Pugh, Olin S., Financing 689 Small Business Firms in South Carolina, 1958-1959: A Study of the Sources, Availability, and Terms of Financing for Small Business Firms in South Carolina, prepared for SBA, University of South Carolina, Columbia, S.C., 1962

Robinson, G. J., Going Public: Successful Securities Underwriting, Boardman & Co., Ltd., London, England, 1961

Rostow, W. W. (Ed.), The Economics of Take-Off into Sustained Growth, Proceedings, Conference of the International Economic Association, St. Martins Press, New York, N.Y., 1963

Rubenstein, A. H., Problems of Financing and Managing New Research-Based Enterprises in New England, Research Report No. 3 to the Federal Reserve Bank of Boston, MIT, Cambridge, Mass., 1958

Savage, H. L., A Banker's Outlook on the Small Business Administration and Small Business Investment Companies, thesis for the Stonier Graduate School of Banking, Rutgers University, New Brunswick, N.J., 1959

Schumpeter, Joseph A., The Theory of Economic Development, Harvard Economic Studies, Harvard University, Cambridge, Mass., 1934

_________, Business Cycles, McGraw-Hill Book Co., New York, N.Y., 1939

_________, History of Economic Analysis, Oxford University Press, New York, N.Y., 1954

Shapero, Albert, Richard P. Howell, and James R. Tombaugh, An Exploratory Study of the Structure and Dyanmics of the R&D Industry, Stanford Research Institute, Menlo Park, Calif., 1964 (reference 1 in this report)

_________, The Structure and Dynamics of the Defense R&D Industry: The Los Angeles and Boston Complexes, Stanford Research Institute, Menlo Park, Calif., 1965 (reference 2 in this report)

Smelser, Neil J., and William T. (Ed.), Personality and Social Systems, John Wiley and Sons, Inc., New York, N.Y., 1963

Smith, Edward K., The Financing of Small Business in New England, Staff Memorandum #6, The Committee of New England of the National Planning Association, Boston, Mass., 1952

Smith, Harold T., Equity and Loan Capital for New and Expanding Small Business, Upjohn Institute for Employment Research, Kalamazoo, Mich., 1959

Smith, Spencer M., Jr., and Michael B. Carter, Performance and Potential of Small Business in R and D Industries, prepared for SBA, University of Maryland, College Park, Md., 1963

Stevenson, Harold W., Equity and Long-Term Financing for Small Manufacturing Firms in Minnesota, prepared for SBA, University of Minnesota, Minneapolis, Minn., 1962

________, Common Stock Financing, University of Michigan, Ann Arbor, Mich., 1959

Swope, O. P., Jr., Aspects of New Enterprises, master's thesis, MIT, Cambridge, Mass., 1948

Taeuber, Conrad, and Irene B., The Changing Population of the United States, John Wiley and Sons, Inc., New York, N.Y., 1958

Teplitz, P., Spin-off Enterprises from a Large Government Sponsored Laboratory, master's thesis, MIT, Cambridge, Mass., 1965

Thompson, Wilbur R., A Preface to Urban Economics, prepared for Resources for the Future, The Johns Hopkins Press, Baltimore, Md., 1965

Turnburke, V. P., Jr., Aspects of New Enterprises--Finance, bachelor's thesis, MIT, Cambridge, Mass., 1949

Twin Cities Metropolitan Planning Commission, Metropolitan Economic Study, Planning Report No. 5, St. Paul, Minn., 1960

Wainer, H. A., The Spin-off of Technology from Government Sponsored Research Laboratories, master's thesis, Lincoln Laboratory, MIT, Cambridge, Mass., 1965

Watson, Leland A., and Thomas Tolan, Hearing Tests and Hearing Instruments, Williams and Wilkins, Baltimore, Md., 1949

Weisenberger, Arthur, Investment Companies, Mutual Funds and Other Types, Arthur Weisenberger & Co., New York, N.Y., 1965

Weissman, Rudolph L., Small Business and Venture Capital, Harper and Bros., New York, N.Y., 1945

White, J. G., Engineering Corp., Economic Analysis of the State of Minnesota, (a report to the Minnesota Resources Committee), New York, N.Y., 1945

DIRECTORIES AND LISTINGS

Kelley, R. E., The SBIC National Directory, 1963, and 1964 Supplement, Keyfax Publications, Los Angeles, Calif., 1963 and 1964

Minneapolis Chamber of Commerce, Directory of Manufacturers for the Minneapolis Area, 1961

_________, Electronic Firms - Twin City Area, undated

_________, Research Organizations, undated

Minnesota Department of Business Development, Minnesota Directory of Manufacturers, 1963 - 1964, St. Paul, Minn., 1964

Northwestern National Bank of Minneapolis, Directory - Minnesota's Electronics and Related Science Industries, 1961-1962, Minneapolis, Minn., January 1962

_________, Directory - Minnesota's Electronics and Related Science Industries, 1964, Minneapolis, Minn., January 1964

St. Paul Area Chamber of Commerce, Manufacturer's Directory St. Paul Metropolitan Area, St. Paul, Minn., 1963

Science Magazine, Scientific Instruments Manufacturers' Listing, November 1964

Small Business Administration, A List of Small Business Concerns Interested in Performing R&D, Government Printing Office, Washington, D.C., 1963

PAMPHLETS, SPECIAL REPORTS, AND SPEECHES

Chamber of Commerce, U.S., Small Business--Its Roles and Its Problems, Washington, D.C., undated

Chicago Area Research and Development Council, Chicagoland: Center of Innovation, Chicago Association of Commerce and Industry, Chicago, Ill., undated

First National Bank of Minneapolis, Special Report No. 1: Electronics in Minneapolis, Minneapolis, Minn., 1960

__________, Special Report No. 2: Tool and Die and Precision Machines in Minneapolis, Minneapolis, Minn., undated

__________, A Report on Electronics-Oriented Students Enrolled in the Upper Midwest Universities, Colleges, and Trade Schools, Minneapolis, Minn., 1959

Griswold, John A., Financing Capital Expansion, Dartmouth College, Hanover, N.H., 1956

Harding, William B., "Financing Small Business," Speech before Institute of Investment Banking, April 5, 1955

Howard, James W., President of Growth Capital, Inc., "Small Business Investment Companies," speech before the Cleveland Security Analysts, Cleveland, Ohio, May 24, 1961

Investment Bankers Association of America, Equity Capital for Small Business Corporations, Washington, D.C., 1955

Lauver, R. C., and W. D. Serfass, "Public Financing of Small Business--A Trying but Rewarding Experience," Price Waterhouse Review, New York, N.Y., Summer 1960

National Association of Small Business Investment Companies, Financing Small Business--1955, New York, N.Y., 1956

__________, The Small Business Investment Program--What an SBIC Can Do for You, Washington, D.C., undated

Northern States Power Co., First National Bank of Minneapolis, Northwestern National Banks of Minneapolis, and Minneapolis Area Development Corporation, Minnesota's Case for the Electronics Industry, Minneapolis, Minn., 1959

Prentice-Hall Special Report, SBIC's, New Opportunities in Small Business Investment Companies, Prentice-Hall, Englewood Cliffs, N.J., 1961

Robert Morris Associates, Financial Statements for Bank Credit Purposes, Philadelphia, Pa., undated

Silberman, Richard T., "Sympathetic Equity Financing for Electronic Companies," Speech before the Western Electronic Manufacturers Association, San Francisco, Calif., April 14, 1960

Vollmer, Howard M., Work Activities and Attitudes of Scientists and Research Managers: Data from a National Survey, Stanford Research Institute, Menlo Park, Calif., 1965

Weaver, Robert A., Jr., Initial Public Financing for the Small Business, Investment Bankers Association of America, Washington, D.C., 1956

GOVERNMENT PUBLICATIONS

Federal Reserve Bank of Atlanta, "Sources of Funds for Capital Investment in the Southeast," Monthly Review, January 1960

Federal Reserve Bank of Boston, "Characteristics of New Enterprises: Part I--the Firm," New England Business Review, June 1957

Federal Reserve Bank of Chicago, "Small Business Investment Companies," Business Conditions, Chicago, Ill., October 1958

__________, "Small Business Investment Companies: A Progress Report," Business Conditions, Chicago, Ill., March 1961

Federal Reserve Bank of Minneapolis, Oscar F. Littener, Where Does Small Business Obtain Its Capital?, Minneapolis, Minn., 1948

__________, Raymond H. McEvoy, Bank Financing of Business Enterprise in the Ninth District, Minneapolis, Minn., 1956

Federal Reserve System, Financing Small Business, Parts 1 and 2, Government Printing Office, Washington, D.C., 1958

__________, "Small Business Financing: Corporate Manufacturers," Federal Reserve Bulletin, Government Printing Office, Washington, D.C., January 1961

__________, "Problems of Small Business Financing," Federal Reserve Bulletin, Government Printing Office, Washington, D.C., July 1957

Minnesota Department of Employment Security, Employment Trends (various issues relating to Twin Cities), St. Paul, Minn.

National Research Council, Doctorate Production in U.S. Universities, 1920-1962, Washington, D.C., 1963

National Science Foundation, Reviews of Data on Science Resources, Vol. 1, No. 2, Washington, D.C., December 1964

U. S. Congress, Committee on Banking and Currency and the Select Committees on Small Business, Financing Small Business, 1958

__________, Small Business Act of 1958, Public Law 536, 1958

U.S. Dept. of Commerce, James C. Dochery, The Small Businessman and Sources of Loans, Small Business Series No. 69, Government Printing Office, Washington, D.C., 1948

__________, Bureau of Census, U.S. Census of Population, 1960, Mobility for States and State Economic Areas, DC(2)28, Government Printing Office, Washington, D.C.

__________, 1963 Census of Manufactures, Government Printing Office, Washington, D.C., 1964

U.S. House of Representatives, Problems of Small Business Financing, Hearings before the Select Committee of Small Business, 1957

__________, Small Business Investment Act Amendments, 1959, Hearings before Subcommittee of the Committee on Banking and Currency, 1960

__________, Impact of Federal Research and Development Programs, Report of the Select Committee on Government Research, 1964

U.S. Office of Education, Degrees in the Biological and Physical Sciences, Mathematics and Engineering, Government Printing Office, Washington, D.C., 1963

__________, Earned Degrees Conferred, 1962-63, Government Printing Office, Washington, D.C., 1965

__________, Engineering Enrollments and Degrees, 1961, Government Printing Office, Washington, D.C., 1963

__________, Survey of Financial Statistics of Institutions of Higher Education, 1961-62, Government Printing Office, Washington, D.C., 1966

U.S. Office of the Secretary of Defense, The Changing Patterns of Defense Procurement, Washington, D.C., 1962

__________, Five Year Trends in Defense Procurement 1958-1962, Washington, D.C., 1963

__________, Military Prime Contract Awards by Region and State, Fiscal Years 1962, 1963, 1964, Washington, D.C., 1965

__________, 500 Contractors Listed According to Net Value of Military Prime Contract Awards for Experimental, Developmental, Test and Research Work, Fiscal Years 1963, 1964, & 1965, Washington, D.C., 1965

U.S. Patent Office, Patents Issued to Residents of U.S., 1956-1965

U.S. Securities and Exchange Commission, Costs of Flotation of Small Issues, Government Printing Office, Washington, D.C., 1940

__________, Costs of Flotation of Corporate Securities, 1951-55, Government Printing Office, Washington, D.C., June 1957

U.S. Senate, Select Committee on Small Business, Operation of Small Business Investment Companies, Government Printing Office, Washington, D.C., 1963, 1964

__________, Small Business Investment Act--1960, Hearings, Government Printing Office, Washington, D.C., 1960

__________, Small Business Investment Act 1960, 1961, Government Printing Office, Washington, D.C., 1961

__________, and Committee on Banking and Currency, Financing Small Business, Hearings, April 21, 1958, Government Printing Office, Washington, D.C., 1958

__________, Briefing on the Investment Act, Government Printing Office, Washington, D.C., 1958 and 1960

__________, Small Business Amendments of 1959, Government Printing Office, Washington, D.C., 1959

U.S. Senate, Subcommittee on Employment and Manpower of the Committee on Labor and Public Welfare, Impact of Federal Research and Development Policies on Scientific and Technical Manpower, Government Printing Office, Washington, D.C.

U.S. Small Business Administration, Government Printing Office, Washington, D.C.
Management Aids for Small Manufacturers

No. 138 Getting Money for Long-Term Growth, Jacoby, Neil H., 1962
No. 150 What Kind of Money Do You Need, Woelfel, B. L., 1963
No. 164 Financial Facts Which Lenders Require, Price, S. E., 1964

__________, Management Series

No. 15 A Handbook of Small Business Finance, Tower, Ralph B., 1962
No. 24 Equity Capital and Small Business, Anthony, Edward L., 1960

__________, Research Series

No. 2 The First Two Years: Problems of Small Firm Growth and Survival, 1961

__________, Bank-SBA Participation Loan Plans, undated

__________, Capital and Long-Term Loans for Small Business through Small Business Investment Companies, 1959

__________, Consolidated Reference Regulations, Small Business Investment Act of 1958, as amended June 1960, 1960

__________, Establishment and Operation of Small Business Investment Companies, undated

__________, Small Business Administration Loans Approved, 1954 through 1964

__________, SBA-Business Loans, 1960

__________, Federal Policies and Programs that Benefit Small Business, prepared for the Cabinet Committee on Small Business, 1957

__________, Handbook for Participation Loans with Small Business Administration, A Guide for Private Lending Institutions, 1960

PERIODICALS

Andrews, Victor L., et al., "Working Capital Financing of Small Businesses," Law and Contemporary Problems, Winter 1959

Blank, Seymour, "Small Business and Tight Money," The Journal of Finance, March 1961

Bower, C. M., "For the Small Electronic Firm; Obtaining Capital; Methods and Pitfalls," Electronic Industries, December 1959

Butler, William F. and Robert P. Ulin, "Business Needs for Venture Capital," Harvard Business Review, July 1950

Chinitz, Benjamin, "Contrasts in Agglomeration: New York and Pittsburgh," American Economic Review, May 1961

Choate, Algie, "Security Purchases of Small Business Investment Companies," The Journal of Finance, May 1961

Cohn, Bernard D., "Capital for Small Business: Sources and Methods," Law and Contemporary Problems, Winter 1959

Danilov, Victor J., "Trends in University Research," Industrial Research, April 1963-1965

De Frenceaux, George W., "Report: An SBIC in Action," Burrough's Clearing House, October 1960

Duke University Law School, "Financing Small Business," Law and Contemporary Problems, Summer-Autumn 1945

George, Edwin B., and Robert J. Landry, "The Federal Reserve Board Report on Small Business Financing," Journal of Business, July 1959

Hartman, Heinz, "Managers and Entrepreneurs: A Useful Distinction?" Administrative Science Quarterly, III, March 1959

Jolivet, Vincent M., "Public Financing for Small Corporations," The Journal of Finance, 1959

Marcum, Robert E., and Edward O. Boshell, Jr., "Financing the Small and Medium-Size Business," Management Review, January 1963

McCallum, Philip, "The Small Business Investment Act of 1958--Its First Year of Operation," Virginia Law Review, Vol. 45, 1959

McKinley, Gordon W., "Life Insurance Company Lending to Small Business," The Journal of Finance, May-June 1961

Miller, Glenn R., "Long-Term Small Business Financing from the Underwriter's Point of View," The Journal of Finance, May 1961

Murphy, Thomas P., "The Big Worry for Small Business: Money," Fortune, July 1957

Norris, Frank W., "New Sources of Capital Funds for your Customers," Commercial West, May 30, 1959

Rieser, Carl, "Minneapolis-Honeywell: The Darn Thing Works," Fortune, May 1959

Schrage, Harry, "The R&D Entrepreneur: Profile of Success," Harvard Business Review, December 1965

Schwieger, Irving, "Adequacy of Financing for Small Business Since World War II," The Journal of Finance, September 1958

Shepard, W. Hardie, "How to Impress Financial Men," Electronics, July 17, 1959

Silberman, Richard T., "Helpful Equity Financing for Electronics Companies," Commercial and Financial Chronicle, April 28, 1960

Stedman, Frank H., "Twin Cities, Minnesota: Industrial Aces Back to Back," Industrial Development and Manufacturers Record, Vol. 131, August 1962, pp. 61-68

Weaver, R. A., Jr., "Equity Financing for the Small Firm," Harvard Business Review, March 1956

Wendt, P. F., "The Availability of Capital to Small Business in California in 1945-1946," The Journal of Finance, October 1947

Wilkinson, Philip D., "Myopia Along Route 128: A Critical Look at Boston's Famed Electronics Industry," Business Review, Vol. 10, Fall 1963

Williamson, Merritt A., "Trends in Research and Development Funding," Research/Development, January 1964

"Adventure Capital," Business Week, August 17, 1946

"American Research," Newsweek, April 4, 1949

"Blue-Ribbon Venture Capital," Business Week, October 29, 1960

"Ebasco Expands Its Horizon," Business Week, November 25, 1947

"If You Need $100,000 or So," Reader's Digest, July 1950

"Investment Test," Business Week, August 10, 1946

"Maico Company, Inc.," Commercial West, October 27, 1945

Minneapolis Star and Journal, various issues, 1945-1966

"New Trends in Finding Funds," Electronics, February 19, 1960

Over-the-Counter Securities Review, various issues, 1958-1966

"Presidents Plan to Provide More Capital to Business," U.S. News and World Report, May 12, 1950

"Problems in Review: Small Business Financing," Harvard Business Review, March-April, 1959

"Problems of Maintaining Equity Control in a Growing Business," Burroughs Clearing House, May 1960

"Risk Capital on Way," Electronics, December 26, 1958

"The Role of Venture Capital in the Microwave Industry," The Microwave Journal, September 1960

"SBIC's--Short-Lived Glamour," Financial World, October 23, 1963

"Scramble to Buy New Issues," Business Week, April 15, 1961

"Something Ventured," Time, August 19, 1946

Upper Midwest Investor (called Mid-American Investor beginning with issue of September/October 1962), various issues during life of publication, April 1961, through December 1963

"Venture Capital," Fortune, February 1950

"Venture Capital," Business Management, 1964

"What Financiers Look For," Electronics, March 27, 1959

"Venture Capital: Money in a Hurry," Dun's Review, November 1963

"Where Do Small Firms Get Capital?", Business Week, December 11, 1948

APPENDIXES

Appendix A

REGRESSION ANALYSIS STUDY OF POPULATION AND WORKFORCE MIGRATIONS

Appendix A

REGRESSION ANALYSIS STUDY OF POPULATION AND WORKFORCE MIGRATIONS

As in the earlier studies, a regression analysis was made of the relationship of the geographic flow of the E/S's in the Twin Cities establishments to the migration patterns of the general Twin Cities population. In this analysis, Y was the percentage of E/S's in the Twin Cities workforce studied that had come from each of 33 subdivisions of the country, and X was the percentage of the general population that had migrated to the Twin Cities from each of the same 33 subdivisions during the 1950-1960 period. For the Twin Cities data, the following equation was computed.

$$Y = -0.00109 + 1.0024X$$

having a variance (σ^2) of 1.8184 and a correlation coefficient of over 0.9. The results of this analysis are shown as a scatter diagram in Figure A-1, which is based upon data in Table A-1.

