Technology Development and Transfer:

A Study of the Process at The

General Motors Technical Staffs

by

Milton Baker

B.S., Lehigh University
(1969)

Submitted to the Alfred P. Sloan School of Management
and the School of Engineering
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE
IN THE
MANAGEMENT OF TECHNOLOGY

at the

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

MAY 1986

Signature redacted

Signature of Author: ______________________
Alfred P. Sloan School of Management
May 1, 1986

Signature redacted

Certified by: ______________________
Edward B. Roberts
Thesis Supervisor

Signature redacted

Accepted by: ______________________
Jeffrey A. Barks
Associate Dean Master's and Bachelor's Programs

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Submitted to the Alfred P. Sloan School of Management and the School of Engineering on April 28, 1986 in partial fulfillment of the requirements for the degree of Master of Science in the Management of Technology

ABSTRACT

The domestic automotive industry is facing increasing competitive pressure from foreign manufacturers. Rising import penetration has been eroding domestic market share.

This paper begins by examining the premise that technology plays an important role in the competitive process in the automotive industry, and concludes that technology is a key strategic variable for the industry.

Having established the importance of technology to the automotive industry, this paper examines how some other successful companies develop and transfer technology. Two other companies were chosen for comparison, IBM Corporation as a large firm with technology and manufacturing operations on a scale comparable to General Motors, and Intel Corporation as a company preeminent in the development of technology. The paper then discusses technology development and transfer at the General Motors Technical Staffs.

The paper develops information on technology development and transfer at the General Motors Technical Staffs, IBM Corporation, and Intel Corporation, primarily through interviews with key technical executives at each company. The interviews are supported by additional research on technology development and transfer, and coursework from the Management of Technology Program at M.I.T.

The conclusion of this thesis is a set of recommendations for how the General Motors Technical Staffs can improve the technology development and transfer process in order to continue to contribute to the future success of the corporation.

Thesis Supervisor: Edward B. Roberts
Title: David Sarnoff Professor of Management of Technology, Sloan School of Management

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CHAPTER 1

INTRODUCTION

1.1 Objective

The objective of this thesis is to develop a set of recommendations for how the technology development and transfer process used by the General Motors Technical Staffs can be improved.

The thesis seeks to accomplish this objective by defining the role and mission of the groups that comprise the General Motors Technical Staffs. From this analysis a set of barriers to the technology development and transfer process has been suggested. These barriers are by no means unique to General Motors Corporation. Similar barriers have been found to exist at other large corporations and the results may be generalizable.

The conclusion of the paper recommends practices to overcome some of the barriers to technology development and transfer that exist at the General Motors Technical Staffs.

1.2 Organization and Methodology

This thesis lays the groundwork for a discussion about technology development and transfer by examining the relevance of technology to the automotive industry. A separate chapter addresses the barriers to technology and innovation that exist in the industry.

The thesis then examines technology management at other successful firms. This information is based on interviews with key technical executives from IBM Corporation and Intel Corporation, library research, and coursework from the Management of Technology Program at M.I.T.

IBM Corporation was chosen for study as a large corporation with technical activities and manufacturing on a scale with General Motors. Intel Corporation was chosen as a company preeminent in the area of technology development.

The paper divides the discussion of technology management into three sections: technology strategy, technology development, and technology transfer. Examples of successful practices are given in each area.

The paper then presents information on the mission, role, and interaction of the groups that comprise the General Motors Technical Staffs. Once again, interviews were used along with research. Executives of three of the Technical Staff groups were interviewed, as well as three executives who are not on the Technical Staff. A complete list of interviewees is provided in Table 1.

From these interviews and research, a set of barriers to the technology development and transfer process at the General Motors Technical Staffs is suggested. These barriers were grouped into general areas. The recommendations of the paper apply the successful practices developed in the thesis to the General Motors Technical Staffs. A matrix is provided which relates the recommended practices to the barrier areas.

The implementation of these recommendations, it is hoped, will enable the Technical Staffs to make an even greater contribution to the future of success of the corporation.

Table 1: Executives Interviewed During Thesis Research

General Motors Corporation

Executive	Title
Mr. Robert J. Schultz*	President, Delco Electronics Corp.
Mr. Charles J. Brady	Vice President, CEMS Staff
Dr. Robert A. Frosch	Vice President, Research Laboratories
Mr. William D. Route	Director, Advanced Product Engineering
Mr. Robert J. Templin	Director, BOC Advanced Engineering
Mr. Kenneth R. Baker	Director, CPC Advanced Engineering
Dr. Nils L. Meunch	Technical Director, Research Laboratories
Dr. James C. Holzwarth	Director Research Laboratories
Dr. Charles J. Tracy	Chief Engineer, Solid State Devices, Delco Electronics

IBM Corporation

Executive	Title
Dr. Lewis Branscomb	Chief Scientist
Mr. Vladimir Chernoshov	Silicon Gate Product Manager
Mr. Paul Calhoun	Silicon Gate M.E. Manager
Mr. Paul Farrar	Senior Engineering Technical Staff

Intel Corporation

Executive	Title
Mr. Alan Baldwin	Technology Exchange Manager
Mr. Robert Lyon	International Human Resources Manager
Dr. Richard Pashley	Director California Technology Development

*Now Vice President and Group Executive CPC.