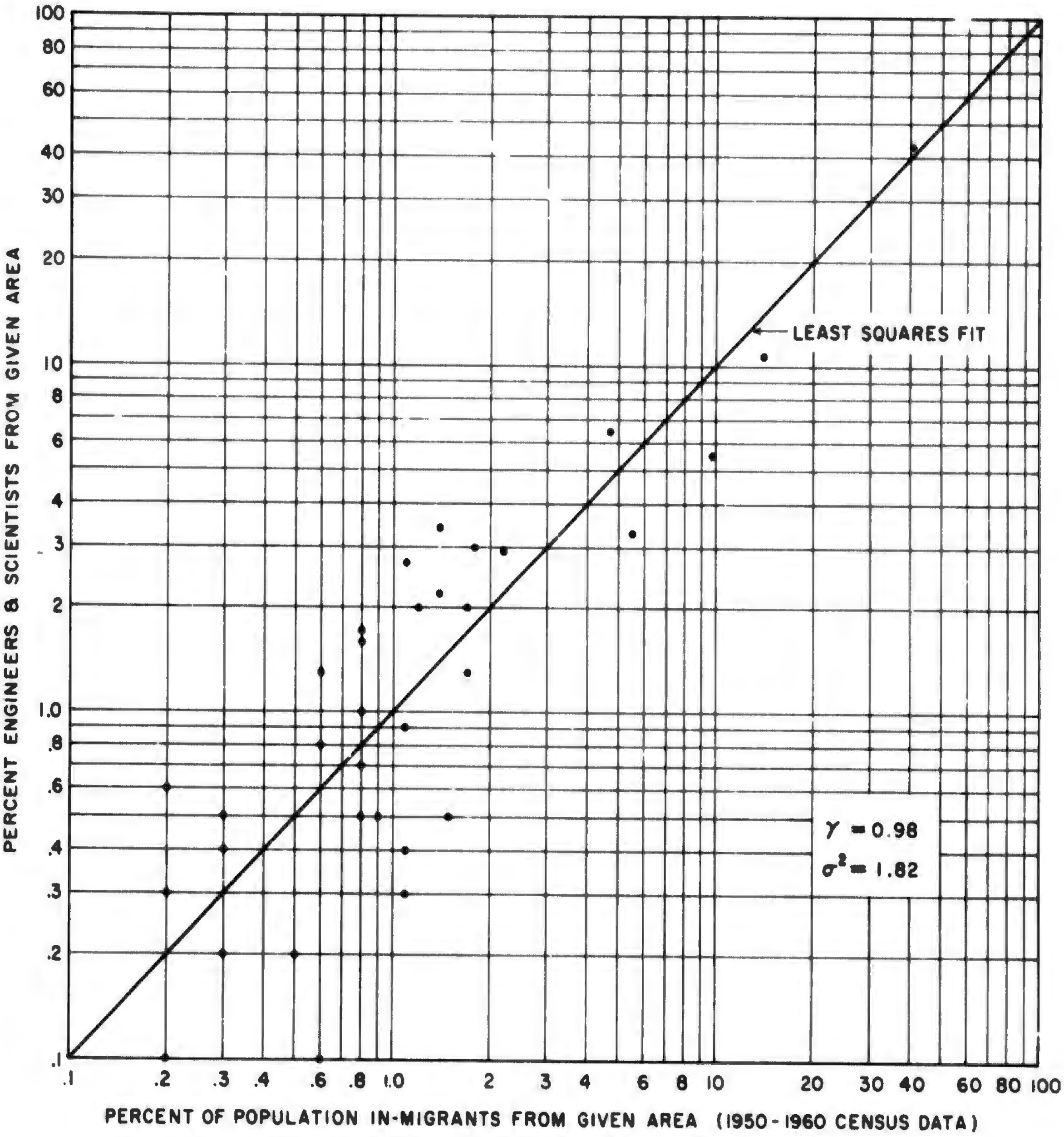


FIG. A-1 SCATTER DIAGRAM RELATING SOURCES OF ENGINEERS & SCIENTISTS TO SOURCES OF GENERAL POPULATION IN TWIN CITIES

Table A-1

COMPARISON OF SOURCE OF TWIN CITIES ENGINEERS AND SCIENTISTS WITH IN-MIGRATION OF GENERAL POPULATION

Geographical Subdivisions	Y Source of E/S's (%)	X Source of General Population (%)
Vermont, N.H., Maine	0.1%	0.2%
Massachusetts	1.3	0.6
Connecticut, R.I.	0.8	0.6
New York	3.0	1.8
New Jersey	1.6	0.8
Pennsylvania	1.0	0.8
Ohio	3.2	1.4
Indiana	2.7	1.1
Michigan	2.9	2.2
Wisconsin	5.5	9.9
Illinois	3.3	5.4
Minnesota	42.3	40.1*
Iowa, N.D., S.D., Neb.	10.8	14.0
Missouri	2.0	1.7
Kansas	0.9	1.1
Maryland, D.C., Del.	1.7	0.8
Virginia	0.5	0.8
W. Va., N.C., S.C., Ga.	0.3	1.1
Florida	0.5	0.9
Alabama	0.4	0.3
Miss., Ky., Tenn.	0.4	1.1
Arkansas, Oklahoma	0.7	0.8
Louisiana	0.2	0.3
Texas	1.3	1.7
California	6.5	4.7
Oregon	0.2	0.5
Washington	2.2	1.4
Montana, Wyo., Idaho, Nev.	0.5	1.5
Utah	0.3	0.2
Arizona	0.5	0.3
New Mexico	0.6	0.2
Colorado	2.0	1.2
Noncontiguous (Alaska, Hawaii)	0.1	0.6

* Movement to the SMSA from other parts of the state is the basis for this percent.

Source: Table 33, U.S. Census of Population, 1960, "Mobility for States and State Economic Areas," DC(2)2B, U.S. Dept. of Commerce, Bureau of Census.

Appendix B

HISTORY OF THE TWIN CITIES DEFENSE R&D INDUSTRY

BLANK PAGE

Appendix B

HISTORY OF THE TWIN CITIES DEFENSE R&D INDUSTRY

General Economic Development*

The coming of the railroads to the Twin Cities from the east and south in the 1860s and their later extension northward and westward set the stage for the rapid growth of the Twin Cities between 1880 and 1890. During this ten-year period, Twin Cities population increased from 88,000 to 298,000.

With the extension of the railroads into the newly opened plains of the Dakotas came a new method for milling the hard spring wheat grown in those regions. From the time the Minneapolis mills introduced the method in the late 1870s, it took less than ten years for Minneapolis to replace St. Louis as the country's number one flour milling city.

The demand for lumber by a rapidly growing United States resulted in the depletion of the New England, Michigan, and Wisconsin forests during the 1800s, so that by 1890, the nation's lumber industry centered in Minnesota. One of the major production centers was at St. Anthony Falls, around which the city of Minneapolis grew. Marketing and financial functions for Minnesota's lumber industry were centered in the Twin Cities and remained important for some time after the last of its sawmills closed in 1919.

The third principal economic activity which developed in the Twin Cities during the latter part of the 19th century was livestock marketing and meat packing. A combination of factors was influential--the livestock grazing regions of the Upper Midwest, the development of the Twin Cities as a regional railroad center, and the existence of a sizable local market.

Thus, by the close of the 1800s, the Twin Cities area--the largest population center northwest of Chicago--was well established as the trade and transportation center of the Upper Midwest, and one of the important centers of the country in the production of food products and lumber.

Since the turn of the century, the major changes in the economic structure of the Twin Cities have taken place in the manufacturing sector.

---

* Based on Twin Cities Metropolitan Planning Commission, Metropolitan Economic Study, Planning Report Number 5, 1960.

Since 1900, with the exception of a few years, 25% to 30% of the Twin Cities labor force has been engaged in manufacturing, but there has been considerable change in the composition of the labor force, by type of industry. Machinery manufacturing, which was just getting started, accounted for less than 10% of manufacturing value added in the Twin Cities in 1900. By 1960, this classification, which includes most of the Twin Cities defense-related industries, accounted for 20% of the value added and manufacturing employment in the Twin Cities. Lumber and wood products and food and related products have been declining in importance, particularly since World War II.

Three other manufacturing categories of a highly technical nature have gained considerable importance, primarily since 1939. These are chemicals, instruments, and ordnance. Combined, these industries now account for over 20% of value added by manufacturing, compared with less than 5% in 1900.

The beginning of the formation of the defense R&D industry base in the Twin Cities can be traced to a few companies formed around the turn of the century. Today, at least 142 companies in several industry classifications can be considered to make up the base of the Twin Cities defense industry. These 142 companies employ approximately 46,500 in the Twin Cities area and have a total production, both defense and nondefense, that has an annual sales value estimated at $890 million. Of this, half is estimated to be for the Department of Defense (DOD) and other federal agencies, particularly the National Aeronautics and Space Administration (NASA) and the Atomic Energy Commission (AEC). In addition to the defense-based industries, the Twin Cities have a considerable capability for R&D that is found in other industry categories such as the food, chemical, and other manufacturing industries.

In keeping with the defense R&D scope of this study, emphasis will be on Twin Cities industries having a significant portion of their business with the Department of Defense. Excluded are a number of companies with research activities but with relatively small sales to DOD in comparison with total sales. In this group are large companies such as Minnesota Mining and Manufacturing Company, Archer-Daniels-Midland Company, General Mills, Inc., Pillsbury Company, Bemis Company, Gould-National Batteries, Inc., and Cargill, Inc.; and medium-sized companies and divisions of companies, such as Economics Laboratory, Inc., Pako Corporation, and the Thermo-King Division of Westinghouse Electric Corporation.

Development of the Major Industries of the Twin Cities Defense R&D Base

The defense R&D industry includes five categories with selected supporting industries and services, and some individual establishments outside these categories. The five categories are:

Automatic Controls and Measuring Instruments
Medical and Surgical Devices and Apparatus

Electrical and Electronic Equipment
Computers and Data Processing Machines
Ordnance and Accessories

The establishments outside these categories are discussed as "Other High Technology Establishments" and "Supporting Industries and Services."

Automatic Controls and Measuring Instruments

The automatic controls and measuring instruments industry in the Twin Cities produces annual sales estimated to be in the range of $350 to $400 million, of which approximately one-half is government business, primarily for DOD, NASA, and AEC. Twenty-four companies, employing around 18,000 persons in the area, essentially constitute this Twin Cities industry. Although Honeywell accounts for most of the activity, the 23 smaller companies have a combined annual sales volume estimated at around $30 million and employ approximately 1,500 people. In the past five years, the estimated combined sales for the 23 smaller companies have increased 2-1/2 times with an approximate doubling of employment.

One of the oldest of the high technology companies in the Twin Cities is Honeywell Inc., which was founded in 1895 as the Minneapolis Heat Regulator Company. Its main product, the original Honeywell thermostat, "damper flapper" as it was called, was developed 80 years ago to control the flues on hand-fired coal furnaces. From this one device, Honeywell branched into many fields and is today considered to be the leading U.S. manufacturer of mechanical, pneumatic, and electrical temperature controls--a total of over 12,000 different devices.

The Minneapolis Heat Regulator Company was merged in 1927 with Honeywell Heating Specialties Company of Wabash, Illinois. The merger combined two successful privately owned companies into the publicly owned Minneapolis-Honeywell Regulator Company (M-H), which, it is reported, at one time controlled three-fourths of the market for household oil-burner controls.

The developments that accelerated M-H's transition into a high technology company included:

1. The acquisition in 1934 of the Brown Instrument Company, a Philadelphia manufacturer of industrial instruments. This merger was the first in a program of diversification for M-H and provided the base for later moves into industrial automation.

2. A decision in 1940 to develop an autopilot for bombers. A circuit for a heating control utilizing the principle of automatic feedback and compensation to provide a constant temperature also served to "trim" the controls of a bomber for its bomb run. M-H not only became the country's largest

producer of autopilots (some 30,000 in World War II) but also developed other military products. In 1949, Honeywell's Aeronautical Division was established, which provided the nucleus for later expansions into inertial guidance, missiles, and other advanced military technology.

3. The 1949 purchase of H. Belfield Company, a small Philadelphia producer of control valves. This was the first of a series of similar acquisitions that enabled Honeywell to add oscillographs, panel meters, and other laboratory test equipment to its product lines.

4. The decision in 1955 to enter the computer field. Originally, Honeywell joined with Raytheon to form Datamatic Corporation, but in 1957 Honeywell acquired Raytheon's 40% interest, dissolved the subsidiary, and continued the operation as a division.

In recent years, Honeywell's R&D expenditures, including both government-sponsored and company-sponsored work, have been around $100 million annually, or 14% of its net sales, which were $700 million in 1965. In the past five years, military and space products, including R&D, have accounted for approximately 30% of total Honeywell sales. About 20% of Honeywell employees are engaged in some form of production engineering and R&D activity.

Basic research is carried on at the Honeywell Research Center near Minneapolis employing 200--approximately 100 E/S's and 100 technicians--compared with a total of 35 employees in 1952. About half the Center's scientists and engineers have advanced degrees.

Of more than 50,000 Honeywell employees, about a third are employed in the Twin Cities. This fraction includes most of Honeywell's military production.

Several smaller companies also have had a part in the early development of the automatic control and measuring instrument industry in the Twin Cities. A listing of these companies and their dates of formation is given in Table B-1.

Medical and Surgical Devices and Apparatus

In the middle 1930s, the technology base in the Twin Cities was broadened by the establishment of a hearing aid and acoustical instrument industry that pioneered in such fields as miniaturization (the use of tiny vacuum tubes and batteries and subsequently transistors and printed circuits) and research in a variety of advanced techniques for possible use in audiometers, electronic stethoscopes, and other acoustical diagnostic instruments. As a consequence, the development of the Twin Cities overall electronics industrial capability was accelerated.

Table B-1

CHRONOLOGY OF COMPANY FORMATION:
AUTOMATIC CONTROLS AND MEASURING INSTRUMENTS

Date of Formation	Company	Comments
1885	Consolidated Temperature Controlling Co.	Successor company - Honeywell, Inc.
1912	D. L. Healy Co.	Successor company - Healy-Ruff Co.
1920	Meyer Governor Co.	
1922	Consolidated Electric Co.	
1930	Control Corp.	Subsidiary of Control Data Corp. since 1960
1934	Automatic Control Co.	
	Liquid Scale Gauge Co.	
1945	Instrument Control Co.	
1946	Pike and Hoff Co.	Successor company - Master Level Controls Co.
	White Manufacturing Co.	
1948	Volutrol Co.	Name changed to National Modulation Co. in 1954
1951	Schmitt Manufacturing Co.	Spin-off from Design Engineering Co.
	Research, Inc.	Spin-off from University of Minnesota Rosemount Aeronautical Laboratory (RAL)
1952	Magnetic Controls Co.	Spin-off from Honeywell, Inc.
	Fluidyne Engineering Corp.	Spin-off from RAL
1953	Ramsey Engineering Co.	Spin-off from Engineering Research Associates
1955	Geophysical Specialties Co.	Purchased by Minnetech Laboratories, Inc. in 1964
1956	Rosemount Engineering Co.	Spin-off from RAL
	Minco Products, Inc.	Spin-off from Honeywell Aeronautical Div.
1960	Electro-Craft Corp.	Spin-off from Honeywell Aeronautical Div.; subsidiary of Napco Industries since 1963
	Superior Electronics Co.	Filed bankruptcy in 1963
	Systematics, Inc.	
	Thermo-Systems, Inc.	Formed by University of Minnesota personnel
1961	Electro-Solid Controls, Inc.	Spin-off from General Electronic Controls, Inc.; moved to Dayton, Ohio in 1963
	Industrial Kinetics, Inc.	
	Minnetech Labs, Inc.	
	Programmed and Remote Systems Corp.	Spin-off from General Mills Mechanical Div.
	Telostat Corp.	Sold to Bachrach Instrument Co., Pittsburgh in 1962

Source: Stanford Research Institute.

The two pioneers in the Twin Cities acoustical aids and instruments industry were Leland A. Watson, founder of Maico Electronics, Inc. (originally called Medical Acoustic Instruments Company) in 1934, and Allen Hempel, founder of Telex, Inc., in 1937.

Mr. Watson, a 1929 graduate of the University of Minnesota and a Rhodes Scholar, although not an M.D. himself, came from a medical family. His father was a Minneapolis ear specialist, and his brother was a member of the University of Minnesota medical staff. While a Rhodes Scholar, Lee Watson became interested in the tiny vacuum tubes used in hearing aids being developed in England. Upon his return to Minneapolis, conversations with his father and brother convinced him of the need for a precision instrument to test hearing. The audiometer developed by Maico is reported to be the first accepted by the American Medical Association. For the ten-year period 1935 to 1945, Maico is credited with producing 90% of all audiometers sold in the United States. Other Maico developments in the late 1930s and early 1940s included the electronic stethoscope and small hearing aids using tiny English vacuum tubes.

Maico filled more than 90% of World War II military requirements for instruments to test and rate hearing. During the 1950s, Maico continued to broaden its electronics base by developing such products as: auditory training equipment for teaching the deaf; lie detectors; automatic headlight dimmers; high-fidelity magnetic tape recording heads; feed rate meters for machine tools; and servo systems employing magnetic recording on stainless steel tape for the automatic control of lathes. In the late 1950s, Maico received several government contracts totaling more than $1 million for the research and development of electronic countermeasures, supersonic communication systems, data processing and display systems, magnetic recording systems, transistorized power converter units, and radiation measuring equipment.

During this same period, the other Twin Cities hearing aid pioneer, Allen Hempel, was developing Telex, Inc. Hempel has been credited with developing the first wearable vacuum tube hearing aid. During World War II, Telex produced more than 120,000 communication headsets and 250,000 receiver units for the Signal Corps. Employing the knowledge and experience obtained from its military contracts, Telex expanded into other electronic products--pillow speakers for hospital patients; group hearing systems; radio speakers with a time control device for turning a radio on or off at a predesignated time; and electronic components.

In the early 1940s, four other hearing aid companies were established in the Twin Cities. These are listed in Table B-2 with other Twin Cities companies that were formed to participate in the medical and surgical devices and apparatus industry. By 1947, Twin Cities companies accounted for 20% of the U.S. hearing aid market, had combined annual sales in excess of $10 million, and employed about 650 persons including some 30 engineers and several hundred technicians. Thus a substantial manpower pool of technical skills was established that was to contribute to the further development of an electronics industry. The Twin Cities area, with at least 12 companies producing hearing aids and components, continues today as an important factor in the U.S. hearing aid industry.

Table B-2

CHRONOLOGY OF COMPANY FORMATION:
MEDICAL AND SURGICAL DEVICES AND APPARATUS

Date of Formation	Company	Comments
1934	Medical Acoustic Instruments Co. (Maico)	Subsidiary of Shaeffer Pen Co. since 1957
1937	Telex, Inc.	Acquired by new management in 1959
1940-42	Aladdin Hearing Aid Co.	Now Johnston Hearing Aid & Electronics
	Microtone Co.	*
	Qualitone Hearing Aid Co.	Division of Seeburg Corp. since 1961
	Vari Corp.	Subsequently Vari Electronics, Inc.
1943	Calectron, Inc.	
1946	American Sound Products, Inc.	Operated in Chicago before moving to Minneapolis in 1957
1948	Dahlberg Co. (now Dahlberg Electronics, Inc.)	Became subsidiary of Motorola, Inc. in 1959, and was repurchased by Dahlberg in 1963
1949	Medtronic, Inc.	Reported to be largest producer of cardiac pacemakers; company formed by a University of Minnesota man upon graduation
1955	Busse Electronics	Spin-off from Telex, Inc.
1956	Wilbrecht Electronics	Spin-off from Dahlberg Co.
1957	Swenko Research and Development, Inc.	Gastric cooling and freezing machines for nonsurgical treatment of ulcers
1958	Prescription Hearing Aid Co.	*
1960	United Medical Products Co.	*
	Whitehall Electronics Corp.	Spin-off from Univac; acquired by Electro-Science Investors, Inc., Dallas, Texas in 1962
	Electronic Medical Systems, Inc.	Spin-off from Univac; acquired by Medtronic, Inc. in 1962
1961	Theratron Corp.	Spin-off from Univac *
	International Medical Equipment Co.	Formed by personnel from Ancker Hospital *
	Biotronics, Inc.	Spin-off from RAL
1962	Electronic Development Co.	Spin-off from Minnesota Electronic Co.
1963	W. R. Medical Electronics	Spin-off from Minnesota Mining and Mfg. Co.
1965	Strato Equipment Co.	Subsidiary of Partmaster, Inc.

* Reported to be no longer in operation.

Source: Stanford Research Institute.

Despite an impressive beginning with acoustic products and instruments as a base, the Twin Cities medical and surgical equipment industry is not large. Combined sales of 16 companies are approximately $15 million, and employment totals about 700. This is less than the combined sales volume and employment for these companies in 1960. (However, a large medical and surgical equipment industry has not developed anywhere in the country.)

At least 10 companies were formed in the Twin Cities in the early 1960s to participate in the medical and surgical equipment field. With one exception, these companies were formed by personnel of local establishments. Only two of them are known to be still in operation in the Twin Cities under their own name. The companies that have gone out of existence had these things in common--their principal source of capital was from public stock issues at the time of company formation, and they had little or no operating experience prior to the stock issue.

Electrical and Electronic Equipment

In addition to the contribution made by the hearing aid industry, companies producing industrial electrical equipment and consumer entertainment items had a part in the early development of the Twin Cities as an electronics center.

Companies in the industrial electrical equipment field began forming in the Twin Cities before World War I. Today, 12 companies largely account for the approximately $75 million annual sales volume of industrial electrical equipment produced in the Twin Cities area. Employment totals around 2,75[illegible] Compared with 1960, sales and employment figures have increased ab[illegible]5%. Of the 12 companies, four are known to have defense business. [illegible]se companies are listed in Table B-3.

The consumer entertainment electronics industry in the Twin Cities began in the 1930s, and today consists primarily of 11 companies producing radio and television sets, stereo and hi-fi equipment, tape recorders, and subassemblies for these products. These companies and their dates of formation are listed in Table B-4. Annual sales volume of the industry is approximately $12 million produced by about 900 employees, which is up from approximately $10 million in sales and 700 employees in 1960.

Other types of electronic equipment manufactured in the Twin Cities include test equipment, teaching aids, bank protective equipment, and electric chimes. Four of these companies have combined annual sales of approximately $2 million produced by more than 200 employees. At least nine other companies, formed between 1959 and 1961 to produce a variety of electric equipment, are reported to be no longer in operation in the Twin Cities. A listing of those and surviving companies producing miscellaneous electronic equipment is given in Table B-5.

The Twin Cities electrical and electronic component industry is comprised primarily of 24 companies having approximately 2,500 employees and

Table B-3

CHRONOLOGY OF COMPANY FORMATION: INDUSTRIAL ELECTRICAL EQUIPMENT

Date of Formation	Company	Comments
1914	Hyser Electrical Mfg. Co.	
1918	Marquette Corp.	
1921	Electric Machinery Mfg.Co.	Division of Worthington Corp.since 1944
1922	States Electric Mfg. Co.	
n.a.*	D. W. Onan and Sons, Inc.	Division of Studebaker Corp.since 1960
n.a.	Western Electric Co.	
1941	Terado Corp.	
1945	Hoffman Engineering Corp.	Acquired by Federal Cartridge Corp.
1946	Oscar A. Schott Co.	
1949	Engineered Specialties	
1950	American Monarch Corp.	
1961	Minneapolis Scientific Controls	Spin-off from Univac

* n.a. = not available.

Table B-4

CHRONOLOGY OF COMPANY FORMATION: CONSUMER ELECTRONICS

Date of Formation	Company	Comments
Pre-1934	Karadio, Inc.	Became: Satchell-Carlson, Inc.
	American Television and Radio Company	Became: ATR Electronics in 1961
1934	Satchell-Carlson, Inc.	TV and radio receivers, record players
1946	Wright Zimmerman	Speakers
1947	Minneapolis Speaker Co.	Speakers
1951	Midwest Television Systems, Inc.	Remote control TV receivers
1952	Callatron Mfg. Co.	Manufactured TV sets until 1962; now repairs TV sets
1953	Nortronics Co.	Stereo components
1955	Viking of Minneapolis, Inc.	Tape recorders
1957	K and N Electronics Co.	Merged with Miratel, Inc. in 1961
1961	Miratel Electronics, Inc.	Citizens band radio, closed circuit TV monitors
	Peptone Electronics, Inc.	Car radios; division of Miniature Instruments, Inc.
	Unitronics, Inc.	Stereo hi-fi

Source: Stanford Research Institute.

Table B-5

CHRONOLOGY OF COMPANY FORMATION:
MISCELLANEOUS ELECTRICAL AND ELECTRONIC EQUIPMENT

Date of Formation	Company	Comments
1947	Protection Equipment Co.	Bank protective equipment; now Peco-McClintock Corporation
1953	Graham Research, Inc.	Test equipment
1957	Jansen Electronic Mfg. Co.	Teaching aids; spin-off from Minnesota Mining and Mfg. Co.
	Nichols Electronics	Electric chimes and tube testers
1959	General Electronic Control, Inc.	Communication systems and test equipment; moved to Texas in 1963
	Leyghton Paige Corp.	Test equipment*
	Standard Electronics Corp.	Water oxidizers and battery activators*
1960	Electro-Nuclear Systems Corp.	Automation equipment; spin-off from Maico Electronics*
	Northern Electronics, Inc.	Starting devices and safety equipment*
	Flo-tronics	Spin-off from Univac
1961	Controldyne, Inc.	Test and training equipment*
	Electro-Educational Developments, Inc.	Teaching aids*
	Motec Electronics	Miscellaneous electronic equipment*
	Nucleonic Controls Corp.	Utility pole rot-detectors*

* Reported to be no longer in operation.

annual sales of around $40 million. Combined sales and employment of these companies have more than doubled since 1960. Most of these companies produce components used in equipment sold to defense agencies. Some of these companies, now producing printed circuits and other electronic components, were formed in the early 1900s. These and other companies in the Twin Cities electrical and electronic component industry are listed in Table B-6. Of the 22 companies formed since 1950, 19 of these, or their successors, continue to operate in the Twin Cities.

Table B-6

CHRONOLOGY OF COMPANY FORMATION: ELECTRICAL AND ELECTRONIC COMPONENTS

Date of Formation	Company	Comments
1900	Bureau of Engraving, Inc.	Printed circuits
1902	Buckbee - Mears Co.	Electronic components
1920	Nu-Line Industries, Inc.	Electrical connectors
1944	A. B. McMahon Co.	A/D converters, timing devices
	Melco Products, Inc.	Transformers
1950	Reuter, Inc.	Electromechanical components
	Washington Scientific Industries, Inc.	Electromechanical components; spin-off from General Mills, Inc.
1952	Twin City Metalseal Corp.	Now Mekco Inc.; housings and incapsulation (potting) for components
1954	Gooley and Barth	Now the Twin City Etching Co.; printed circuits
1956	Printed Circuits, Inc.	Spin-off from Twin City Metalseal Corp.
1957	Ault Magnetics, Inc.	Pulse transformers, coils, power supplies
	Electramatics, Inc.	Wire harness and cable assembly
	Midwest Circuits, Inc.	Printed circuits; spin-off from Univac; became Fabri-Tek, Inc.
	Fabri-Tek, Inc.	Computer memories
	Transistor Electronics	Spin-off from Univac
*	Beck's, Inc.	Printed circuits; acquired by Control Data Corp. in 1963
*	Robert E. Harvey Co.	Relay components †
*	Dayton Rogers Photo Mechanical Co.	Printed circuits; acquired by John Weston Photo Mechanical Co.
1958	Tronics Corp.	Indexing motor for computers†
1959	General Magnetics, Inc.	Magnetic components; spin-off from Univac
1960	Mag-Con Engineering	Transformers and magnetic devices
	National Connector Corp.	Spin-off from Magnetic Controls Co. and General Magnetics, Inc.
1961	Action Labs, Inc.	Cables, timers, and printed circuits
	Micro-Sonic Industries	Accelerometers†
1962	Precision Electrical Mfg. Co.	Wire-wound components; spin-off from General Mills, Inc.
	Universal Circuits, Inc.	Printed circuits
1963	Cepco	Power supplies, pulse transformers, coils, and chokes
1964	Astro Tech, Inc.	Electromechanical assemblies

* Formed prior to 1958.
† Reported to be no longer in operation.

Source: Stanford Research Institute.

Computers and Data Processing Machines

The computer industry in this country got its start 20 years ago with the introduction in 1944 of the stored program computer, the Mark I, developed at Harvard. This was followed in 1946 by the development of the first electronic computer, ENIAC, at the Moore School of Electrical Engineering of the University of Pennsylvania.

The Twin Cities entered the computer scene in 1946 with the formation of a new company, Engineering Research Associates (ERA). The growth of the computer and data processing industry in the Twin Cities compared to growth in the United States is shown in Figure B-1, which compares Twin Cities and U.S. employment in the industry. Today, the Twin Cities industry has ten establishments that employ about 13,000 persons producing annual sales of more than $250 million. It is estimated that more than 50% of these sales are to agencies of the federal government.

The nucleus of ERA at the time of incorporation in 1946 consisted of 40 scientists, engineers, and technicians who had been associated, both as reserve officers and civilians, during World War II with three Navy organizations performing communications, computing, and related research. The organizations involved were the Naval Communications Supplementary Activity (Chief of Naval Operations) in Washington, D.C.; the Naval Computing Machine Laboratory (Bureau of Ships) stationed at the National Cash Register Company in Dayton, Ohio; and the Naval Ordnance Laboratory (Bureau of Ordnance) in Washington, D.C.

The Naval Communications Supplementary Activity performed research in three major areas--conventional communications equipment, special communications equipment, and mathematical techniques. The Naval Computing Machine Laboratory built hardware for some of the special communications equipment used by the Washington communications group. The Naval Ordnance Laboratory came into the picture because of a previous professor-student relationship of employees within the two Washington organizations.

After the cessation of hostilities in 1945, officers* of the first two groups discussed the possibility of keeping intact some of the engineering talent brought together during the war years--by forming a company to continue work on the application of their research findings to both military and commercial equipment. Initial organization plans were made, and a preliminary contact of key technical personnel indicated a favorable response. After organization authorization was received, personnel in the three Navy organizations were contacted to determine their interest in joining a new company if it were to be established. As a consequence, around 50 military and civilian government employees signed up.

---

* These were identified as Admiral Joseph Wenger, in charge of Naval Communications Research, and Captain Howard T. Engstrom, Chief of the Naval Communications Supplementary Activity, in an article by T. A. Wise in the March 1966 issue of Fortune.

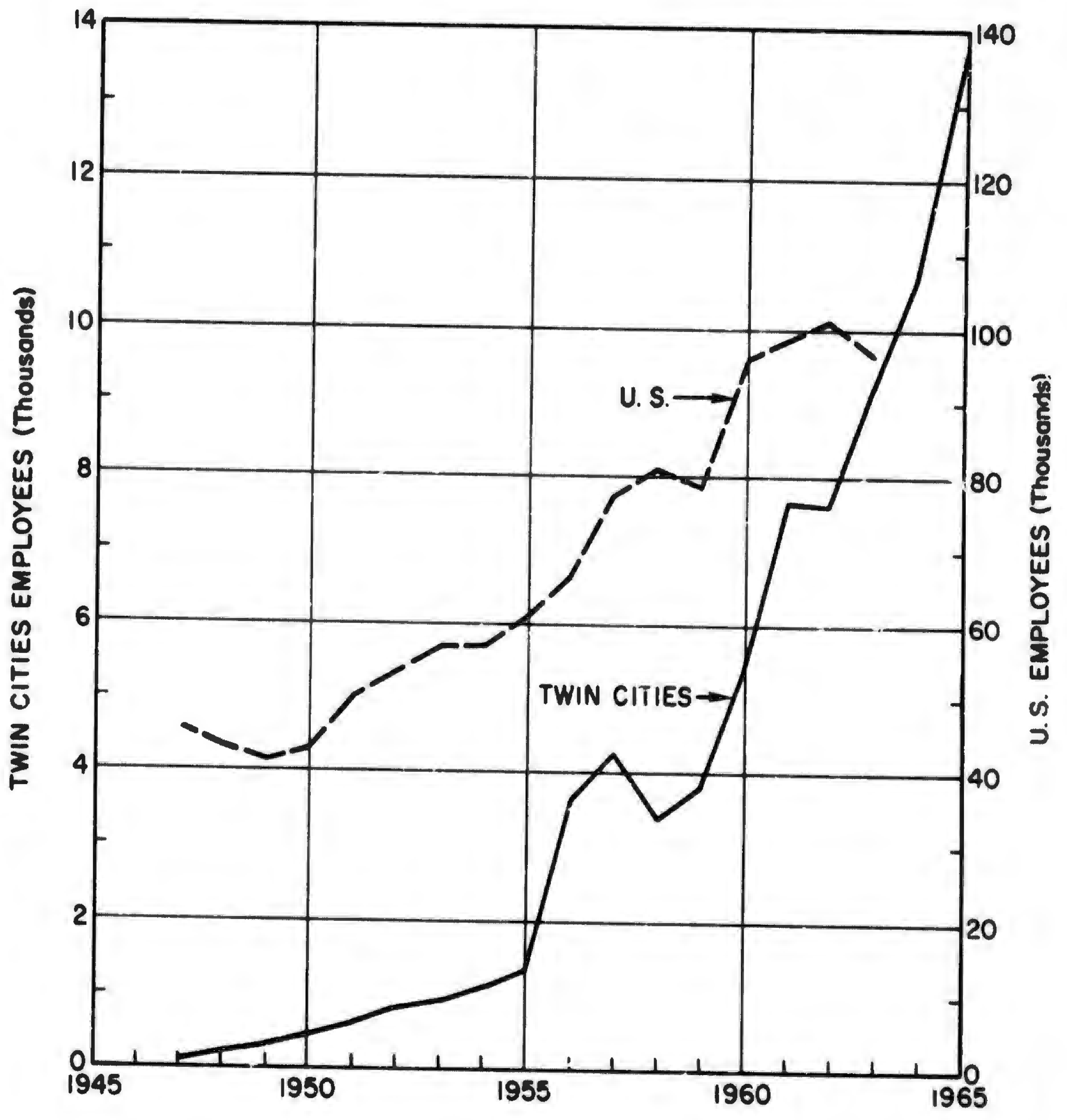


FIG. B-I EMPLOYMENT IN TWIN CITIES COMPUTER INDUSTRY AND U.S. COMPUTING AND RELATED MACHINES INDUSTRY (SIC 3571)

Source: U. S. Dept of Commerce and Composite Employment Data of Fourteen Twin Cities Computer-Oriented Companies.

Why was St. Paul chosen as a location for ERA? Although two of the men happened to be from the Twin Cities, they were not officers of the newly formed company. The choice of locations hinged largely on the availability of financing. Though there were adequate facilities available in a number of cities, risk capital was scarce for an organization such as this.

Ultimately, the Navy group teamed up with John E. Parker, a partner then in the brokerage firm of Auchincloss, Parker and Redpath, and also President of the Northwest Aeronautical Corporation (NAC), producers of Air Force gliders during World War II. Although NAC had only one engineer, they had a plant and a supporting business organization including personnel, accounting, and purchasing functions. Further, Mr. Parker had a good record as a supplier of military equipment and some risk capital. The amount of "seed" money responsible for the establishment of a computer industry in the Twin Cities in 1946 was only $10,000.*

ERA was established with Mr. Parker as President, and ex-Navy personnel filling other key positions--three as vice presidents, and two as directors of technical activities. Mr. Parker held 50% of the capital stock, and the other 50% was distributed between key technical personnel at a price of ten cents per share. The sources of the original group of ERA were:

Previous Organization	Number of Persons
Naval Communications Supplementary Activity	39
Naval Computing Machine Laboratory	2
Naval Ordnance Laboratory	6
Other	5

As personnel were released from active duty, it was the responsibility of Navy Reserve Lieutenant Commander William Norris, chief aide to Captain Engstrom, to relocate them in St. Paul. Of the original ERA group, 70% were professional engineers and scientists, 25% were technical support personnel, and the remaining 5% were administrative personnel.

Because ERA did not have any operating history, its first government business--for specialized communication equipment and spare parts--took the form of a subcontract from NAC, in support of a prime contract for the equipment from the Bureau of Ships. Subsequently, ERA became the prime contractor for the equipment.

---

* Computation based upon 100,000 shares at ten cents per share.

Thus, the Twin Cities, through ERA, became one of the first communities in the country to become involved in the new technology of computers at a time when the only two other principal sources of computer "know-how" during the years 1946-52 were the Eckert-Mauchly group in Philadelphia and a laboratory group at Harvard University in Boston.

Besides carrying out the large instrumentation program for the Army Corps of Engineers underground explosion tests in Utah in 1951, ERA made several major contributions to computer technology during its six-year existence. One of its engineers holds a number of key patents relating to magnetic memory drums. Subsequently, ERA licensed IBM to use the memory drum in their first fast computer marketed--the 650 series.

ERA's first important computer development was the ERA-1101, a high-speed, electronic special purpose computer, originally built for the Navy. By 1951, ERA had established a reputation in the computer field, and at that time five of ERA's key engineers were hired by Remington Rand, Inc., to staff its Laboratory for Advanced Research at Norwalk, Conn. These same engineers were influential in sparking Remington Rand's interest in acquiring ERA.

A difference of opinion among ERA management as to the advisability of a merger with Remington Rand has been reported. Several of the ERA associates preferred the freedom and flexibility of being independent. President Parker believed that merger with a larger company was essential to obtain the financing necessary to survive in the computer field.

ERA merged with Remington Rand in 1952 shortly after Remington Rand acquired Eckert-Mauchly. At the time, just six years after being founded, ERA's annual sales were about $8 million and employment totaled 800. ERA's Parker, Engstrom, and Norris became vice presidents of Remington Rand. The acquisition of Eckert-Mauchly and ERA, combined with Remington Rand's Laboratory for Advanced Research, made them dominant (practically a monopoly position) in 1952. Remington Rand, Inc. merged with Sperry Corporation in 1955 to form Sperry Rand Corporation, at which time all electronic computer and tabulating machine operations of the combined operations were consolidated into the Univac Division. The operations affected were the ERA Division of Remington Rand in the Twin Cities, the Eckert-Mauchly Division at Philadelphia, the Laboratory for Advanced Research at Norwalk, Conn., and the Tabulating Division of Remington Rand at New York City.

From the time of acquisition of ERA in 1952 to establishment of the Univac Division in 1955, Remington Rand's ERA Division increased from 800 employees to 1,150. As indicated in Figure B-1, growth of the Twin Cities Univac operations continued at a rapid rate. By the middle of 1957, the total number of Twin Cities Univac employees exceeded 4,000.