1.3 Definition of Technology

Before beginning a discussion of the technology development process, it is appropriate to define the term "technology". Horwitch and Friar define technology as "the ability to create a reproducible way for generating improved products, processes and, services."[1] This is an appropriate definition for this thesis as it applies technology to all areas not just to new products. Technology as viewed by this paper includes product and process improvements, as well as improved services, tools and techniques, and new management systems.

Technology development should be viewed from an integrated systems perspective. Schoen, recognizing the systems nature of the technology development process, writes "technology development is the total process by which companies translate a technological advance, an idea or an invention into products, processes, or services."[2] Abernathy, Clark, and Kantow discuss the "hardware" aspects (equipment, buildings, and machinery) and "software" aspects of technology (people management, organizational systems, and corporate strategies) as a basis for a systems approach.[3] This concept is embodied in the new General Motors Saturn project, described as not just a new car but a new way of doing business.

Barriers to the technology development process are not based on technology problems alone. If the people systems, and business systems are not improved in a corresponding manner, difficulties may be encountered. The best new product technology is diminished by process technology and people systems that are not ready for the new technology. For example, the M.I.T. Management in the 1990s Program estimates that technology changes faster than people's ability to assimilate the new technology.[4] This gap is a barrier to the technology process.

A practical example of this is provided by Lewis Ross, an executive of the Ford Motor Company. Speaking about the potential of new technology for the auto industry, he raised the issue of the serious mismatch of available technical skills with current technology. Three-fourths of his company's engineers have had no previous experience with CAD/CAM and are going back to school to learn.[5]

In summary, technology viewed from a system perspective affects the firm's products, processes, and services. The interrelationship among the firm's products, processes, and services is the management system that the firm employs. This paper focuses on management systems, both people management and business management, that can improve the system of technology development and transfer for the firm.

CHAPTER 1

FOOTNOTES

1. Horwitch, Mel, and Friar, John, "The Emergence of Technology Strategy, A New Dimension of Strategic Management," Technology in Society, Volume 7, 1985, p. 2.

2. Schoen, Donald R., "Managing Technological Innovation," Harvard Business Review, May-June 1969, p. 156.

3. Abernathy, William J., Clark, Kim B., and Kantrow, Alan M., "The New Industrial Competition," in Kantrow, Alan M., Survival Strategies for American Industry, John Wiley & Sons, Inc., 1983, p. 77.

4. Mirvis, Phillip, H., "The Implementation and Adoption of New Technology in Organizations," Massachusetts Institute of Technology Management in the 1990s Working Paper, December, 1985, p. 4.

5. Wards 1985 Automotive Yearbook, Detroit, Michigan, p. 7.

CHAPTER 2

THE IMPORTANCE OF TECHNOLOGY TO THE AUTO INDUSTRY

It is necessary to establish the importance of technology to the automotive industry as a prelude to discussing how technology may be better developed and transferred. If technology is not important to the auto industry or the firm, an exercise that studies it and suggests improvements will be seen as having little value.

The domestic automotive industry is under intense pressure from foreign competition. Sales data from Figure 1 show that from the period 1973 to 1985 domestic market share has been falling, while the foreign market share has increased.

For the period 1973-1985 total vehicle sales averaged 9.82 million units. In the same period import sales increased from 14.9% of the market to 28.3%, with unit import sales increasing from 1.7 million units to 3 million units.

It may be asked, is some portion of this market erosion related to technology? This thesis develops and supports the position that the competitors view technology as a key strategic variable.

Figure 1

DOMESTIC AND IMPORTED VEHICLE SALES IN THE U.S.
(Period Covered: 1973-1985)

Year	Domestic (%)	Import (%)	Total Units (millions)
1973	85.1	14.9	11.4
1974	84.1	15.9	8.8
1975	81.3	18.6	8.6
1976	85.1	14.9	10.1
1977	81.2	18.8	11.2
1978	82.3	17.7	11.3
1979	78.3	21.7	10.6
1980	73.3	26.7	9.0
1981	73.0	27.0	8.5
1982	72.5	27.5	8.0
1983	74.0	26.0	9.2
1984	77.0	23.0	10.4
1985	71.7	28.3	10.6
1988 (est.)	62.6	37.4	10.7

Source: Wards 1985 Automotive Yearbook Detroit, Mich., p. 10.

Horwitch and Friar describe technology as a key strategic variable for the firm.[6] A strategic variable is defined as one that can alter the basis for competition in an industry. Horwitch and Friar trace the rise of technology as a strategic variable for the firm to five historical factors. Two of these, the high priority given to technology by foreign competition and a rise in the importance of manufacturing, bear directly on the auto industry.