Sperry Rand's financial decisions were made from corporate headquarters in New York. With "absentee" corporate management, Univac Division had difficulty getting approval of its plans, and to add to the problem, the former ERA engineers were at odds with Eckert-Mauchly personnel. Within a few years, Univac's lead in the computer field was lost to IBM.

In August 1957, four former members of the predecessor ERA left Univac and organized Control Data Corporation (CD). The founders came from managerial positions with Univac. Within a few months, about 15 people from the predecessor ERA (1946-1952) had come to CD, most of them via Univac.

As is often the case when key employees leave a company to form their own firm, Sperry Rand filed an injunction suit in April 1958 against CD for "use of inventions, ideas, and technical data in which Sperry Rand has a proprietary right as the result of many years of creative effort and expenditure of millions of dollars." This case was settled out of court in November 1962, more than four years later. The settlement decree prohibits the use of nine Sperry Rand trade secrets unless CD pays SR 5% of the manufacturing costs of parts requiring the trade secrets. The settlement decree also stated that Sperry Rand would not interfere with CD's use of seven trade secrets in its performance of federal government contracts. When these seven trade secrets would be used by CD in nongovernment production, the 5% fee to Sperry Rand would apply.

In November 1957, within three months after organization, CD made the first of 21 acquisitions of companies, divisions, and products spanning the eight-year period ending July 31, 1965. CD's first acquisition, Cedar Engineering, was at least three times the size of CD. Cedar Engineering, a Twin Cities company established in 1952, had achieved annual sales of around $2 million, and employed 165 people in the production of instruments and control devices for the Department of Defense and various aerospace companies. A total of 1,266,030 shares of CD common stock were issued for the 17 acquisitions about which published information was obtained. This is equivalent to 17% of the total shares of CD common stock outstanding in mid-1965.

CD's policy of growth by acquisition has been summarized by its President, William C. Norris, as follows:

> "We're not finished by any means. There will definitely be more. There are two reasons why we haven't tried to expand entirely from within. First, we didn't have the time; we had to move quickly to stay competitive. Second, we didn't have enough cash to do it internally, and the companies we have acquired were all willing to take stock. Most of them were in the struggling stages that all small, young companies encounter."*

During late 1957 and 1958, the future of CD was questionable. There was a shortage of working capital and all salaries were cut in half so that the 1604 computer could be completed. When finally developed, the 1604, the first solid state computer to hit the commercial market (first delivered in January 1960), justified all CD's efforts.

---

* Forbes Magazine, Sept. 15, 1965.

Below is a summary of CD's sales and profitability from inception through fiscal year ending June 30, 1965.

Fiscal Year Ending June 30	Total Revenues*	Net Income (Loss)*
	(millions of dollars)	
1958	$ 0.6	($0.1)
1959	4.6	0.3
1960	9.7	0.6
1961	19.8	0.8
1962	41.0	1.5
1963	63.1	3.1
1964	121.4	6.1
1965	160.5	7.9

Following ERA, Univac, and Control Data, the fourth Twin Cities company to announce its entry in the computer field was the Mechanical Division of General Mills, Inc. Announcement and display of its medium sized computer, Model 2003, was made in March 1960. Also offered was a 2001 computer, a smaller portable version of the 2003, and planning was under way for a complete line of computers, including a larger 2005 model.

In announcing its line of computers, General Mills could not be strictly considered a newcomer to the field. In fulfilling various military contracts through the years, General Mills gradually developed a computer capability. As an example, for its remote-controlled mechanical arms, an analog controller was developed to provide programmed manipulation for operations requiring a repetition of motions. Concurrent with the development of a capability for missile guidance, fire control, bombing, and navigation systems which required computers, General Mills also acquired a capability for developing computers. General Mills officially recognized this capability by establishing the Digital Computer Laboratory in its Mechanical Division in 1957.

The number of General Mills computers produced was never large. Most, if not all, deliveries were to military or government agencies. In October 1961, General Mills announced that a computer had been delivered to NASA's Goddard Space Flight Center and that four more had been ordered by NASA for ground stations in its orbiting astronomical observatory program. In 1963, General Mills withdrew from the computor field.

At the time of the General Mills announcement of its entry in the computer field, statements attributed to two executives of Twin Cities

* As given in annual reports for the respective periods.

companies were prophetic of the increased rate of new technological company formation which was to follow.

President Norris of CD was quoted as saying:

> "If General Mills is serious about entering the computer field, it will increase the scope of electronics activity here tremendously. This in itself will lead to the formation of many more small companies and tend to attract scientists here from other areas."*

In a similar vein, Dr. Finn J. Larsen, Vice President of Honeywell Research at the time, was quoted:

> "The General Mills decision means that this area will have higher scientific standards. It means that all companies here will be able to attract more scientists and better qualified men. It means that the stronger companies will continue to spawn many new small companies--probably at a stepped-up pace."*

One year after General Mills announced its entry in the computer field, Advanced Scientific Instruments, Inc. (ASI), was incorporated and became the fifth Twin Cities company to produce complete computer systems. The two salaried officers and founders of ASI had been previously associated with the Mechanical Division of General Mills. The same individuals credited with the development of the General Mills Model 2003 computer were associated with the development of the ASI line of computers.

Because of the success of Control Data in getting established and because of the computer engineering and marketing backgrounds of the two "operating" founders of ASI, initial financing was not too difficult. The two principals found a number of people who were interested in providing financial backing, and so it became a matter of selecting the best group.

At the time of incorporation in March 1961, ASI possessed paid-in capital of $112,000 received from the sale of 112,000 shares of common stock at $1.00 per share to the incorporators. Between March and August 1961, an additional $20,000 was obtained from 20,000 option shares exercised at $1.00 per share by the incorporators. In August 1961, ASI offered and sold to the public 875,000 shares of common stock at $1.15, the 15 cents representing commission to the underwriter. This public offering compares with Control Data's first public issue in 1957 of 600,000 shares of common stock at $1.00.

Within seven months after incorporation, ASI had a computer prototype in the advanced stages of assembly. Making up the family of ASI general purpose digital computers were the 210, the 420, and the Advance II, priced as follows, depending upon size and capability of the memory system and other equipment: ASI 210--$115,000 to $200,000; ASI 420--$400,000 to $600,000; and Advance II--$800,000 to $1,000,000.

---

* Minneapolis Star, April 5, 1960.

In November 1961, the first order of an ASI 210 computer was received from NASA and delivered within five months. The second contract for a 210 came in February 1962 from the AEC's Argonne National Laboratory. An order from Chance Vought Corporation for the third 210 was also received in 1962. It is reported that all of these orders were for lease of the equipment rather than for outright sale.

During the first year of operation, ASI employment increased to 75. From the offering price of $1.15 per share, the stock reached a high of $8.00 in December 1961. The subsequent progress of ASI is perhaps reflected in the per share price range of the company's stock:

	High	Low	Dec. 17
1962	$6.25 (Jan.)	$1.12-1/2 (July)	$1.75

By January 1963, the ASI stockholders became aware of the company's need for additional capital or the alternative--a temporary suspension of operations. At that time (January 21, 1963), the price of the ASI common stock was around 25 cents a share. A financial statement sent to stockholders showed a net loss of $346,565 as of January 27, and the financial problems of the company were attributed to the trend for leasing rather than selling equipment outright. In February, ASI stockholders approved the sale of the company to Electro-Mechanical Research, Inc., Sarasota, Florida, a wholly owned subsidiary of Schlumberger, Ltd., of Houston for $825,000 cash. ASI now operates in Minneapolis as a division of Electro-Mechanical Research. Employment at the end of 1964 was about 160.

Another strong contender in the competitive computer field is Honeywell, Inc., but its Electronic Data Processing Division is located in Massachusetts. However, Honeywell's Central Research Center near Minneapolis plays an important role in the computer field through its basic and applied research in such related fields as magnetic materials, microcircuitry, solid state physics, ceramics, and computer memories.

The other "big name" associated with the growth of Minnesota's data processing industry is IBM, which established a plant at Rochester, Minnesota, in 1956, but its location 80 miles away places it outside the Twin Cities metropolitan area. The Rochester operation, which is a part of IBM's General Product Division, produces peripheral equipment for data processing. Initial production of punched card collators was followed by card reproducers, interpreters, readers, and punches, as well as banking equipment. Counting model variations, more than 25 different products have been manufactured at the Minnesota plant. Rochester has its own Product Development Laboratory. In early 1962, production began on the IBM 188 Collator, a punched card collator with a core memory, the first "all-Rochester" product to be developed from the drawing board stage. Because of its location in the medically famous city, IBM Rochester formed a medical applications engineering group to work with the Mayo Clinic doctors to develop data processing equipment having medical application. IBM employment in Minnesota exceeds 3,000, practically all of it in Rochester.

Four companies have been formed in the Twin Cities since 1958 to develop amd manufacture peripheral equipment for computer systems--Data Display, Inc., Diginamics Corporation, Data Products Corporation, and Probe, Inc. Also, the Mass Memory Division of Anelex Corporation has operated a branch operation in Minneapolis. This segment of the Twin Cities computer industry accounts for sales of approximately $7 million produced by around 350 employees.

Data Display, Inc. was formed in 1958 by engineers from the Univac Division of Sperry Rand to produce visual display equipment for computer systems. Control Data Corporation was Data Display's first customer and continued to be an important customer until January 1965, when Data Display became a wholly owned subsidiary of Control Data. At the time of acquisition, Data Display's employment was over 200, and annual sales were $3-4 million.

With the development of computer "hardware," the formation of computer "software" (data processing services) companies in the Twin Cities followed: Scientific Computers, Inc. (1959); Data Management, Inc. and Data Systems, Inc. (1961); Aries Corporation (1962); and International Analysts, Inc. (1966). All except Data Systems, Inc. continue to operate. Three of the surviving companies had a combined employment of about 100 and sales of over $2 million for 1964.

The chronology of company formation in the computer and related field is shown in Table B-7.

Ordnance and Accessories

The principal producers of ordnance and accessory items in the Twin Cities are the Federal Cartridge Corporation, the Northern Ordnance Division of FMC Corporation, and the Ordnance Division of Honeywell, Inc. These three establishments are estimated to have combined sales of approximately $75 million, produced by about 5,500 employees. The bulk of production is for military agencies.

The predecessor company of the Federal Cartridge Corporation dates back to World War I. During World War II, Federal Cartridge and a prime contractor operated the federal government's Twin Cities Arsenal. During the Korean conflict in the 1950s, Federal Cartridge was called upon by the U.S. government to reactivate the arsenal. Under the contract, Federal Cartridge operated the plant as a private cohtractor on a cost-plus-fixed-fee basis similar to its arrangement during World War II. After the Korean conflict, the plant was again placed on a standby status, as it had been after World War II, until the Vietnam conflict required its reactivation in 1965. Federal Cartridge also has its own plant and manufactures a complete line of small arms ammunition.

Table B-7

CHRONOLOGY OF COMPANY FORMATION:
COMPUTERS AND DATA PROCESSING

Date of Formation	Company	Comments
	Computers	
1946	Engineering Research Associates (ERA)	Formed by ex-Navy personnel
1952	Univac Div., Sperry Rand Corp.	Acquired ERA which became ERA Div. of Remington Rand Corp., and later, Univac Div. of Sperry Rand Corp. (1955)
1957	Control Data Corp.	Spin-off from Univac
1960*	Mechanical Div. General Mills, Inc.	Withdrew from computer field in 1963
1961	Advanced Scientific Instruments (Div. of Electro-Mechanical Research, Inc.)	Spin-off from General Mills Mechanical Div.
	Other Data Processing Equipment	
1958	Data Display, Inc.	Visual display equipment for computer systems; spin-off from Univac; subsidiary of Control Data Corp. since 1965
1961	Diginamics Corp.	Analog to digital data converters; spin-off from Honeywell Aeronautical Div.; assets sold to Minnesota Mining and Mfg. Co. in 1963
1961	Data Products Corp.	Computer memories and printers; spin-off from Telex, Inc.
1964	Probe, Inc.	R&D on peripheral equipment for computers; spin-off from Midwest Technical Corp.
	Computer Services	
1959	Scientific Computers, Inc.	Formed by University of Minnesota research personnel
1961	Data Management, Inc.	Spin-off from Univac
1961	Data Systems, Inc.	No longer operating
1962	Aries Corp.	Spin-off from Univac
1966	International Analysts, Inc.	Spin-off from Aries Corp.

* Date of introducing computer.

Source: Stanford Research Institute.

Northern Ordnance, Inc. was organized in 1942 as a wholly owned subsidiary of Northern Pump Company to produce equipment for the Navy. During World War II, principal production was hydraulic gun mounts for the Navy. The company's developments include an automatic rapid-fire anti-aircraft gun mount. During the 1950s, Northern Ordnance developed and produced for the U.S. Navy the world's first automatic missile stowage, handling, and launching system for ships. These systems have also been supplied to navies of other countries, including Australia, France, Italy, Japan, the Netherlands, and West Germany. More recent work at Northern Ordnance includes the design and manufacture of a new version of the dual purpose (air and surface) 5-inch gun mounts developed by Northern Ordnance for World War II vessels. One of the men responsible for much of the company's successful R&D work is G. A. Kane, who until 1965 was executive vice president and general manager of the operation. Mr. Kane was cited by the Navy in 1956 for the design and development of more modern naval ordnance equipment than anyone else living at that time.

The Ordnance Division of Honeywell, formed in 1949, has grown in 15 years from a few offices in Minneapolis to a multi-plant operation in the Twin Cities, Los Angeles, and Seattle. Ordnance work includes missile systems and components, fuses and arming devices, stabilization and fire control systems for self-propelled weapons and vehicles, and underwater demolition and sounding devices. In the Twin Cities plants, Honeywell's Ordnance Division has designed and produced more than 25,000 mechanical, electrical, hydraulic, and electronic tank turret and fire control systems for nearly every type of U.S. armored vehicle in use today. The Ordnance Division entered the missile field in 1951 when a prime contract for a warhead system was received. Since then, the Ordnance Division has been active in the design, development, and production of missile systems and subsystems, and during the Korean conflict, was a major supplier of proximity mortar fuses. In July 1965, the Division received a $10 million initial contract to produce Mark 46 antisubmarine torpedoes for the Navy. Although Honeywell has been a prime contractor for ASROC, a Navy antisubmarine missile system, it has not had previous experience as a producer of torpedoes. Honeywell's planning for the Mark 46 Torpedo began in 1963 in anticipation that the Navy eventually would want a second source. Final assembly of the Mark 46 torpedo is scheduled for Honeywell's Twin Cities plants.

Other High Technology Establishments

In addition to the industry classifications already discussed, there are a number of Twin Cities establishments which do not fall into these classifications. Included are the multi-discipline applied research organizations and establishments specializing in the fields of high altitude and atmosphere research and instrumentation, and air contamination control products. These are listed in Table B-8.

In the category of applied research establishments are the Applied Sciences Division of Litton Industries and North Star Research and Development Institute, both having diversified research capabilities.

Table B-8

CHRONOLOGY OF COMPANY FORMATION:
OTHER HIGH TECHNOLOGY ESTABLISHMENTS

Date of Formation	Company	Comments
	Applied Research	
1963	Applied Sciences Div., Litton Industries	Acquired aerospace and engineering departments of the Electronic Div. of General Mills
	North Star R&D Institute	Sponsored jointly by the Upper Midwest R&D Council and the University of Minnesota
	High Altitude and Atmosphere Research and Instrumentation	
1929	Thompson Lightning Protection, Inc.	Lightning arrestor systems
1946	Lightning and Transients Research Institute	Formed by University of Minnesota personnel
1948	Winzen Research, Inc.	Spin-off from General Mills Mechanical Div.
1955	G. T. Schjeldahl Co.	Spin-off from Bemis Co.
1960	Viron Div., GCA Corp.	Division of GCA Corp.
1965	Minnesota Aerospace Corp.	Spin-off from Viron
	Air Contamination Control Products	
1915	Donaldson Corp.	Air filtration products
1959	Dexon, Inc.	Contamination control cabinets; spin-off from Honeywell

Litton established its Applied Sciences Division in the Twin Cities in 1963 when it acquired the aerospace and engineering departments of the Electronics Division of General Mills. At the time, "some 360 highly skilled engineers, scientists, and technicians" were reported to be involved in the acquisition, with a level of employment estimated to produce sales of over $5 million. The Division has done considerable R&D for federal agencies on advanced scientific instruments for use in space and oceanology.

The General Mills Electronics Division had its beginning prior to World War II as a seven-man service and repair shop at the company's Minneapolis flour mill. Later designated as the Mechanical Division, one of its principal activities during World War II was the production of gun sights. At the end of the war, with employment at 1,600, the Division converted to the production of small home appliances. In 1954, the appliance business was sold to McGraw Electric Company, and the Mechanical Division specialized in the R&D of electronic equipment and precision instruments. During the late 1950s and early 1960s, the Division employed about 1,500 in the Twin Cities area, and its activities were primarily in the following areas: R&D in physics, electronics, mechanics, and material; automatic handling equipment; and balloon and aerospace systems. Annual sales from operations during that period are estimated to be over $20 million.

North Star Research and Development Institute, sponsored jointly by the Upper Midwest Research and Development Council and the University of Minnesota, was incorporated in January 1963 as a nonprofit organization to perform contract research in the physical, biological, and social sciences. The 1964 Directory of Minnesota's Electronics and Related Science Industries reported a total employment of 26. Based upon published announcements, most of North Star's sales volume through 1965 has come from government contracts, primarily agencies other than the Department of Defense.

The Twin Cities area has developed considerable capability in the field of high altitude research and instrumentation. In addition to the Applied Sciences Division of Litton Industries, other companies in this field include: the Viron Division of GCA Corporation, a producer of the inflation system for the Echo II satellite; Winzen Research, Inc.; and Minnesota Aerospace Corporation, formed in 1965. The G. T. Schjeldahl Company, located in Northfield, Minnesota, about 40 miles from the Twin Cities, is also in this field.

Two Twin Cities organizations--Lightning and Transients Research Institute, and Thompson Lightning Protection, Inc.--perform R&D and production of equipment related to the atmospheric problems of lightning and other forms of transient electrical phenomena. Lightning and Transients Research Institute was chartered as a nonprofit corporation in 1946. It took over the work started in 1941 at the University of Minnesota and continued during World War II under the sponsorship of the Air Force and Navy. The principals of the Institute were associated with the University of Minnesota prior to incorporation.

These six establishments, which are engaged in high altitude and atmosphere research, employ approximately 650 people in Minnesota who produce annual sales of over $8.5 million. With the exception of the Schjeldahl Company and Thompson Lightning Protection, these organizations sell largely to federal agencies.

Donaldson Company and Dexon, Inc. are two Twin Cities companies engaged in the development and manufacture of air contamination control products used by defense agencies and companies producing equipment for DOD.

Donaldson Company employs more than 900, and in 1965 sales were $21.5 million. The company was started in 1915 by Frank A. Donaldson, Sr., a young engineer who had been dismissed by his employer, a Twin Cities tractor manufacturer, for suggesting that the company use a cleaner he had devised for spinning the dirt out of the air before it entered and fouled the tractor engines. As the story is reported, young Donaldson was recalled from Utah to the home office and dismissed for implying that the company's tractor was not perfect. In recent years, around 10% of the Donaldson Company's sales have been to defense agencies. This amount includes an $800,000 R&D contract with the Army to develop a filter to protect personnel in tanks and similar vehicles from chemical, biological, and radiological attack.

Dexon, Inc. was organized in 1959 by a former employee of Honeywell. Dexon, which had fiscal 1965 sales of about $800,000 and employs more than 50 people, specializes in the development and production of contamination control equipment. Dexon ultra-clean cabinets, which provide dust control and fume exhaust, are used in place of clean rooms for many applications. Dexon's customers include defense agencies and a number of companies producing military equipment.

Supporting Industries and Services

Of considerable benefit to the development of a technological complex is the local existence of a variety of supporting industries and services. Included are such activities as precision metalworking, testing laboratories, test equipment repair, and engineering services. Companies of this kind are listed in Table B-9. The existence of these establishments, most of them prior to 1960, provided the Twin Cities with a mature industrial base to support the rapid development of new technological companies during the late 1950s and early 1960s.

Sixteen Twin Cities precision metalworking companies employing about 600 employees have a combined sales volume of approximately $7 million. Sales to Twin Cities defense-related companies account for a large portion of this business. Of these 16 companies, 13 were formed prior to 1960.

A number of Twin Cities companies provide a variety of testing and test equipment repair services. The predecessor of the Twin Cities Testing and Engineering Laboratory dates back to 1910. Five companies employ more than 100 people and have combined annual sales of approximately $1 million. Several Twin Cities firms provide engineering services to defense-related companies. Seven firms have combined annual sales of more than $4 million and employ in excess of 400 people.

Table B-9

CHRONOLOGY OF COMPANY FORMATION:
SUPPORTING INDUSTRIES AND SERVICES

Date of Formation	Company	Comments
	Precision Metalworking	
1899	Farwell Metal Fabricating Div.	Division of Farwell, Ozmun, Kirk and Co.
1944	Mack Engineering	Spin-off from Honeywell, Inc.
1946	Clarus, Inc.	
1947	Professional Instrument Co.	
1949	Mid-Continent Engineering, Inc.	
1950	Modern Machine and Engineering Co.	Spin-off from Honeywell, Inc.
	Jet-O-Matic Engineering, Inc.	Spin-off from Minneapolis-Moline Co.
1951	Lake Engineering	Spin-off from General Mills, Inc.
1954	Nedmac, Inc.	Spin-off from Micro Products
1956	Quality Stamping Co.	
	Precise Products Corp.	Spin-off from Washington Scientific Industries, Inc.
1957	Precision Sheet Metal Co.	Spin-off from General Mills, Inc.
*	Precision Industries, Inc.	
1959	Dyna/Mation, Inc.	Spin-off from Clarus, Inc.
	T and A Products, Inc.	
1962	Aro Industries, Inc.	Spin-off from Precision Industries, Inc.
	Thomas Machine Co.	Spin-off from T and A Products, Inc.
	Testing and Test Equipment Repair	
1910	Twin City Testing and Engineering Lab, Inc.	
1945	Instrument Control Co.	Spin-off from Honeywell, Inc.
1961	Environ Laboratories, Inc.	Spin-off from Honeywell Aeronautical Div.
1962	Cartier Engineering Co.	Spin-off from Twin City Testing and Engineering Lab, Inc.
1963	Materials Processing Labs, Inc.	
	Engineering Services	
1946	Brodie Engineering Corp.	
1955	Minneapolis Engineering	
1957	Servo Engineering Corp.	Reported as no longer in operation
*	Minnesota Engineering Co.	
1961	Frontier Engineering and Service Co.	
	Strom Engineering Corp.	
1962	Dyna-Search Control, Inc.	Spin-off from Servo Engineering Corp.
1963	Consolidated Design, Inc.	

* Formed prior to 1958.

Source: Stanford Research Institute.

Appendix C

DETAILED TABLES ON TWIN CITIES E/S CHARACTERISTICS

Table C-

EDUCATIONAL SPECIALIZATION OF THE
Twin Cities, Los Angeles, and B

Time Period of Hire	Mech. Eng.	Aero. Eng.	Elect. Eng.*	Genl. Eng.	Civil Eng.	Ind. & Mgt. Eng.	Other Eng.†	Phys-ics‡	Chem., Biochem.	Ceram-ics	Metal-lurgy	Met ol
												Educational Spec (percent of E/S's in current wo
Twin Cities												
1935-39	22.7%	%	4.5%	%	%	%	%	%	%	%	%	
1940-44	12.5	7.5	35.0					2.5				
1945-49	16.3	7.0	38.4						2.3		1.2	
1950-54	25.6	7.8	40.3	1.7	0.3	0.3	0.3	5.5	1.7		0.3	
1955-59	17.2	4.0	43.6	2.1	0.5	1.0		7.0	2.3		0.2	
1960-64	10.8	4.9	46.3	0.9	0.4	0.8	0.1	8.0	1.8	0.1		0.
Current workforce	15.3	5.2	43.5	1.3	0.4	0.8	0.1	6.8	1.9	0.1	0.2	0.
Los Angeles												
1935-39	23.7	31.9	5.1	12.1	1.2	0	1.2	1.6	1.6	0	0	0.
1940-44	20.3	19.0	8.9	12.2	5.0	0.3	2.5	2.8	3.0	0	0.3	0.
1945-49	20.7	30.9	9.5	9.8	1.1	0.8	1.7	2.1	3.2	0	0.4	0.
1950-54	21.9	16.1	18.2	10.4	3.2	0.9	1.3	4.3	4.2	0.1	0.5	0.
1955-59	19.0	11.8	23.3	9.3	2.4	0.8	1.4	7.0	6.8	0.1	0.8	0.
1960-64	17.7	10.1	26.4	7.5	1.6	1.4	1.4	8.1	5.4	0.2	1.1	0.
Current workforce	18.7	12.4	23.4	8.4	2.0	1.1	1.4	7.1	5.4	0.1	0.9	0.
Boston												
1940-44	10.0	3.3	46.6	6.7	0	0	3.3	0	0	0	0	0
1945-49	10.4	3.0	35.9	3.0	1.5	3.0	0	8.0	0	0	0	0
1950-54	11.3	3.3	45.8	5.7	5.0	2.8	0.9	9.4	2.4	0	0	0
1955-59	14.4	3.6	35.8	3.4	1.1	3.1	0.8	10.3	3.4	0.3	0.7	0.
1960-64	13.6	5.5	33.5	2.5	1.1	3.9	0.7	10.6	3.5	0.3	0.6	0.
Current workforce	13.7	4.8	34.8	2.9	1.1	3.3	0.7	10.3	3.4	0.3	0.6	0.

* Includes telecommunications, radio communications, electronics.
† Includes structural, tool, industrial design, nuclear engineering.
‡ Includes astrophysics, engineering physics, geophysics.
§ Figures do not always total 100.0% because of rounding.

Source: Stanford Research Institute.

Table C-1

OF THE ENGINEER/SCIENTIST WORKFORCE
s, and Boston Defense R&D Centers

ional Specialty at Time of Hire
current workforce hired in time period shown)

tal-gy	Meteor-ology	Physio., Med., Bio.	Psych.	Math. & Stat.	Econ. & Bus. Ad.	Mil. & Naval Sci.	Other Tech. Specialties	Nontech. Specialties	Un-known	Total Percent§	Total Number
%	%	%	%	%	%	%	%	%	72.7%	99.9%	22
				2.5					40.0	100.0	40
.2				7.0				1.2	26.7	100.1	86
.3		0.3		6.5	0.3		0.3	1.7	6.8	99.7	293
.2		0.2	0.5	11.5	1.6		0.9	3.8	3.7	100.1	574
	0.1	0.2	1.8	17.8	1.4	0.1	0.8	2.6	0.9	99.8	951
.2	0.1	0.2	1.0	13.3	1.2	0.1	0.7	2.7	5.3	100.2	1,966
	0.2	0.4	0	3.1	2.3	0.4	3.1	4.3	8.2	100.4	257
.3	0.1	0.7	0.2	5.8	2.6	0	3.6	8.4	4.8	100.5	607
.4	0.2	0	0	5.2	1.1	0	1.6	4.2	7.4	99.9	967
.5	0.3	0.4	0.4	4.7	2.2	0.2	2.1	5.7	2.7	99.8	3,151
.8	0.2	0.3	0.5	6.7	1.7	0.2	2.3	3.3	2.5	100.4	6,008
.1	0.1	0.5	1.0	8.7	2.4	0.3	2.1	2.6	1.2	99.8	15,735
.9	0.2	0.5	0.8	7.5	2.2	0.2	2.1	3.3	2.1	99.8	26,725
	0	0	0	0	0	0	13.3	3.3	13.3	99.8	30
	0	0	0	7.5	3.0	0	1.5	10.5	12.0	100.3	67
	0	0	0	3.8	3.8	0.5	2.4	1.8	5.2	99.6	212
.7	0.2	0.1	0.1	8.1	3.3	0.2	1.8	2.9	6.6	100.2	1,230
.6	0.1	0.2	0.6	9.9	2.7	0.2	2.2	2.4	5.9	100.0	2,853
.8	0.1	0.2	0.4	9.0	2.9	0.2	2.1	2.7	6.3	99.8	4,392

B

Table C-2

GEOGRAPHIC SOURCE OF ENGINEERS AND SCIENTISTS AT TIME OF HIRE
Los Angeles, Boston, and Twin Cities Defense R&D Industry

Geographic Source (Census region, Census division, and state)	Percent of Los Angeles E/S's Hired from Source Given (N = 26,342)			Percent of Boston E/S's Hired from Source Given (N = 2,911)			Percent of Twin Cities E/S's Hired from Source Given (N = 1,935)		
	State Total	Division Total	Region Total	State Total	Division Total	Region Total	State Total	Division Total	Region Total
Northeast region	%	%	14.5%	%	%	80.7%	%	%	7.8%
New England division		5.0			64.1			2.2	
Vermont, New Hampshire, Maine	0.9			3.1			0.1		
Massachusetts	2.5			56.3			1.3		
Connecticut, Rhode Island	1.5			4.8			0.8		
Middle Atlantic division		9.5			16.6			5.6	
New York	4.9			10.3			3.0		
(New York City)	(2.1)			(4.9)			(2.0)		
(Other New York)	(2.8)			(5.4)			(1.0)		
New Jersey	1.9			3.1			1.6		
Pennsylvania	2.7			3.1			1.0		
North Central region			15.5			6.7			73.6
East North Central division		10.8			5.7			17.6	
Ohio	2.5			1.4			3.2		
Indiana	1.9			1.1			2.7		
Michigan	2.3			1.3			2.9		
Wisconsin	1.0			0.4			5.5		
Illinois	3.1			1.4			3.3		
West North Central division		4.7			1.0			56.0	
Minnesota	0.9			0.2			42.3		
Iowa, North Dakota, South Dakota, Nebraska	2.0			0.3			10.8		
Missouri	1.1			0.3			2.0		
Kansas	0.7			0.2			0.9		
Southern region			9.3			7.0			5.9
South Atlantic division		4.5			5.3			3.0	
Maryland, D.C., Delaware	1.8			3.3			1.7		
Virginia	0.7			0.9			0.5		
West Virginia, North Carolina, South Carolina, Georgia	0.9			0.5			0.3		
Florida	1.0			0.6			0.5		
East South Central division		1.7			0.7			0.7	
Alabama	0.6			0.2			0.4		
Mississippi, Kentucky, Tennessee	1.1			0.5			0.4		
West South Central division		3.1			1.0			2.2	
Arkansas, Oklahoma	0.9			0.1			0.7		
Louisiana	0.3			0.1			0.2		
Texas	1.9			0.8			1.3		

			[illegible]			[illegible]			73.6
East North Central division		10.8			5.7			17.3	
Ohio	2.5			1.4			3.2		
Indiana	1.9			1.1			2.7		
Michigan	2.3			1.3			2.9		
Wisconsin	1.0			0.4			5.5		
Illinois	3.1			1.4			3.3		
West North Central division		4.7			1.0			56.0	
Minnesota	0.9			0.2			42.3		
Iowa, North Dakota, South Dakota, Nebraska	2.0			0.3			10.8		
Missouri	1.1			0.3			2.0		
Kansas	0.7			0.2			0.9		
Southern region			9.3			7.0			5.9
South Atlantic division		4.5			5.3			3.0	
Maryland, D.C., Delaware	1.8			3.3			1.7		
Virginia	0.7			0.9			0.5		
West Virginia, North Carolina, South Carolina, Georgia	0.9			0.5			0.3		
Florida	1.0			0.6			0.5		
East South Central division		1.7			0.7			0.7	
Alabama	0.6			0.2			0.4		
Mississippi, Kentucky, Tennessee	1.1			0.5			0.4		
West South Central division		3.1			1.0			2.2	
Arkansas, Oklahoma	0.9			0.1			0.7		
Louisiana	0.3			0.1			0.2		
Texas	1.9			0.8			1.3		
Western region			60.8			5.6			12.7
Pacific division		56.9			4.7			8.9	
California	55.0			3.7			6.5		
(Southern California)	(52.7)			(3.2)			(5.2)		
(Northern California)	(2.3)			(0.5)			(1.3)		
Oregon	0.3			0			0.2		
Washington	1.4			1.0			2.2		
Hawaii	0.2			0			0.1		
Alaska	*			0			0		
Mountain division		3.9			0.9			3.8	
Montana, Wyoming, Idaho, Nevada	0.5			*			0.5		
Utah	0.6			*			0.3		
Arizona	0.5			*			0.5		
New Mexico	0.8			0.4			0.6		
Colorado	1.5			0.3			2.0		
Total	99.9%	100.1%	100.1%	99.8%	100.0%	100.0%	100.3%	100.0%	100.0%

Note: Columns may not add to 100.0% because of rounding.

* Less than 0.05%.

Source: Stanford Research Institute.

B

Table C-3

GEOGRAPHIC SOURCE OF MOST RECENT UNIVERSITY DEGREE OF ENGINEERS AND SCIENTISTS
Los Angeles, Boston, and Twin Cities Defense R&D Establishments

Geographic Source of Degree (Census region, Census division, and state)	Percent of Current Los Angeles E/S's Receiving Most Recent Degrees from Source Given (N = 24,149)			Percent of Current Boston E/S's Receiving Most Recent Degrees from Source Given (N = 2,803)			Percent of Current Twin Cities E/S's (Complex) (N = 1,693)			Percent of Ex-Minnesota E/S's in Los Angeles (N = 214)		
	State Total	Division Total	Region Total	State Total	Division Total	Region Total	State Total	Division Total	Region Total	State Total	Division Total	Region Total
	%	%		%	%		%	%		%	%	
Northeast region			33.3%			82.3%			8.9%			4.2%
New England division		16.5			65.0			4.3			3.3	
Vermont, New Hampshire, Maine	4.9			4.4			0.6			0.5		
Massachusetts	7.9			55.6			2.6			1.4		
Connecticut, Rhode Island	3.7			5.0			1.0			1.4		
Middle Atlantic division		16.8			17.4			4.7			0.9	
New York	9.8			12.2			2.8			0.9		
(New York City)	(4.3)			(5.8)			(1.4)			0.9		
(Other New York)	(5.5)			(6.4)			(1.4)			0		
New Jersey	2.5			1.5			0.8			0		
Pennsylvania	4.4			3.8			1.1			0		
North Central region			27.7			9.6			83.2			90.7
East North Central division		19.5			8.1			21.1			6.1	
Ohio	3.6			1.8			2.1			0.5		
Indiana	4.3			2.0			3.3			1.9		
Michigan	4.3			1.9			4.1			1.4		
Wisconsin	1.7			0.6			8.2			1.9		
Illinois	5.5			1.8			3.4			0.5		
West North Central division		8.2			1.5			62.0			84.6	
Minnesota	1.9			0.3			42.2			78.0		
Iowa, North Dakota, South Dakota, Nebraska	3.7			0.5			17.4			5.1		
Missouri	1.7			0.6			1.4			0.9		
Kansas	0.9			0.1			1.0			0.5		
Southern region			14.3			6.5			4.4			1.9
South Atlantic division		6.6			4.1			1.9			0.9	
Maryland, D.C., Delaware	2.3			2.3			0.6			0		
Virginia	1.1			0.6			0.4			0		
West Virginia, North Carolina, South Carolina, Georgia	2.0			0.9			0.6			0.9		
Florida	1.2			0.4			0.4			0		
East South Central division		2.5			1.1			0.7			0.5	
Alabama	0.9			0.4			0.1			0.5		
Mississippi, Kentucky, Tennessee	1.6			0.6			0.6			0		
West South Central division		5.2			1.3			1.7			0.5	
Arkansas, Oklahoma	1.8			0.5			0.6			0		
Louisiana	0.6			0.1			0.1			0		
Texas	2.8			0.7			0.9			0.5		
Western region			24.8			1.6			3.5			3.3

(New York City)	[illegible]			[illegible]			(1.4)			0.9		
(Other New York)	(5.8)			(6.4)			(1.4)			0		
New Jersey	2.5			1.5			0.8			0		
Pennsylvania	4.4			3.8			1.1			0		
North Central region			27.7			9.6			83.2			90.7
East North Centra' division		19.5			8.1			21.1			6.1	
Ohio	3.6			1.8			2.1			0.5		
Indiana	4.3			2.0			3.3			1.9		
Michigan	4.3			1.9			4.1			1.4		
Wisconsin	1.7			0.6			8.2			1.9		
Illinois	5.5			1.8			3.4			0.5		
West North Central division		8.2			1.5			62.0			84.6	
Minnesota	1.9			0.3			42.2			78.0		
Iowa, North Dakota, South Dakota, Nebraska	3.7			0.5			17.4			5.1		
Missouri	1.7			0.6			1.4			0.9		
Kansas	0.9			0.1			1.0			0.5		
Southern region			14.3			6.5			4.4			1.9
South Atlantic division		6.6			4.1			1.9			0.9	
Maryland, D.C., Delaware	2.3			2.3			0.6			0		
Virginia	1.1			0.6			0.4			0		
West Virginia, North Carolina, South Carolina, Georgia	2.0			0.9			0.6			0.9		
Florida	1.2			0.4			0.4			0		
East South Central division		2.5			1.1			0.7			0.5	
Alabama	0.9			0.4			0.1			0.5		
Mississippi, Kentucky, Tennessee	1.6			0.6			0.6			0		
West South Central division		5.2			1.3			1.7			0.5	
Arkansas, Oklahoma	1.8			0.5			0.6			0		
Louisiana	0.6			0.1			0.1			0		
Texas	2.8			0.7			0.9			0.5		
Western region			24.8			1.6			3.5			3.3
Pacific division		21.1			0.8			0.8			1.9	
California	20.6			0.7			0.5			1.9		
(Southern California)	(19.6)			(0.6)			(0.4)			(1.4)		
(Northern California)	(1.0)			(0.1)			(0.1)			(0.5)		
Oregon	0.1			0			0.1			0		
Washington	0.3			0.1			0.3			0		
Hawaii	*			0			0			0		
Alaska	*			0			0			0		
Mountain division		3.7			0.8			2.7			1.4	
Montana, Wyoming, Idaho, Nevada	0.3			0			0.4			0		
Utah	0.3			0			0.1			0		
Arizona	0.1			0			0.1			0		
New Mexico	0.9			0.5			0.1			0.9		
Colorado	2.0			0.3			0.4			0.5		
Total	99.7%	100.1%	100.1%	100.2%	100.1%	100.0%	100.1%	99.9%	100.0%	100.1%	100.1%	100.1%

Note: Figures may not add to 100.0% because of rounding.