Dr. Bruce Rubinger, writing about research and development at Toyota, notes that the perception of technology as a strategic variable is pervasive in Japanese industry.

> The Japanese auto industry has served as a technology-driver for the Japanese economy. It continues to play this pivotal role as a producer and consumer of advanced technology as Japan's industrial structure evolves toward high technology. For instance, the industry currently consumes 10% of all integrated circuits and 20% of all robots.
>
> Toyota Motor Company is actually a high-technology firm as measured by traditional indices. For instance, during the early 1980's Toyota had the largest R&D budget of any Japanese firm, though it yielded this position to Hitachi in 1984. With aggregate expenditures of 190 billion yen in fiscal year 1984, Toyota's R&D budget greatly exceeds that of Toshiba, Fujitsu, or Matsushita, firms widely acknowledged as technical leaders in intensely competitive high tech sectors.[7]

Rubinger continues

> As a result of its ability to balance the requirements of technical innovation with 'bottom line' performance, Toyota has emerged as a technological leader and is reported to be the most profitable Japanese corporation listed on the Tokyo stock exchange.[8]

As the world automotive market becomes increasingly competitive, manufacturers are using technology to capture competitive advantage in both products and processes. Two of the defendable competitive strategies developed by Michael Porter[9], low cost and differentiation, are present in the high volume automotive market segment.

Technology is important for each of these strategies. With the low cost strategy new design process and business systems can provide a lower cost product as a competitive advantage. Low cost is a competitive advantage in two ways. If a manufacturer can sell at the market price and produce at lower cost than the competition, a competitive profit advantage can be developed. If the manufacturer produces at a lower cost and sells below the market prices, a competitive advantage in sales can be gained. In the cost of production area, the domestic auto manufacturers have been at a competitive disadvantage. Studies by several groups estimating the manufacturing cost differential (MCD) between Japanese and American manufacturers have estimated the MCD to be $1300 to $1973 favoring the Japanese. Figure 2[10] shows four of these estimates.

Figure 2

Author	MCD Estimate
Abernathy, Clark, Kantrow	$1304-$1973
Abernathy, Harbour, Henn	$2050
Ford Motor Company	$1800
Harbour (DOT)	$2488

Although the magnitude of the MCD may be disputed, the direction is not.

Technology can be a driving factor in the second of Porter's sustainable strategies, differentiation. Advanced features offering additional functions, reliability, quality, safety, performance, economy, etc., can be used to separate a particular product from the pack. An example of this might be a passenger car with four-wheel drive. A mixture of both strategies, producing at a lower cost and adding more features at a given market price may be a particularly difficult strategy to overcome.

As evidence that this strategy is being used, Abernathy, Clark, and Kantrow write

> The productive capacity of some new entrants enjoys a significant cost advantage over that of the Americans. The Japanese have been especially skillful in exploiting this advantage by adding performance and quality to their cars. This combination of competitive price and high quality has been tremendously successful in reaching consumers in the American market.[11]

The Japanese automotive technological agenda, as reported in <u>High Technology</u>[12] describes future technology being developed for the Japanese automotive industry including twenty four valve engines, fiber reinforced aluminum alloys, continuously variable transmissions, navigation systems, backup sonar systems, artificial intelligence for fault detection, and ceramic engines, the latter offering the potential for significant fuel economy and weight advantages.

Abernathy, Clark, and Kantrow trace the historical rise in the importance of technology to the industry.

> In the 1950s and 60s, product technology was competitively neutral. Except perhaps for their reliance on economies of scale...[American producers] tended to compete by means of styling, marketing, and dealership networks. In the 1980s, however, the necessity for advantage through innovation is steadily growing.[13]

> In a time of expensive energy, by their success in the marketplace, Japanese producers have rekindled interest in the automobile as a product and thus have offered the way for technology to be a relevant basis of competition in the American market. Technological innovation in its radical as well as incremental form again has vital, competitive significance.[14]

In discussing manufacturing systems alone, Abernathy, Clark, and Kantrow estimate that 17% of the productivity difference between Japanese and U.S. producers is in design and process technology.[15] If process yield is also labelled technology relating to methods, practices, operating patterns and quality controls, this accounts for another 49% of the difference in productivity between U.S. and Japanese manufacturers, a total of 66% of the difference can be attributed to technology; the remaining 34% is attributed to work force management differences.

Abernathy, Clark, and Kantrow offer the following conclusions regarding revitalization of the industry.

> The following factors are the prime elements in the renewal of the auto industry: (1) an increasing premium in the marketplace on innovation, (2) a growing diversity in the technology of components and production processes, and (3) an increasingly radical effect of factors 1 and 2 on long established configuration in the productive unit as a whole.[16]

Having established the importance of technology to the auto industry, the next section discusses some of the barriers to technology that exist in the industry.