* Less than 0.05%.

Source: Stanford Research Institute.

B

Table C-4

GEOGRAPHIC LOCATION OF PROCUREMENT BY RESEARCH AND DEVELOPMENT PRIME CONTRACTORS IN SELECTED LOCATIONS

Location of Vendor or Subcontractor	Percent Purchased by Prime Contractors Located in Various Defense R&D Centers											
	Boston			Los Angeles			Twin Cities			Charlotte		
	State Total	Division Total	Region Total	State Total	Division Total	Region Total	State Total	Division Total	Region Total	State Total	Division Total	Region Total
Northeast region	%	%	66.4%	%	%	26.0%	%	%	18.8%	%	%	10.8%
New England division		45.9			18.8			3.8			4.3	
Vermont, New Hampshire, Maine	0.5			0.7			0.1					
Massachusetts, Rhode Island	40.7			12.9			2.3			2.0		
Connecticut	4.6			5.2			1.4			2.3		
Middle Atlantic division		20.5			7.2			15.0			6.5	
New York City	10.6			2.4			8.2			3.0		
Other New York	0.1											
New Jersey	7.4			1.0			1.9			1.2		
Pennsylvania	2.4			3.8			4.9			2.3		
North Central region			7.4			4.4			59.0			9.7
East North Central division		6.3			3.4			7.6			9.1	
Ohio	4.1			1.6			0.2			4.0		
Indiana	0.3			0.2			1.7			0.1		
Illinois	1.0			1.2			3.7			4.0		
Michigan	0.6			0.2			0.2			1.0		
Wisconsin	0.3			0.2			1.8			0.1		
West North Central divison		1.1			1.0			51.4			0.6	
Minnesota	0.9			0.5			50.6			0.2		
Iowa, North Dakota, South Dakota, Nebraska	0.1			0.4			0.2			0.1		
Missouri	0.1			0.1			0.6			0.3		
Southern region			6.5			7.3			9.0			23.6
South Atlantic division		5.1			2.9			0.[illegible]			21.9	
Maryland, D.C., Delaware	3.4			1.0			0.5			0.7		
Virginia	0.4			1.3						0.2		
West Virginia, North Carolina, South Carolina, Georgia	1.1			0.3						20.3		
Florida	0.2			0.3			0.3			0.7		
East South Central division		0.2			0.4			2.2			1.6	
Alabama				0.3						0.4		
Mississippi, Kentucky, Tennessee	0 2			0.1			2.2			1.2		
West South Central division		1.2			4.0			6.0			0.1	

Pennsylvania	2.4			3.8			4.9			2.3		
North Central region			7.4			4.4			59.0			9.7
East North Central division		6.3			3.4			7.6			9.1	
Ohio	4.1			1.6			0.2			4.0		
Indiana	0.3			0.2			1.7			0.1		
Illinois	1.0			1.2			3.7			4.0		
Michigan	0.6			0.2			0.2			1.0		
Wisconsin	0.3			0.2			1.8			0.1		
West North Central divison		1.1			1.0			51.4			0.6	
Minnesota	0.9			0.5			50.6			0.2		
Iowa, North Dakota, South Dakota, Nebraska	0.1			0.4			0.2			0.1		
Missouri	0.1			0.1			0.6			0.3		
Southern region			6.5			7.3			9.0			23.6
South Atlantic division		5.1			2.9			0.8			21.9	
Maryland, D.C., Delaware	3.4			1.0			0.5			0.7		
Virginia	0.4			1.3						0.2		
West Virginia, North Carolina, South Carolina, Georgia	1.1			0.3						20.3		
Florida	0.2			0.3			0.3			0.7		
East South Central division		0.2			0.4			2.2			1.6	
Alabama				0.3						0.4		
Mississippi, Kentucky, Tennessee	0.2			0.1			2.2			1.2		
West South Central division		1.2			4.0			6.0			0.1	
Arkansas, Oklahoma	0.2			1.9						0.1		
Texas	1.0			2.1			6.0					
Western region			13.4			60.4			9.6			28.6
Mountain division		2.6			0.7			5.3			0.1	
Montana, Wyoming, Idaho	2.1											
Colorado	0.3			0.4						0.1		
New Mexico	0.1						0.6					
Nevada, Arizona	0.1			0.3			4.7					
Pacific division		10.8			59.7			4.3			28.5	
Southern California	7.5			55.1			4.3			28.5		
Northern California	2.7			4.3								
Oregon	0.3			0.1								
Washington	0.1			0.2								
Hawaii	0.2											
National and otherwise non-distributable	6.3	6.3	6.3	1.9	1.9	1.9	3.4	3.4	3.4	27.2	27.2	27.2
Total	99.9	100.0	100.0	100.0	100.0	100.0	99.8	99.8	99.8	99.8	99.9	99.9

Source: R. Howell, W. Breswick, E. Wenrick, An Exploratory Study of the Economic Impact of Defense R&D Expenditures: In Terms of Value Added and Employment Generated, Stanford Research Institute, February 1966, p. D-4.

8

Appendix D

BACKGROUND MATERIAL FOR CHAPTER IV

Appendix D

BACKGROUND MATERIAL FOR CHAPTER IV

D-1 The "Dollar Stock Market"

Common to many of the technical company stock prospectuses was an enclosed form letter from a company official stating that "because of the heavy interest indicated in this offering, we have had to greatly limit the shares which could be made available to persons expressing an interest therein," or similar wording. In the same letter, there was usually a statement to the effect that: "In order to purchase the shares allotted to you, you must sign and return one copy of the Subscription Agreement together with your check payable to the order of (the company) for the full amount of the shares for which you subscribe. These must be received by the company on or before (a specified date). The company cannot hold the shares allotted for sale to you beyond this date."

A number of the stock prospectuses of new issues did not include audited financial statements. For those that did, the certifications by the CPA firms were often qualified to such an extent that they were of little value.

Typical are the following:

"We did not make an examination of the operating and income accounts."

"As this was the first audit of the company's accounts, we made no physical tests of the inventory on hand at the beginning of the period, and, therefore, can express no opinion on the overall fairness of the statement of operations."

"However, we have not employed all of the procedures required in the case of an audit, which precludes us from expressing an independent accountant's opinion on the representations contained in the statements."

"Our examination of the accounts was limited in scope to the office records and information submitted by management, and did not include independent verification of the accounts or procedures requisite to the expression of an opinion. Accordingly, no auditor's opinion is rendered."

In some cases, audits reported in the prospectuses were audits of the balance sheet only. In place of profit and loss statements, statements of receipts and disbursements were sometimes reported. This made it more difficult for the reader of the prospectus to detect operating losses. It was common practice to capitalize (i.e., report as an asset) research and development costs. In the case of one technical company, capitalized R&D costs accounted for two-thirds of its $37,000 of assets.

In some cases, the stock could be sold at the time of offering for various prices, as indicated by the following statement from one prospectus:

> "None of the selling stockholders is obligated to sell all of the securities being offered hereby at the same price, and in fact, sales of these securities may be made by each of said stockholders to different purchasers at different prices."

For a number of the new stock issues, there was no provision for making refunds to purchasers if the offering was not successful. The following statement from one of the prospectuses is indicative:

> "The company does not intend to refund subscriptions even if a substantial part of the offering remains unsold after a reasonable time, but proposes to initiate the business operations with whatever capital it receives."

Occasionally, the prospectus brought the potentially artificial nature of the "after-market" price of a new stock issue to the attention of prospective purchasers by such statements as the following:

> "In connection with this offering, the underwriter may over-allot or effect transactions which stabilize or maintain the market price of the stock of the company at a level above that which might otherwise prevail in the open market. Such stabilizing, if commenced, may be discontinued at any time."

Until the latter part of 1960, a statement regarding the speculative nature of the new stock offerings of technical companies was not generally included in the prospectuses. When it was included, it was usually not prominently shown in the prospectus. By 1961, it was the practice to print "These are speculative securities" on the first page of the prospectus. By mid-1961, when new technical issues were being offered at the rate of about two a week, introductory statements often contained a cautionary note such as the following:

> "The shares offered hereby are speculative in nature and prospective investors should be advised of the following:
>
> 1. The company began operations on or about __________. It has no history of earnings and has no significant operating record.

2. The company proposes to develop and sell ________, but no assurance can be given that such can be done profitably. The company does not have an established competitive position. Although the company believes certain of the devices it is trying to develop might be unique, it has not made a thorough investigation of this question.

3. The success of the company will depend to a great extent upon its ability to obtain research or production contracts from government agencies or contractors. No assurance can be given regarding the ability of the company to obtain such contracts, and the company frequently may be competing with firms of substantially greater resources and facilities when bidding for such contracts.

4. There is neither a market for nor a determinable market value of the company's stock. The offering price of _____ per share has been arbitrarily established by the company's board of directors. Such offering price is not based on earnings as the company has had none and should not be construed as any representation that the stock has a market value of or could be sold at that price.

5. Prior to this offering the company issued _____ shares of common stock to certain officers at a price of _____ per share.

6. No assurance can be given that the proceeds of this offering will provide sufficient capital for carrying out all of the plans of the company."

Also, by mid-1961, a Statement of Purchase was being enclosed with prospectuses to be signed by purchasers of the stock. A typical statement was worded as follows:

"I have today purchased from XYZ, Inc., _____ Common Shares, par value _____, for which I have paid _____ a share. I have been furnished with a prospectus which I have read and understood, and I realize that this company is recently organized to engage in research, development, manufacture and sales in the field of __________.

"I realize that this is a highly speculative venture, but I have sufficient business and financial means to enable me to assume the risks involved."

D-2 Small Business Administration (SBA)

For business loan purposes, the SBA defines a small business as one that is independently owned and operated and non-dominant in its field.

A manufacturing concern is considered small if its average employment in the preceding four calendar quarters was 250 people or less. A company may be considered small if its previous average employment was between 250 and 1,000 employees, depending on the SBA employment size standard developed for particular industries.

There are two principal types of loans--participation loans, and direct loans. In a participation loan, the SBA joins with a bank or other private lending institution. In a direct loan, the loan is made entirely and directly by the SBA to the borrower. By law, the SBA may not make a direct loan if a participation loan can be arranged.

SBA participation (maximum of 90%) may be either under a loan guarantee plan or on an immediate basis. On a guarantee basis, SBA agrees that, on 90 days' default as to principal or interest, it will purchase its guaranteed portion of the outstanding balance of the loan. On an immediate basis, the SBA purchases, at the time the loan is consummated, a fixed percentage of the original amount of the loan. Under the law, the SBA may not enter into an immediate participation if it can do so on a guarantee (deferred) basis.

By law, in general, the maximum amount that the SBA can have outstanding to any one borrower is $350,000. "Pool loans," however, can be made to corporations formed by groups of small businesses. For this type of loan, the maximum is $250,000 multiplied by the number of small businesses participating in the group. In parts of the country designated as "redevelopment areas" by the Department of Commerce and "areas of substantial unemployment" by the Department of Labor, the SBA permits loans up to 25% larger than those normally provided.

The maximum maturity of SBA loans is generally ten years. Loans for working capital, however, usually are limited to six years; loans for construction may have a ten-year maturity plus the estimated time required to complete construction.

With certain exceptions, the interest rate on SBA direct business loans and the SBA share of participation loans is 5-1/2%. A private lending institution may set a higher rate than 5-1/2% on its share of a participation loan, provided the rate is legal and reasonable. It also may set a higher rate than 5-1/2% on the SBA portion of a guaranteed loan, the higher rate on the SBA portion to apply until such time as SBA may purchase its guaranteed portion. The interest rate on the SBA portion of a loan may not be less than 5%. Exceptions to the foregoing are interest rates on small business loans to veterans, insured by the Veterans Administration, which may not exceed 5-1/4%. Also, the SBA has lowered to 4% the interest rate on loans made to small businesses in redevelopment areas and areas of substantial unemployment.

D-3 Small Business Investment Companies (SBICs)

In 1958, the Small Business Investment Act was passed and provided for the establishment of Small Business Investment Companies (SBICs), privately organized and operated, and primarily privately financed as suppliers of long term capital to small businesses unable to get money from the usual investment channels. To qualify for a loan, a small business is defined generally as having total assets under $5 million, a net worth below $2.5 million, and an average net income not over $250,000 annually. The SBICs can lend such a company as much as $500,000, or 20% of the SBICs capital and surplus, whichever is smaller.*

As an increased incentive to investors, the Act provides for two-to-one matching funds up to $400,000, if private funds are not available, and for special tax incentives. Thus, $150,000 of SBIC money contributed by stockholders can obtain $300,000 from the SBA at 5% interest. The tax concessions are for both the SBICs and their stockholders. While profits are allowed to get capital gains treatment, losses can be deducted from ordinary income. Also, SBICs are allowed a 100% deduction of dividends from a taxable domestic corporation, rather than the 85% deduction normally allowed corporations.

Table D-1 lists the 11 Twin Cities SBICs which had been licensed by 1966--three in 1959, two in 1960, four in 1961, and two in 1962. Table D-2 presents the number and capitalization of SBICs in the United States and Twin Cities.

The investment policies of Twin Cities SBICs are summarized below:

Investment Policies	No. of SBICs†
Will invest in any business with growth potential	6
Will invest in new businesses	6
Equity participation desired or usually required	6
Security generally required	3
Interested in participation financing	6
Consulting contracts generally required	1

In the following discussion of Twin Cities SBIC experience, information has been derived from a sample of transactions accounting for an estimated 70% of the $11 million of financial assistance provided by Twin Cities SBICs from 1959 to 1965.

---

* For companies located in a "differential area"--i.e., an area designated by federal agencies as a "redevelopment area" or "area of substantial unemployment"--the definition of a small business includes companies with total assets up to $6.25 million, a net worth up to $3.125 million, and a maximum net income of $312,500.

† Based upon seven reporting SBICs.

Table D-1

SMALL BUSINESS INVESTMENT COMPANIES
LICENSED IN THE TWIN CITIES

Name of SBIC	Date Licensed	Capital and Surplus ($ million)	Status 12/31/65
Arrowhead Small Investment Co.	1961	$ 0.3	Transferred to Denver 1964
Bonzer Investment Co.	1962	0.3	Functioning
Community Investment Enterprises, Inc.	1961	0.4	Functioning
First Bancstock Equity Corp.	1959	1.0	License surrendered 1965
First Continental Capital Corp.	1961	0.3	Functioning
First Midwest Capital Corp.*	1959	1.0	Functioning
Marquette Capital Co.	1960	0.5	Dissolved 1962
Minnesota Capital Corp.	1961	2.5	Certificate of dissolution filed 1964
Minnesota Small Business Investment Co.	1959	1.2	Functioning
Northwest Growth Fund, Inc.	1960	2.5	Functioning
Retailers Growth Fund, Inc.	1962	0.3	Functioning
Total for 11 SBICs		$10.3	
Total for 7 SBICs remaining as of 12/31/65		6.0	

* One of the first two SBICs in the country, and the first SBIC with a public stock issue.

Sources: Minneapolis Office of Small Business Administration; The SBIC National Directory, 1963.

Table D-2

NUMBER AND CAPITALIZATION OF SMALL BUSINESS INVESTMENT COMPANIES--
UNITED STATFS AND TWIN CITIES
December 31, 1963

Capitalization	Total United States				Twin Cities			
	No. of SBICs	% of U.S. Total	Capital & Surplus ($ million)	% of U.S. Total	No. of SBICs	% of T.C. Total	Capital & Surplus ($ million)	% of T.C. Total
Over $5 million	22	3.2%	$260	45.8%	0	0 %	$ 0	0 %
$1 to $5 million	43	6.2	94	16.5	5	50.0	9.0	84.1
Under $1 million	625	90.6	214	37.7	5	50.0	1.7	15.9
Total	690	100.0%	$568	100.0%	10	100.0%	$10.7	100.0%

Source: The SBIC National Directory, 1963 and 1964 Supplement.

Of the total financial assistance provided by Twin Cities SBICs, approximately 30% has been given to 16 companies considered to be technically oriented (i.e., having R&D expenditures greater than the 3.4% of sales average for all manufacturing industries).

Financial assistance by Twin Cities SBICs has taken various forms:

	No. of SBICs
Term loans	6
Debentures with no conversion rights Convertible debentures Debentures with detachable warrants	8
Capital stock	5
Combinations of the above	8

As indicated by Table D-3, 76% of the dollar value of financial assistance provided by Twin Cities SBICs has consisted of various types of debentures, primarily debentures convertible to capital stock and debentures with warrants to buy capital stock, as compared with a national SBIC debenture experience of 51% Loans, however, make up a much smaller percentage. Twin Cities SBICs re ort that only 11% of financial assistance has been provided as loans, compared with a national SBIC figure of 38%. The percentage of investment in capital stock (equity financing) by Twin Cities SBICs has paralleled the national experience--13% compared with 11%.

In an analysis of interest rates of Twin Cities SBICs, 42 loans and investments totaling $4.5 million were examined, including 14 loans and investments to technical companies totaling $1.7 million. As indicated in Table D-4, the effective interest rate on Twin Cities SBIC transactions with technical companies was identical with the effective rate on their transactions with all companies. Twin Cities SBIC interest rates have been considerably lower than those obtained by all U.S. SBICs.

Table D-3

NUMBER AND TYPE OF SBIC FINANCIAL TRANSACTIONS--UNITED STATES AND TWIN CITIES

	United States*				Twin Cities†			
	Transactions		Amount		Transactions		Amount	
	Number	% of Total	Millions of Dollars	% of Total	Number	% of Total	Millions of Dollars	% of Total
Loans	3,910	57%	$138	38%	13	17%	$0.8	11%
Debentures	1,910	27	185	51	44	60	5.4	76
Capital stock	1,117	16	37	11	17	23	0.9	13
Totals	6,937	100%	$360	100%	74	100%	$7.1	100%

* U.S. figures are based upon 606 SBICs and transactions through December 31, 1962.

† Twin Cities figures are based upon financial assistance to 52 companies accounting for approximately 60% of the value of Twin Cities SBIC transactions through March 31, 1965.

Sources: Report of Select Committee on Small Business, U.S. Senate, Operations of Small Business Investment Companies, 1963; annual reports of various Twin Cities SBICs, 1961 through 1965

Table D-4

INTEREST RATES ON LOANS AND DEBT SECURITIES --
TWIN CITIES AND ALL SBIC'S
Twin Cities SBICs through December 31, 1965
All SBICs through December 31, 1962

	Range	Median	Effective Rate*
Twin City SBICs			
Transactions with all companies	4% to 10%	7%	6.8%
Transactions with technical companies	6% to 8%	7%	6.8%
All U.S. SBICs	†	8.0% to 8.9%	8.5%

* Weighted average.

† Not available, but 20% of all transactions by U.S. SBICs through December 13, 1962 carried interest rates of 11% to 15%.

Sources: Office of Investment, SBA, 1963; annual reports of Twin Cities SBICs.