CHAPTER 2

FOOTNOTES

6. Horwitch, Mel, and Friar, John, op. cit., p. 3.

7. Rubinger, Bruce, "Toyota's Approach to R&D: Decision-Making, Organization and Technical Goals," preprint, to be published in Technology in Society, Volume VII, Nos. 2 & 3, 1985, p. 2.

8. Rubinger, Bruce, op. cit., p. 3.

9. Porter, Michael E., Competitive Strategy, The Free Press, New York, NY, 1980, p. 35.

10. Cole, Robert and Yakushiji, Taizo, The American and Japanese Auto Industries in Transition, Center for Japanese Studies, University of Michigan, Ann Arbor, MI, 1984, p. 131.

11. Abernathy, Clark, and Kantrow, op. cit., p. 76.

12. High Technology, August 1985, p. 36.

13. Abernathy, Clark, and Kantrow, op. cit., p. 76.

14. Abernathy, Clark, and Kantrow, op. cit., p. 87.

15. Abernathy, Clark, and Kantrow, op. cit., p. 84.

16. Abernathy, Clark, and Kantrow, op. cit., p. 89.

CHAPTER 3

BARRIERS TO TECHNOLOGY IN THE AUTO INDUSTRY

A major barrier to the introduction of new technology in the auto industry is described by William Abernathy.[17] In modeling the maturity of the industry, Abernathy characterizes the early period as one where many different designs were competing in the marketplace. There were steam engined vehicles, electric powered vehicles, and gasoline powered vehicles. This early period was characterized by a high rate of product innovation, low production runs, and a very flexible manufacturing process.

As the industry continued to mature, a dominant design emerged. This is a design which is most favored in the marketplace. Most manufacturers began to produce the dominant design which was the gasoline powered, closed steel body, automobile.

From this point the emphasis in the industry began to switch from product innovation, which became less of a factor due to the dominant design, to process innovation. Manufacturers began to compete on the basis of cost. The flexible manufacturing "job-shops" were gradually replaced with assembly lines of specialized equipment.

Process innovation led to the development of highly capital intensive, specialized, high volume processes to reduce cost. These processes, such as automated machining and transfer lines, are tailored to a specific product and represent a major barrier to innovation. Every decision to innovate may involve obsoleting a high volume process at very high cost. This investment is sometimes referred to as the "in-place tooling capacity."

Abernathy and Utterback[18] have generalized this result arguing that this cycle of maturity exists in many industries. The pattern of maturity in the semiconductor industry parallels the automotive industry; early emphasis was on innovation and, as the industry matured, competition moved to process technology in the high volume "merchant" semiconductor market.

A second barrier to the introduction of new technology in the auto industry has been the marketplace.

> In 1973, when Lee A. Iacocca was asked about the competitive advantage of innovation as perceived by Ford, he responded, 'Give them (American consumers) leather. They can smell it.' In Ford's reading of the U.S. market, innovation did not pay; styling did.[19]

Key success factors for the industry were to be able to design an attractive product and be able to change the sheet metal exterior on a somewhat annual basis.

As can be seen the success factors for the industry in the 1980s and 1990s will be very different from the ones that existed in the 1950s and 1960s. Technology is being demanded in the marketplace and the industry's investment in high volume tooling is a barrier to the introduction of new technology.

Successful technology management practices will contribute to more rapid introduction of new products, processes, and services, and a reduction of barriers to innovation. The next chapter of the thesis examines successful technology management practices used by other firms.

CHAPTER 3

FOOTNOTES

17. Abernathy, William, J., The Productivity Dilemma Roadblock to Innovation in the Automobile Industry, The Johns Hopkins University Press, Baltimore, Maryland, 1978.

18. Abernathy, William J. and Utterback, James M., "Patterns of Industrial Innovation, or How to Make Things Happen," Editors of Technology Review, p. 58.

19. Abernathy, Clark, and Kantrow, op. cit., p. 76.

CHAPTER 4

A STUDY OF TECHNOLOGY MANAGEMENT

This chapter attempts to describe successful technology development and transfer practices. A question that may be asked at the outset is what constitutes the criterion for judging a practice successful?

This thesis began by studying successful companies. From interviews with executives of these companies, research, case studies, and coursework from the M.I.T. Management of Technology Program, common practices emerged. These practices are seen to be common among successful companies not only in the United States but also Japan.

These common practices used by successful companies are described in detail in this thesis. The thesis defines these common elements as successful technology development and transfer practices. The empirical information is supplemented with theoretical explanations when available.

4.1 Technology Strategy

A key concept in the management of technology, is the development of a technology strategy for the firm. A technology strategy is an organized, long-term plan for technology development and implementation by the firm.

The strategic plan for the corporation defines what business the company is in and the areas where the firm seeks to sustain a competitive advantage. Michael Porter has defined techniques for developing a strategic plan.[20]

The technology strategy supports the strategic goals and objectives for the firm. As Kantrow writes, "Technology bears an integral relationship to a company's strategic thinking by helping to define its range of possibilities. At the same time it provides a good portion of the means by which a strategy once decided upon is to be carried out."[21]

The objectives of a technology strategy are to define the key technologies that will be important for the future of the business, and to plan for the development of these key technologies.

A technology strategy is important to the firm for several major reasons. First of all, through the technology strategy, the product and research groups reach a general consensus on what technologies are important for the future. These technologies form the basis for research and development projects.

An example of goal congruence driven by a technology strategy is discussed in-depth in the IBM example section 4.1.1. This goal congruence between research and downstream users, achieved through the vehicle of a technology strategy, is seen as having significance in the transfer of technology.

The second reason a technology strategy is important is for managing the firm's technology development process using both inside the firm, and outside sources for technology.

Horwitch and Friar[22] have developed a three dimensional model which helps to visualize this concept. This model is shown in Figure 2.

Technology development can be viewed with respect to the three axes shown in the figure: structure, domain, and competition. Large corporations have tended to develop technology internally (in-house), and competitively (privately), viewing technology development as a point at the origin of this three dimensional space. However, a host of new alternatives exist.

Large companies can seek to capture more of the entrepreneurial spirit and closeness to the market of small companies by forming independent business units.

Corporations can develop technology externally by acquisition of firms with needed technology, contract research, licensing, strategic alliances with smaller technology companies, and university research.

Corporations can also develop technology cooperatively through joint ventures, research consortiums like The Microelectronics and Computer Technology Corporation (MCC)

3 Axis Model
For Technology Development

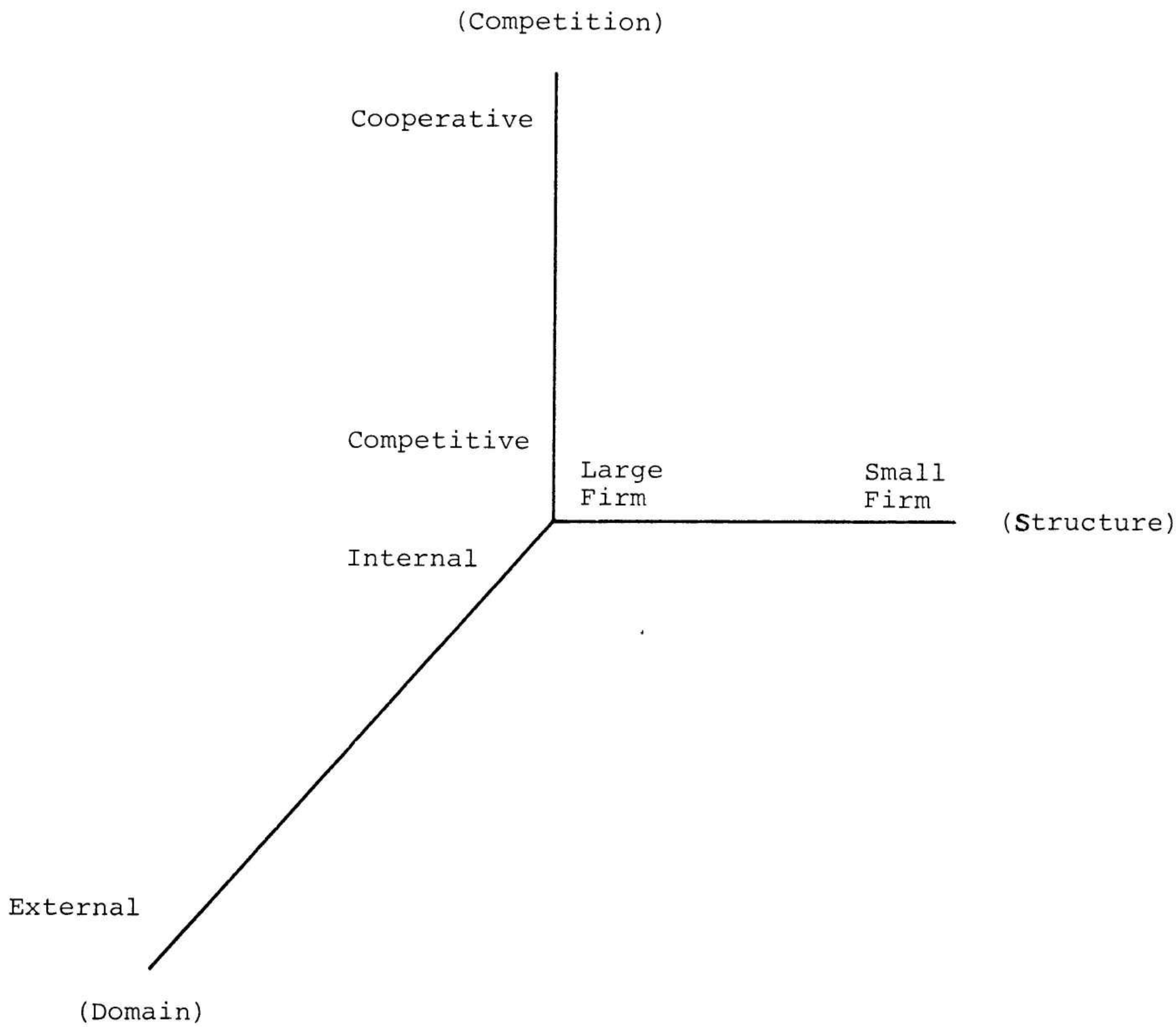

Figure 2

and the Semiconductor Research Corporation (SRC); and through R&D partnerships.