D-4 Insurance Companies and Other Institutional Investors

Some long term financing of Twin Cities R&D-based companies was done by an out-of-state insurance company. In 1958, a year after formation and the sale of common stock to the public at $1 a share, Control Data Corporation privately sold $350,000 of preferred stock to Sears Allstate Insurance. Warrants for the purchase of 80,000 shares of common stock at $4.25 a share accompanied the sale of preferred. The 80,000 shares represented slightly over 10% of Control Data's common stock outstanding at that time, and after stock splits, was the equivalent of approximately 4.6% of the common shares currently outstanding. The Allstate financing was arranged by the investment firm of Dean Witter and Company, for which they received, as compensation for this and other financial services, an option to purchase 15,000 shares of common stock at $6.875 a share. The options were exercised by Allstate and Dean Witter and Company in May and June of 1959. It also has been reported that Data Display, Inc., formed in 1958 and since early 1965 a wholly owned subsidiary of Control Data, received financing from Sears Allstate.

The amount of investment in local technical companies by Twin Cities insurance companies has been limited. Of the 75 insurance companies in the

Twin Cities, the Northwest National Life Insurance Company is reported to have had one of the more aggressive programs.

At the beginning of 1965, six organizations in the Twin Cities were sponsoring mutual funds:

General Securities, Inc.
Imperial Financial Services, Inc.
Invested Dollars Fund, Inc.
Investors Group Funds
Liberty Fund
Mairs and Power Funds

The largest of these, and also the largest in the world, is the Investors Group Funds with total net assets of $4.6 billion at the beginning of 1965. Its five funds were established during the period 1940 through 1957.

Imperial Financial Services established its Imperial Capital Fund in 1949. It had assets of $24.8 million at the beginning of 1965.

One of the more recently established funds has been the Invested Dollar Fund which made its initial public offering of 15 million shares of stock at $1.09 a share in 1963. The prospectus stated that the fund's normal policy will be "to invest in common stocks which management considers to have growth possibilities," with consideration being given to "such factors as new products and services, modern technology, or intensive research and development programs."

An examination of the investment portfolios of the five Investors Group Funds and the Imperial Capital Fund* showed investments in "seasoned" common stocks of the following Twin Cities companies:

Investor	Value of Investment (millions of dollars)
Investors Group Funds	
Litton Industries	$24.2
Minnesota Mining & Mfg. Co.	8.2
Honeywell, Inc.	4.5
Imperial Capital Fund	
Control Data Corp.	0.4
Honeywell, Inc.	0.2

* Weisenberger, Arthur, "Investment Companies, Mutual Funds and Other Types," 1965 ed.

From this examination, it appears that investment by Twin Cities mutual funds in "unseasoned" Twin Cities technical companies has been limited.

During the "dollar stock market" period, some investment companies were formed in the Twin Cities to invest in scientific and technological "growth" companies. Two of the more familiar investment companies formed were the Midwest Technical Development Corporation and Search Investments Corporation.

Two of the founders of Midwest in 1958 were previously associated with ERA and were among the founders of Control Data when it spun-off from the Univac Division of Sperry Rand in 1957. As indicated by its prospectus, Midwest's investment objectives were as follows:

> The Company was organized for the primary purpose of seeking out and acting upon investment opportunities in young or new companies believed by the management to be working on the technological frontier. It is a fundamental policy of the Company, ... (to invest in) companies or other enterprises which are principally engaged in the development or exploitation of inventions, technological improvements, new processes, or products not previously available. Prospective rate of growth is an important factor in selecting such companies, many of which are young or new enterprises, the securities of which will have no public market.

Midwest's first public offering of stock in May 1959 was for 500,000 common shares at $3.00 a share. By the following year, the market price of the stock had reached a high of $23.50 per share. During most of 1965, the price of the stock was down to about a dollar per share--ranging between 15/16 and 1-1/4.

Midwest's investments in technical companies in July 1960 totaled $1.5 million in the following technical fields: electronics, communications, automatic controls, instruments, computers and related machines, and electromechanical equipment. Distribution of investments by state was as follows:

State	Percent of Total Investment
Minnesota	33%
California	21
Connecticut	17
New York	17
Illinois	10
Florida	2
	100%

In 1962, an action was brought against various officers and directors of Midwest by the Securities and Exchange Commission (SEC). Although the Federal Court in its decree in December 1963 did not sustain all of the charges presented by the SEC, it did find that the defendants collectively had violated a number of provisions of the Investment Company Act of 1940. During 1963, three separate legal actions involving guarantees by Midwest were settled by agreement. In November 1965, there were four additional lawsuits and claims pending against Midwest.

In December 1965, stockholders of Midwest voted to sell its assets to Midtex, Inc., a new Minneapolis company. The purpose of Midtex was stated in the prospectus as "to acquire profitable operating companies in the electronics and other technological fields."

Search Investments Corporation was formed in 1960 to invest in scientific and technological "growth" companies. One million shares of stock were sold to the public at $1 per share in 1961. In its report to stockholders for the six months ended June 30, 1964, only $270,402 had been invested in common stocks, and the balance of $914,273 was in government securities. In January 1965, stockholders of Search voted to change the firm from an investment company to an operating company. As an investment company, Search was subject to the restrictions of the Investment Company Act of 1940. The net asset value of Search in the latter part of 1964 was indicated as $1.15 per share.

D-5 The Entrepreneur

Each addition to the number of local establishments doing work relevant to defense R&D is the result of a human decision process that is often discussed under the heading of entrepreneurship, and the individuals who play major parts in this decision process are referred to as entrepreneurs. The literature on entrepreneurship and entrepreneurs includes a broad range of definitions and interpretations of these terms. At one end of the range is the view that entrepreneurship is company-starting and that the entrepreneur is the man who starts the company. At the other end is the view that entrepreneurship is a broad organizing and decision-making function, and that the entrepreneur is a team of corporate leaders.

In this study, the entrepreneur is considered in the narrower sense of an active initiator of a new enterprise, since we are primarily interested in the process of formation of new companies. The entrepreneur is considered here in terms similar to those of Collins, Moore and Unwalla in their book, "The Enterprising Man," in which they use the term entrepreneur in the sense of "the innovating entrepreneur who has developed an ongoing business activity where none existed before." With them, we distinguish between "the independent or innovating entrepreneur and the bureaucratic entrepreneur," though exceptional cases of the latter have been observed in the course of these studies. As used in this study, the entrepreneur is the active initiator of a new enterprise in the form of a new company. He plays a major role in starting the company and managing it, and usually has an important equity position in it. The R&D-oriented entrepreneur is the entrepreneur who, through personal experience, education, or skill, is more likely to find his entrepreneurial expression in a technical company. (From Collins, O. F., D. G. Moore, and D. B. Unwalla, The Enterprising Man, MSU, 1964.)

This interest in new company formation grew out of an earlier study in this series.[1] The report on that study of the Denver, Tucson, and Orlando defense R&D industries stated:

> "The extent to which R&D-oriented entrepreneurs are present in a community, are attracted to it, and are able to find the required financial support in it, appears to play a major part in the development of a local R&D complex. To enable a defense R&D complex to develop requires some critical number and variety of companies. Once this number and variety has been reached, the area can continue to maintain a basic workforce and the organizational matrix required for the generation and exploitation of new technology.
>
> The achievement of this critical (and unknown) number and variety of companies is highly dependent on the activities of entrepreneurial individuals with a defense R&D orientation. In each of the areas studied, whatever defense R&D industry was in existence aside from the single major company in each area could be traced to the activities of such individuals or groups of individuals. Certain kinds of environmental and organizational conditions appear to attract or develop such R&D-oriented entrepreneurs. For example, in the areas studied it appeared that the smaller companies were more productive of new, successful local companies than were the very large companies. The large companies in these areas had not generated a single successful local spin-off, while there were small companies that had been the source of as many as five other companies."

During the present study, questions were raised concerning the extent to which R&D-oriented entrepreneurs played a role in the development of the Twin Cities defense R&D industry base, and the conditions that appeared to be associated with activating the formation of new companies in the industry. Three sources of information were used in seeking answers to these questions: historical data on company formation; interviews with founders of several Twin Cities technical companies; and interviews with key individuals from industry, the financial community, and the press.

An effort was made to obtain detailed data on the formation and early survival of existing companies in the Twin Cities to identify common factors or conditions that could be associated with these events. In every case where the principal of a company was interviewed or where some other key industrial, financial, or community figure was interviewed, the interviewee was asked to describe: the conditions that led up to the formation of his own or some other company; the specific event which precipitated the move; the problems faced in early survival; and in retrospect, what the act of company formation looked like from a later vantage point. As a result of these interviews and a review of available historical data, it was possible to identify a number of factors or conditions that, alone or in combination, appeared to have been associated in some way with the formation and early survival of companies in the Twin Cities defense R&D industry base. Of special interest here is the occurrence of the "dollar stock market" with its subsequent high rate of company formations, which provided a special situation for examining the influence of financial conditions on the formation of companies.

In every case where there was information on a group of men who had started a new company, there appeared to be one individual who, more than the others, had been the chief initiator or prime mover in launching the process by which the company was finally formed. In those cases where data were obtained directly from the principal officers of technical companies that had formed in the past fifteen years, they made it clear that they had had the intention of going into a business of their own long before the actual company formations took place. Many indicated that they had known "from childhood," "while I was still in the University," "from the day I got out of school" that they wanted to start a company of their own.

In all of the company formations studied, there appeared to be a preformation period in which there was some combination of "pulls" and "pushes," or positive and negative conditions, that operated on the company founder or founders to make them "more ready" for the decisive action. First among the positive "pulls" that operated in the Twin Cities in the post-World War II (high company formation) period was the relatively "easy" initial financing made available by the local "dollar stock market" between 1959 and 1961. To some of the entrepreneurs, the financing made available by the "dollar stock market" was the trigger inducing them to form a company of their own. To others, it was a way to easy profits, obtained by forming a company for the purpose of promoting the stock and subsequently selling it at higher prices. During this period, there were 111 stock offerings involving local technical companies. Of course, not all companies that were formed during this period responded to the pull of the "dollar stock market."

Another form of positive "pull" that operated in a number of Twin Cities company formation was the guaranteed initial market--an R&D contract, or an order for a service or product. In the majority of these cases, the initial sale was to a government agency that knew of the entrepreneur's work from previous contact. In one case, the initial order was for a computer component, and the government provided not only the order but also the materials, thus triggering the act that launched the company.

Negative "push" appeared as a precondition more often than did positive "pull" in the formation of the Twin Cities companies studied. The type of "push" most often identified in these formations was some form of external threat. Among these external threats were: the threat of a cutback in the business and staff of the organization in which the potential entrepreneurs were found; the more undifferentiated threat of an "absentee" management that might make arbitrary decisions (or that did make unpopular decisions) affecting the Twin Cities organization with which the potential entrepreneurs were associated; the threat of an organization change; and in one case, the very real threat that the corporate organization was planning to divest itself of the division in which the potential entrepreneurs were employed. In most of the cases where this kind of "push" operated, the men responded and acted on the threat rather than on the realization of the threat.

Another form of negative "push" can be designated as "creator's frustration," which results from a negative decision or lack of interest by a company's management concerning the device or idea that has been proposed or developed by a designer, inventor, or group of design engineers. In one such Twin Cities company formation, the preconditioning "push" came from a management decision to disregard the approach proposed by a design group, which subsequently formed a company to develop the proposed device.

An analysis of the technical company formations in the Twin Cities since World War II points up the observation that was earlier quoted from the study of Denver, Tucson, and Orlando--certain kinds of environments and organizations appear to be more highly associated with subsequent company formations than others. For example, six companies are known to have been formed by University of Minnesota personnel, but four of them came from one organization, the Rosemount Aeronautical Laboratories. Another example is Engineering Research Associates (ERA); some of its original personnel not only were responsible for the Univac Division of Sperry-Rand, but also went on to form Control Data Corporation, which in turn spawned other companies. Furthermore, ERA personnel located in Washington, D.C. were founders of Atlantic Research Corporation and General Kinetics, Inc. As already pointed out in the discussion on spin-offs, four Twin Cities organizations were the source of 36 spin-offs, of which 30 were still in existence, in one form or another, in 1965. This observation has also been made in studies of other communities.*

Based on the Twin Cities data and data from other community studies, the identification of a large number of company formations with certain "source" organizations and certain previous associations may indicate the operation of an important conditioning factor in the entrepreneur's decisions. The suggested conditioning factor is the establishment, in the perception of the entrepreneur, of the credibility of his forming a company. This perception of credibility is related to the entrepreneur's personal knowledge or observation of others who have formed companies, or the awareness that someone who had held the same job and had the same apparent capabilities had succeeded in forming a company. This is particularly well illustrated by the Twin Cities experience. When a Univac vice

---

* These are two master's theses which were written by P. Teplitz and H. A. Wainer, respectively, under the direction of Professor E. B. Roberts, and which dealt with spin-offs from MIT's Instrumentation Laboratory and its Lincoln Laboratory. See Bibliography.

president successfully formed Control Data, there was little immediate emulation. However, when a second company was formed by Univac employees, who were staff or project engineers, and the stock issue was successful, it was followed by a large number of company formations, which was the beginning of "the dollar stock market." One of the principals in the second Univac spin-off pointed out that following his company's successful formation, he heard other would-be entrepreneurs say, "You're only an engineer like I am. If you can do it, I can too."

The necessity for establishing the personal perception of credibility on the part of the potential entrepreneur receives plausible support from the examples of small successful companies that are the sources of many other small successful companies. The small company is one environment where the potential entrepreneur not only gains a great deal of experience with the total company process, but also sees "up close" that a man who formed the company is not a superman. Further plausible support comes from the example that was given of ERA being the ultimate source of many company formations. It suggests that even after the men were no longer associated with ERA, the fact that former close associates had successfully formed companies made the act more personally credible for them. Finally, this may also explain why it is reported that a number of entrepreneurs come from families in which the father was an entrepreneur or company officer.

Examination of spin-offs from the University of Minnesota's Rosemount Aeronautical Laboratory (RAL) perhaps provides some insight into the entrepreneural requisites for the successful formation of technological companies. Three successful spin-offs were:

Company	Year of Incorporation	1965 Net Sales (millions of dollars)
Fluidyne Engineering Corp.	1952	> $2.0 (est.)
Research, Inc.	1951	5.1
Rosemount Engineering Co.	1956	8.5

Even though the principal executives of these companies at the time of incorporation were young (ages 27 to 34), the length of their previous job experience, primarily in research and design, ranged from 10 to 13 years. Two of these entrepreneurs had had previous experience in five different organizations. For all three, the longest period of job experience prior to forming their own companies was with RAL, this period ranged from four to eight years. All of these entrepreneurs, as employees with responsible positions at RAL, had a thorough background in the highly competitive arena of government R&D contracting. In contrast, the spin-off from RAL in 1961 which did not survive involved an individual having only two years of experience with RAL following graduate school.

D-6 The University of Minnesota

Defense R&D

Most of the increase in research expenditures at the University of Minnesota in recent years has been for research sponsored by federal agencies. Since 1959-1960, sponsorship by all nonfederal sources has been between $2.6 and $3.1 million, annually. Between the academic years 1950-1951 and 1963-1964, the University of Minnesota research expenditures sponsored by defense agencies totalled over $35.8 million and ranged between $1.2 and $3.0 million. In the academic year 1964-1965, defense sponsored research expenditures were 10.0% of the University's total.

As noted in Table D-5, Minnesota has been among the 20 top-ranking states in terms of receipt of defense R&D prime contract awards to schools during the period FY 1961-1965. However, Minnesota has dropped both in ranking and in total awards during this period. Defense R&D awards to Minnesota schools (almost entirely to the University of Minnesota) have declined from $2.4 million (0.7% of total) in FY 1961 to $1.8 million (0.5% of total) in FY 1965. The Minnesota ranking has dropped from 16th in FY 1961 to 22nd in FY 1965, having been outranked by Wisconsin and Alaska. During this period, the 20 top-ranking states (including the District of Columbia) have accounted for more than 96% of total R&D defense prime contract awards to schools.

Approximately one-third of the University of Minnesota's $28 million of research for the academic year 1964-1965 was for work by its Institute of Technology. Table D-6 shows the growth in research volume performed by the Institute (from $46,000 for the academic year 1940-1941 to $7.4 million for 1963-1964), and the breakdown by sponsor (88% federal government, 5% state government, 5% business and industry, and 2% from all other sources). The Institute's defense R&D expenditures hit a peak of $2.7 million for the academic year 1959-1960, as compared with $2.3 million for 1963-1964. Over 90% of the University's defense R&D has been performed by the Institute.

By department, the Institute of Technology research expenditures during the 24-year period ended June 30, 1964 were as shown in Table D-7.

Table D-5

R&D DEFENSE PRIME CONTRACT AWARDS TO SCHOOLS BY STATE
TOP 20 IN RANK ORDER
FY 1961-1965

State	1961 Amount	1961 % of Total	1962 Amount	1962 % of Total	1963 Amount	1963 % of Total	1964 Amount	1964 % of Total	1965 Amount	1965 % of Total	5-Year Total Amount	5-Year Total % of Total
Massachusetts	$119.4	36.6%	$117.1	33.9%	$117.8	30.8%	$146.8	33.2%	$134.9	36.5%	$ 636.0	34.1%
Maryland	45.8	14.0	50.1	14.5	67.1	17.6	60.3	13.6	51.2	13.8	274.5	14.7
California	38.5	11.8	42.7	12.3	44.4	11.6	59.1	13.4	29.3	7.9	214.0	11.5
New York	25.3	7.8	24.7	7.1	32.9	8.6	39.2	8.9	29.3	7.9	151.4	8.1
Illinois	18.8	5.8	27.1	7.8	26.4	6.9	23.9	5.4	14.0	3.8	110.2	5.9
Michigan	14.2	4.4	10.9	3.2	11.7	3.1	17.9	4.0	16.2	4.4	70.9	3.8
Pennsylvania	9.5	2.9	11.0	3.2	11.8	3.1	14.7	3.3	18.2	4.9	65.2	3.5
Ohio	7.2	2.2	7.1	2.1	8.5	2.2	8.6	1.9	6.5	1.8	37.9	2.0
Washington, D.C.	4.2	1.3	6.6	1.9	8.0	2.1	7.5	1.7	10.1	2.7	36.4	2.0
Texas	4.4	1.3	5.2	1.5	5.3	1.4	6.0	1.4	6.3	1.7	27.2	1.5
New Jersey	5.5	1.7	4.0	1.2	3.9	1.0	4.8	1.1	5.9	1.6	24.1	1.3
Colorado	2.9	0.9	5.2	1.5	3.5	0.9	6.4	1.4	5.4	1.5	23.4	1.3
Washington	3.5	1.1	4.0	1.2	4.8	1.3	4.0	0.9	4.4	1.2	19.7	1.1
Rhode Island	4.7	1.4	2.6	0.8	3.6	0.9	3.5	0.8	3.1	0.8	17.5	0.9
North Carolina	1.4	0.4	3.5	1.0	2.5	0.7	6.7	1.5	3.3	0.9	17.4	0.9
New Mexico	2.6	0.8	3.8	1.1	3.7	1.0	3.4	0.8	3.6	1.0	17.1	0.9
Indiana	1.9	0.6	3.3	1.0	2.9	0.8	3.7	0.8	2.5	0.7	14.3	0.8
Florida	2.3	0.7	1.7	0.5	2.5	0.7	3.3	0.7	3.0	0.8	12.8	0.7
Minnesota	2.4	0.7	2.1	0.6	1.9	0.5	1.8	0.4	1.8*	0.5*	10.0	0.5
Utah	1.2	0.4	1.4	0.4	3.0	0.8	1.5	0.3	2.1	0.6	9.2	0.5
Subtotal	$315.7	97.1%	$334.1	96.8%	$366.2	96.0%	$423.1	95.5%	$351.1	95.0%	$1,789.2	96.0%
Total for all schools	326.3	100.0	345.9	100.0	381.9	100.0	442.2	100.0	369.9	100.0	1,866.2	100.0

* Minnesota replaced by Wisconsin ($2.2 million and 0.6%) in top 20 for 1965.