The technology strategy determines the appropriate path for technology development once the goals of the firm have been established. Some technology can be developed internally; some can be developed externally or cooperatively.

With this range of possibilities a management tool to channel resources to a common goal is required. If technology is to be managed, it must have a plan which is consistent with the firm's business objectives. "Managers [should not] treat decisions about technology as a sole responsibility of technical experts or as the indifferent residue of their own in-baskets."[23]
A technology strategy is seen as this type of plan. A senior executive or committee may have the job of monitoring the progress of the technology strategy.

Successful technology management can be a significant competitive advantage. Consider a large firm that defines technological objectives and then finds small firms with some of the needed technology. This technology may be acquired and brought to market quicker than a competitor who seeks to develop the same technology. In effect, the technology is developed before the window of opportunity closes.

4.1.1.Technology Strategy: IBM Example

An interesting example of technology strategy is provided by the IBM Corporation. IBM many years ago created the post of Chief Scientist who reports to the Chairman of the Board. Currently this position is held by Dr. Lewis Branscomb. Dr. Branscomb describes his mission as "guiding the scientific and technological activity of the company for the long term."[24]

The Chief Scientist is responsible for steering the technical effort of the company in support of its business goals. Dr. Branscomb describes the business goals in two categories:

1) to be the performance and function leader at the high end of the market
2) to be the low cost leader at the low end of the market

The Chief Scientist functions with a Corporate Technical Committee (CTC) which is comprised of six preeminent technologists representing various IBM locations. Typically, one-half of the committee is composed of IBM Fellows, the most prestigious technical title in the corporation. This committee of six serves the Chief Scientist for one year, after which the personnel are reassigned and a new group of six members is chosen.

The Chief Scientist and Corporate Technical Committee function as an exception mechanism to the planning of the IBM line and staff organizations, making sure the proper long-range tradeoffs are made. It should be noted that the Chief Scientist has no formal authority over the division and staff organizations. However the reporting path to the Chairman of the Board conveys power to this position.

Division and staff planning is reviewed yearly. In this review the CTC attempts to determine what areas of the business have been satisfactorily planned for the future, and in what areas the technical efforts of the corporation are in need of improvement. This determination is made by translating future product needs into technology requirements. These required technologies form the basis for a technology strategy.

For example, IBM's General Technology Division in Burlington, Vt., is producing 1 megabit dynamic random access memory (DRAM) integrated circuits. The product divisions see the need for 4 megabit and 16 megabit DRAM integrated circuits in the near future.

These new integrated circuits will go from 1 micron line rules today to .2 micron line rules in the 1990s. New technology must be developed to support these new products. New lithography tools such as X-ray, E-beam, and flood E-beam technologies must be developed. The role of the Chief Scientist and the CTC is to convince the research organizations that these technologies need to be developed at IBM .

This division and staff planning review helps to develop goal congruence between the product divisions and the research staffs. The product divisions, on the one hand, are driving the technology needs, and the research divisions are responding with the technology development. This goal congruence is seen as significant in aiding the technology transfer process.

IBM has a procedure in place to resolve disagreements between the Chief Scientist and a division or staff organization. Although these disagreements are rare, sometimes honest disagreements about technology exist.

The first step in the dispute resolution process is for the CTC to try to pursuade the division or staff with sound technical arguments. If these arguments fail the Chief Scientist may write a "non-concurrence" indicating a lack of agreement between the CTC and the staff or line organization has been reached. The non-concurrences are reviewed at high levels of the organization and may eventually go to the Chairman of the Board if the non-concurrence still exists. This was illustrated in the Bubble Memory Case.[25]

Dr. Branscomb describes the IBM culture as functioning with "cooperative contention" where the units can honestly disagree on technical issues; argue these issues before the Chairman of the Board, and, once a decision is made, pull together and support the decision.

In addition to the technology strategy developed in conjunction with the IBM Divisions, the Corporate Technical Committee focuses efforts in three additional areas.

1) Threats from competitors-The Corporate Technical Committee keeps the corporation aware of competitive movement in technology that may significantly affect IBM's business. A senior IBM executive described the Corporate Technical Committee's concern when Exxon Corporation was buying diverse office automation equipment companies in an attempt to produce an integrated office automation system.

2) New Business Opportunities-The Corporate Technical Committee seeks to define potential future business opportunities that fit within the corporate mission but for which the technology does not exist today. The CTC attempts to convince the research groups that R&D in these technology areas is important for the future of the corporation.