Source: Office of the Secretary of Defense, "Military Prime Contract Awards, by Region and State," FY 1962-1965; and "The Changing Patterns of Defense Procurement," June 1962.

Table D-6

INSTITUTE OF TECHNOLOGY
RESEARCH EXPENDITURES BY SPONSOR
(1953-54 through 1963-64)

Academic Year	Expenditures by Sponsor (thousands of dollars) Dept. of Defense	Other Federal	State	Other*	Total
1953-1954	$1,714	$ 179	$ 89	$ 93	$2,075
1954-1955	1,954	138	132	64	2,288
1955-1956	1,602	157	137	172	2,068
1956-1957	2,140	596	144	198	3,078
1957-1958	2,309	758	163	389	3,619
1958-1959	2,505	986	151	330	3,972
1959-1960	2,666	1,778	122	313	4,879
1960-1961	2,542	1,866	161	387	4,956
1961-1962	2,507	2,251	189	421	5,368
1962-1963	2,314	2,802	188	374	5,678
1963-1964	2,257	4,315	446	397	7,415

* Business and industry (67%); foundations (21%); and endowments, gifts, and miscellaneous (12%).

Table D-7

INSTITUTE OF TECHNOLOGY
RESEARCH EXPENDITURES BY DEPARTMENT
(1940-41 through 1963-64)

Department	Total Research Expenditures (millions of dollars)
Aeronautical engineering*	$13.5
Physics (since 1956-1957)	11.4
Chemistry	6.8
Electrical engineering	4.9
Mineral and metallurgical engineering†	3.7
Mechanical engineering	3.2
Civil engineering	3.1
Chemical engineering	1.9
Mathematics and mechanics	1.9
Hydraulics laboratory (since 1960-1961)	1.4
All other	1.6
Total	$53.4

* Includes Rosemount and Hypersonic Laboratories.
† Includes Mines Experiment Station and Chemical Metallurgy.

Degrees

In the 1962-1963 school year, universities and colleges in Minnesota accounted for 1.7% of the 54,264 bachelor degrees conferred nationally in the relevant fields, 1.1% of the relevant master's degrees, and 1.8% of the relevant doctorates. A comparison of the Minnesota E/S "production rate" with that of the states in which Los Angeles, Boston, Denver, and Tucson are located is shown in Table D-8.

For the six academic years 1960 through 1965, the University of Minnesota's Institute of Technology conferred a total of 2,419 bachelor degrees. Approximately 255 quarter hours are needed for a bachelor's degree from the Institute of Technology of the University of Minnesota. The first-year curriculum is the same for all students in the College of Engineering and some of the other departments. Table D-9 shows by year the number of bachelor degrees conferred by each department of the University of Minnesota's Institute of Technology.

Questionnaires sent to 2,419 University of Minnesota Institute of Technology students at the time of receiving their bachelor degree were answered by 2,167--or 90%. Of those replying, 144 were planning to serve in the armed services, and 197 had not yet accepted a position or made a decision. Of the 1,826 graduates who had made placement decisions at the time of the survey, 77.1% indicated that they accepted full-time positions (primarily in industry), and 22.9% stated that they were entering graduate school. This information is detailed by department in Table D-9. With two exceptions, the percentage of bachelor degree graduates taking full-time positions from all departments ranged between 75.6% (aeronautical engineering) and 86.3% (electrical engineering). The majority of bachelor degree graduates in chemistry and physics (78.6% and 70.1% respectively) continued their academic work toward advanced degrees. The number and percentage of Institute of Technology bachelor degree candidates planning to take graduate work have steadily increased from 1960-1961 to 1964-1965, as shown in Table D-10.

Of the 1,408 bachelor degree graduates indicating, in the survey, an acceptance of a full-time position at the time of graduation, 48.5% were with establishments located in Minnesota (43.7% in the Twin Cities, and 4.8% at other Minnesota locations).

Evening Graduate Program in Electrical Engineering

This program, established in 1961, enables graduate engineers of sponsoring firms to complete the requirements for a master's degree in three years by attending evening classes. Under the program, which offered 33 courses in the academic year 1964-1965, a student can complete a major with emphasis in some particular areas, such as control theory. When the demand for particular courses is insufficient to warrant evening courses, such as solid state devices, desired courses can often be taken during the late afternoon hours.

Table D

DEGREES CONFERRED IN FIELDS RELEVANT T
SELECTED A
1962-19

Relevant Fields*	United States Bachelor's	United States Master's	United States Ph.D.	Minnesota Bachelor's	Minnesota Master's	Minnesota Ph.D.	Arizona Bachelor's	Arizona Master's
Total all fields	450,592	91,418	12,822	10,162	1,360	314	3,565	986
Percent of U.S.	100.0%	100.0%	100.0%	2.3%	1.5%	2.4%	0.8%	1.1%
Relevant fields, as percent of U.S.	Total Degrees Conferred							
Engineering	33,458	9,635	1,378	1.1%	1.2%	2.1%	0.8%	1.0%
Physics	4,785	1,567	752	2.5	1.1	1.1	0.2	1.1
Math & statistics	16,121	3,323	490	2.6	0.7	2.2	0.5	0.9
Total relevant	54,264	14,525	2,620	1.7	1.1	1.8	0.7	1.0
Relevant fields, as percent of all fields								
Engineering	7.4%	10.5%	10.7%	3.5	8.7	9.2	8.0	9.9
Physics	1.1	1.7	5.9	1.2	1.3	2.6	0.3	1.7
Math & statistics	3.5	3.6	3.8	4.2	1.7	3.5	2.0	3.2
Total relevant	12.0%	15.8%	20.4%	8.9%	11.7%	15.3%	10.3%	14.8%

* Relevant fields are considered to be engineering, physics, mathematics and statistics; professionals in R&D defense centers previously studied.

Source: U.S. Office of Education, "Earned Degrees Conferred, 1962-63."

Table D-8

ELEVANT TO THE DEFENSE R&D INDUSTRY--
ELECTED AREAS
1962-1963

	Arizona		California			Colorado			Massachusetts		
	Master's	Ph.D.	Bachelor's	Master's	Ph.D.	Bachelor's	Master's	Ph.D.	Bachelor's	Master's	Ph.D.
	986	66	34,489	7,826	1,307	6,164	1,843	239	19,501	5,535	946
%	1.1%	0.5%	7.7%	8.6%	10.2%	1.4%	2.0%	1.9%	4.3%	6.1%	7.4%
	Percent of Total U.S. Degrees Conferred										
%	1.0%	0.1%	8.1%	13.2%	14.8%	1.5%	1.6%	1.0%	5.1%	8.6%	12.2%
	1.1	0.3	8.6	7.9	17.0	0.7	1.0	2.3	6.7	5.0	9.7
	0.9	0.4	5.4	6.2	12.0	1.0	1.4	0.7	3.8	4.1	6.9
	1.0	0.2	7.3	11.0	14.9	1.3	1.5	1.3	4.9	7.1	10.5
	9.9	3.0	7.8	16.3	15.6	8.1	8.4	5.9	8.8	14.9	17.8
	1.7	3.0	1.2	1.6	9.8	0.6	0.9	7.1	1.6	1.4	7.7
	3.2	3.0	2.5	2.6	4.5	2.6	2.5	0.8	3.1	2.4	3.6
%	14.8%	9.0%	11.5%	20.5%	29.9%	11.3%	11.8%	13.8%	13.5%	18.7%	29.1%

atistics; these are the degree fields for over 80% of the more than 30,000 technical

BLANK PAGE

Table D-9

PLACEMENT OF BACHELOR DEGREE GRADUATES FROM INSTITUTE OF TECHNOLOGY, BY DEPARTMENT
1960-1965

	No. of Graduates			% of Total to Industry & Grad. School	
Department	Total Number	% U.S. Total	No. to Industry & Grad. School	Industry	Grad. School
Aeronautical Eng.	188	1.7%	131	75.6%	24.4%
Agricultural Eng.	37	1.6	21	76.2	23.8
Architecture	142	1.8	45	84.4	15.6
Chemical Eng.	200	1.1	158	79.7	20.3
Chemistry	111	0.3	70	21.4	78.6
Civil Eng.	232	0.8	181	86.2	14.8
Electrical Eng.	693	1.1	591	86.3	14.7
Mathematics	65	*	51	82.1	17.9
Mechanical Eng.	523	0.9	406	85.7	14.3
Mines & Metallurgical Eng.	83	1.0	55	76.4	24.6
Physics	145	0.5	117	29.9	70.1
Total	2,419	0.9%‡	1,826†	77.1%‡	22.9%‡

* Not comparable with U.S. totals.

† To this number, add the following to get total: 144 going into armed forces; 197 undecided at time of survey; and 252 not responding.

‡ Average %.

Source: University of Minnesota.

Table D-10

DISTRIBUTION OF UNIVERSITY OF MINNESOTA
BACHELOR DEGREE ENGINEERING GRADUATES
1960-61 through 1964-65
(Earlier Years Included for Comparison)

Academic Year	Location of Employment						Other Destinations		No Response or Undecided†	Total Graduates
	Twin Cities	Other Minn.	Total Minn.	Other Loca-tions	All Loca-tions	% Minn. to Total	Armed Forces	Graduate School		
1920-21*	n.a.	n.a.	58	94	152	38%				
1930-31*	n.a.	n.a.	164	110	274	60				
1937-38*	n.a.	n.a.	170	141	311	55				
1960-61†	89	5	94	124	218	43	15	49	101	383
1961-62†	118	17	135	124	259	52	32	45	79	415
1962-63†	96	9	105	128	233	45	27	54	45	359
1963-64†	81	13	94	78	172	55	23	116	40	351
1964-65†	94	11	105	128	233	45	17	124	28	402
Annual Average 1960-61/1964-65	96	11	107	116	223	48				

n.a. = not available.

* At June 1940.
† At time of graduation.

Sources: J. G. White Engineering Co., Economic Analysis of the State of Minnesota, 1945; University of Minnesota.

The average quarterly enrollment in the program has been:

Academic Year	Average Quarterly Enrollment
1961-1962	40
1962-1963	50
1963-1964	114
1964-1965	178

The companies which have provided partial financial support of the program and the average yearly enrollments by sponsoring company are shown in Table D-11.

Evening Graduate Program in Business Administration

Another evening graduate program established at the University of Minnesota in recent years has been the Master of Business Administration (MBA) evening program. For the period 1960-1961 through 1964-1965, a total of 477 students from more than 120 Twin Cities establishments have been admitted to the program. Significantly, 182 (40%) of those admitted to the program had engineering or science undergraduate degrees. About two-thirds of those enrolled for 1964-1965 had engineering or science undergraduate degrees. Through the academic year 1964-1965, there have been 41 MBA graduates from the program. Nine (22%) of these had engineering or science undergraduate degrees. Technical companies represented in the program and the total number of students from these companies admitted to the program are shown in Table D-12.

Table D-11

ENROLLMENT BY COMPANY IN UNIVERSITY OF MINNESOTA EVENING GRADUATE PROGRAM IN ELECTRICAL ENGINEERING
Academic Years 1961-62 through 1964-65

Sponsoring Company	1961-62	1962-63	1963-64	1964-65	4-Year Total
Electro-Mechanical Res., Inc.*				1	1
Control Data Corp.	6	5	21	28	60
Electro-Nuclear Systems Corp.†	3	1			4
Fabri-Tek, Inc.				1	1
General Mills, Inc.	3	1		1	5
Honeywell, Inc.	17	29	56	84	186
IBM (mainly Rochester plant)			10	21	31
Magnetic Controls Co.	1			1	2
Mayo Clinic, Rochester			1		1
Medtronics, Inc.					
Minnesota Mining & Mfg. Co.		1	3	3	7
Northern Ordnance Div., FMC Corp.			1	2	3
Northern States Power Co.			1	1	2
Onan Div., Studebaker Corp.					
Rosemount Engineering Corp.				1	1
Univac Div., Sperry Rand Corp.	10	13	21	34	78
Total	40	50	114	178	382

* Advanced Scientific Instruments Div.
† No longer in business.

Source: University of Minnesota.

Table D-12

ENROLLMENT IN UNIVERSITY OF MINNESOTA
EVENING GRADUATE PROGRAM IN BUSINESS ADMINISTRATION

Company	Employees Admitted: E/S's	Employees Admitted: Other Backgrounds	Employees Graduated: E/S's	Employees Graduated: Other Backgrounds
Control Data Corp.	22	13		
Donaldson Co.	3	1		
General Mills	10	21		
Honeywell, Inc.	55	59	6	7
Litton Industries	2			
Minnesota Mining & Mfg. Co.	21	10	1	1
Northern States Power Co.	6	3		1
Northwestern Bell Tel. Co.	3	3		
Rosemount Engineering	3			
Univac Div., Sperry Rand Corp.	14	9	1	
Westinghouse Corp.	2			
Whirlpool	5	2		
All other establishments	36	174	1	23
Total	182	295	9	32

Seminars

During the period July through early September 1965, the Institute of Technology and the Center for Continuation Study of the University of Minnesota presented a series of one-day and two-day seminars on engineering and scientific topics:

- Industrial Uses of Nuclear Energy
- Modern Methods in Circuit Analyses
  - Pole-zero Techniques
  - Flow-Graph and Matrix Techniques
- Modern Control Theory
- Modern Methods of Data Presentation and Analysis
- Modeling and Models in Problem Solving
- Transistor Switching Circuits
- Random Processes in Engineering Systems
- Value Engineering
- Dynamic Programming--Concepts and Applications
- High Vacuum Technology
- Electron Mirror Microscopy
- Application of Mass Spectrometry
- Magnetohydrodynamics
- Computer-Assisted Problem Solving

Advance registrations on July 23, 1965 totalled 260 for the 15 sessions. Summarized, the registrants orginated as follows:

Minnesota Registrants	No. of Advance Registrations
Univac Div., Sperry Rand Corp.	75
Honeywell, Inc.	53
Control Data Corp.	28
Northern States Power Co.	20
Fabri-Tek, Inc.	10
IBM, Rochester	10
Minnesota Mining and Mfg. Co.	9
Onan Div., Studebaker Corp.	8
Applied Sciences Div., Litton Industries	2
Telex Corp.	2
Other establishments	21
Total Minnesota registrants	238
Out-of-state registrants	22

Other Courses

In addition to the foregoing special courses and seminars provided by the University of Minnesota, the General Extension Division offers evening degree-credit classes in engineering and physical and technical sciences. In 1964-1965, 51 undergraduate and 18 graduate courses were offered in these fields.

To determine the extent to which employees of Twin Cities technical companies participated in this program, 22 undergraduate courses and 14 graduate courses for 1964-1965 were analyzed:

In the 22 undergraduate courses, there were 600 registrations, with 507 (85%) completing the course. In the 14 graduate courses, there were 730 registrations, with 681 (93%) completing the course.

Department	No. of Courses	Total Regist.	Completion No.	Completion Percent
Undergraduate				
Electrical Eng.	9	222	208	94%
Mechanical Eng.	4	68	50	74
Mechanics/ Materials	4	112	83	74
Physics	5	198	166	83
Total	22	600	507	85%
Graduate				
Electrical Eng.	6	176	171	97
Mechanical Eng.	2	32	29	91
Mathematics	6	552	481	87
Total	14	760	681	90%

Twin City technical companies supplied the majority of registrants for these 36 engineering and science courses.

Technical Company	Number of Registrants Undergraduate	Number of Registrants Graduate
Honeywell, Inc.	133	125
Univac Div., Sperry Rand Corp.	37	108
Control Data Corp.	44	85
Minnesota Mining & Mfg. Co.	43	41
Donaldson Co.	15	10
McQuay, Inc.	18	2
General Mills, Inc.	7	12
Applied Sciences Div., Litton Ind.	4	8
Other technical companies	64	49
Total company registrations	365	440
Percent of total registrations	61%	60%

Instructors from local technical companies were used for 40% of the 36 courses analyzed.

Department	Undergraduate Courses: Total No. of Courses	Undergraduate Courses: Industry Instructors	Graduate Courses: Total No. of Courses	Graduate Courses: Industry Instructors
Electrical Eng.	9	9	6	2
Mechanical Eng.	4	0	2	0
Mechanics/Materials	4	0	-	-
Physics	5	3	-	-
Mathematics	-	-	6	0
Total	22	12	14	2

Local companies supplying evening instructors for University of Minnesota technical classes during the academic year 1964-1965 were:

Honeywell, Inc.
Control Data Corp.
Univac Div., Sperry Rand Corp.
Northern States Power Co.
Electric Machinery Mfg. Co.

Advice and Consultation

As stated in the University of Minnesota faculty handbook, the Board of Regents has adopted the following policy with respect to outside consulting by faculty members:

> "No full-time member of the faculty shall receive from any outside source either an annual retaining fee or a regular salary unless the arrangement has been approved by the staff member's department head and the Board of Regents. The rule applies to such things as consultantships or other teaching appointments, but not the writing of books, articles or occasional speeches."

During the six-year period of 1960 through 1965, 211 Institute of Technology faculty consulting agreements were approved by the University Board of Regents. Table D-13 summarizes the number of consulting agreements in terms of departments of the Institute of Technology.

Membership on Company Boards of Directors

University of Minnesota faculty are permitted to serve on company boards of directors with the approval of the Board of Regents. As stated by the University of Minnesota Office of the Vice President for Academic Administration: "There is no written or unwritten policy pertaining to

Table D-13

INSTITUTE OF TECHNOLOGY FACULTY CONSULTING AGREEMENTS APPROVED
1960-1965

Departments	1960 T.C.*	1960 Other†	1961 T.C.	1961 Other	1962 T.C.	1962 Other	1963 T.C.	1963 Other	1964 T.C.	1964 Other	1965 T.C.	1965 Other	Totals T.C.	Totals Other
Aeronautical Eng.				3		5	3	5	1		1	6	5	19
Chemical Eng.	1	2				2			1	1		2	2	7
Chemistry	1	1	1	3	2	1	1	2		2	1	5	6	14
Civil Eng.							2	2			2		4	2
Electrical Eng.	4	3	7	1	7	2	6	2	7	6	4		35	14
Mathematics								1				1		2
Mechanical Eng.	1	4	2	7	3		2	1	4	2	5	5	17	19
Mines/ Metallurgy	1	1	1		2	1	3	4	3	3	1	7	11	16
Physics	1	2	—	9	1	5	1	5	1	7	—	6	4	34
Total	9	13	11	23	15	16	18	22	17	21	14	32	84	127
Establishments related to defense, space, atomic energy	5	9	7	19	8	9	12	12	10	11	6	18	48	78

* T.C. = Twin Cities establishments.
† Other = other establishments.

Source: University of Minnesota.

University faculty serving as officers of companies, except as these instances would be included under the policy regarding the need for Board of Regents approval of each such situation. Each such instance would involve the certification of the department and the college unit involved that the work could be undertaken without detriment to the faculty member's obligations to his department and his college, and individual consideration by the Board of Regents in order that it is clear that such service is to the advantage of the University and does not involve a conflict of interest."