3) Timing-In areas where the corporation agrees as to the necessity for a new technology but the timing is not agreed upon, the CTC serves as a corporate reminder to make sure the issue is eventually resolved.

The range of possibilities for technology development described by Horwitch and Friar is illustrated by the IBM Corporation. IBM develops technology in-house at its research labs.

In order to compete with small, entrepreneurial firms in the personal computer industry, IBM formed an independent business unit (IBU) in Boca Raton, Florida to develop the IBM PC. The office of the Chief Scientist was a significant factor behind the use of an IBU for the development of the IBM PC.

IBM uses strategic alliances with Intel Corporation to speed up the development and manufacture of advanced integrated circuits for IBM products.

IBM has many joint ventures, among them a PC network developed jointly with a vendor and the IBM-Motorola Radio Pager. IBM sponsors extensive amounts of university reserach.

In technology areas critical to the business in which IBM has little expertise such as communications, IBM acquired technology through the acquisition of firms such as Rolm and the joint venture and then partial acquisition of Satellite Business Systems, later folded into MCI.

4.1.2. Technology Strategy: An Intel Example

Intel Corporation is regarded as preeminent in the development of semiconductor technology. Two Intel inventions, the microprocessor and EPROM Memory, have had a significant impact on the semiconductor industry. One Intel scientist, Dr. Marcian (Ted) Hoff was named one of the seven most influential scientists in the 20th century by the British magazine The Economist.[26] Intel has been a strong performer financially, with revenue and net income growing at a 28% compound annual rate over the period 1975 to 1984. R&D expenses grew over the same period at a compound rate of 29%.[27]

Intel Corporation is organized into three major product groups: memory components, microprocessors, and systems.

Technology strategy at Intel Corporation is similar to the IBM example, and, as such will not be discussed in as much depth. Intel uses the Strategic Long Range Planning (SLRP) process as the focal point for technology strategy. The Strategic Business Segments (SBS) plan the evolution of Intel's product line. Future technology requirements are developed from these product plans. A Strategic Capability Segment (SCS) is responsible for defining the technology requirements for the future, planning for their development, and monitoring development progress. Next generation technology needs, as seen by Intel, include sub-micron line rules and new lithography tools.

Once the technology plan is in place Intel uses a variety of sources to develop technology. Intel contracts out future research on "blue-sky" ideas to universities. Intel also uses universities for "gap filling" science, to explain technologies that are in use in industry today, but not clearly understood. The Intel central research activity called Components Development uses the results of university research to determine which new technologies have the most promise for Intel products. The group acts as a funnel, passing ideas to the Technology Development activity which converts these technologies into new processes. Intel is a member of the Semiconductor Research Corporation, and uses the SRC as part of its research effort.

Intel has joint ventures with several companies including Harris and Lotus to speed the development of products to market.

Intel uses technology exchange as a way to trade Intel proprietary technology for proprietary technology from other companies. Intel's recent entry into the applications specific integrated circuit (ASIC) market was accelerated by its acquisition of standard cell libraries from Zymos in exchange for Intel's proprietary CMOS II process.

In summary a technology strategy is seen as important for the following reasons:

- A technology strategy provides a way to define and manage the technology needs of the firm in support of the business goals.
- A technology strategy is an effective way to manage the technology development process along the internal/external, competitive/cooperative, large firm/small firm continuum and thereby speed the technology development and transfer process.
- A technology strategy provides a vehicle for obtaining goal congruence on technical needs between research activities and downstream users with market input. As a result a technology strategy can aid the technology transfer process.
- A number of successful companies are using the concept of a technology strategy to aid the technology development and transfer process

This concludes the section on technology strategy. The next section of the paper addresses successful practices for improving the technology development process.

4.2 Technology Development

This section describes in detail common practices that successful companies use to enhance the technology development process. The section is by no means all inclusive but is intended to capture significant points.

4.2.1. Top Level Concern for Technology

A trait that is seen at successful technology companies is top management concern and support for technology. Abernathy and Hayes in their article "Managing our Way to Economic Decline"[28] attribute a decline in innovation in U. S. businesses to the fact that many companies are run by executives with little or no product experience. Typically, these CEOs tend to be lawyers and accountants who look upon the business as dispassionate experts, managing the financials, and concerned with short-run returns on investment as compared with long-term competitiveness. This same concept is discussed by Hayes and Wheelwright.[29]

As a contrast to this, Robert Noyce, Vice Chairman at Intel, states "Our top three officers have grown up in technical positions, not as lawyers, not as accountants, not as paper pushers, but as doers."[30]

Top management concern for technology is seen in many Japanese companies. At Toyota, "technical policy is established at the top of the corporation by the Board of

Directors."[31] Imai, Nonaka, and Takeuchi, in a study of the product development process at five major Japanese companies write that top management decides on a broad strategic direction or goal by constantly monitoring the external environment. Very frequently this involves technology direction. The example cited is Canon, where "unlike all other front runners who license auto focusing technology from Honeywell, the challenge was to develop the new product using Canon's original core of technology."[32]

Top level managers dealing with technology produces executives with a much broader vision than just the financials. For example, T. Vincent Learson, former Chairman of IBM Corporation headed the Data Products Division in early 1960s. He was concerned that each new computer IBM was introducing was incompatible with the previous model and new software was required. As a result customers would consider IBM along with competitive products since new software was required for all the choices. His concern for technology led to the detailed debate in the company centering on a line of compatible computers with expansion capability that would allow the customer to upgrade to a bigger machine and still retain the same software. The result of the debate was the IBM 360, the company's most successful product.

When Intel invented the microprocessor the marketing department refused to market it, believing the worldwide demand to be less than 2,000 units. Mr. Noyce believed in the potential and when the marketing department resisted, he replaced the head of the marketing department.[33] James Brian Quinn writes, "Executive vision is more important than a particular management background-as IBM, Genentech, AT&T, Merck, Elf Acquitaine, Pilkington and others in my sample illustrate. CEOs of these companies value technology and include technical experts in their highest decision circles."[34]

Top level concern for technology is vital in the areas of long range planning and resource allocation.

4.2.2 Long Range Planning and Resource Allocation

Top management must support the development of a long term business plan and a technology strategy. This area of management support has been discussed at length with relation to technology strategy at IBM and Intel.

As important as this issue is, not many U.S. companies actively plan business and technology strategies for the long term future of the business. Robert Szakonyi in his paper on long range planning and its role in technology development states, "one would think that given the large sums of money that companies spend on R&D, companies would be committed to doing effective long range planning . . . most companies, however, are not committed to long range planning. Of the over 100 companies at which I have had discussions during the last couple of years, only a small percentage of these companies take long range planning very seriously."[35] "The first necessary condition for getting long range planning done effectively and used is having a CEO who really wants long range planning done and used."[36]

A second critical area for top management support is in the area of resource allocation. Once resources are allocated for R&D, via the long term plan, resource commitments must be honored. As Alvin Lehnerd, CEO of Sunbeam Corporation, formerly of Black and Decker, describes it "The first decision we made is that we are in this business for life."[37] Short term resource re-allocation decisions, which may negatively impact the future of the company, make little sense when viewed from the life time business perspective. Mr. Lehnerd describes managing long term resource commitments at Black and Decker that survived business cycles. During this period of time Black and Decker was able to reduce the price of its power drill by 73% in nominal dollars and expand the market by over 300% to become virtually unchallenged in the consumer power tool market.

Another example of top management commitment to long term allocation of resources is seen at Toyota. "Another unique aspect of R&D at Toyota is that the Board of Directors will periodically initiate research efforts. This role insures the necessary support for long term activities essential to the future competitiveness of the firm. Long term research is thereby insulated from the tough hurdles which ordinary research much pass."[38]

Although net income fell by 69% at Intel Corporation from 1980 to 1982, (from 97 million dollars to 30 million dollars), research and development expenses were steadily increasing during the period from 96 million dollars to 130 million dollars.[39]

4.2.3 Corporate Culture

Successful technology companies are observed to strategically use the corporate culture of the organization. Corporate culture as used in this context is defined as the norms of behavior and values that are accepted in the organization. The strategic use of corporate culture is used to denote the practice of developing the corporate culture in a purposeful manner to improve the technology development process.

Risk taking

In a number of successful companies, risk taking is encouraged and along with the risk there is no penalty for failure. This helps to encourage people with fresh, new ideas that they will have a chance to pursue these ideas without paying a career penalty.

Several examples of this illustrate the point. As previously mentioned in the 1960s, IBM Corporation faced a major decision on the future of its computers, whether to build the 8000 Series, an incrementally more powerful computer, or to develop a radically new design of a family of upwardly compatible computers. Mr. Fred Brooks was the driving force behind the 8000 Computer. There was a tough internal debate regarding the future and Brooks' project was scrapped in spite of his strong, competent advocacy. Brooks was then put in charge of part of the competing project, the 360 program. Here management demonstrated that although a person advocated a project that failed, a person's career would not suffer because of it.[40]

At Intel Allen Baldwin describes that "A person can not only survive but thrive with failure."[41] At Toyota many good ideas are supported by funding from management. "Industry insiders estimate that the percentage of R&D proposals which result in new products, parts or components, is less than 5%. The low success rate reflects the large number of competing R&D proposals within the Toyota group."[42] Another example of this is provided by 3M Corporation. "From top to bottom 3M management provides active, spirited encouragement for new venture generation. The company speaks of a special Eleventh Commandment, Thou Shalt Not Kill a New Product Idea."[43]

At Sony according to its top R&D managers, the research climate does not penalize the losing team. " A strikeout at Sony is okay, but you must not just stand there, you must swing at the ball as best you can."[44]

Many companies including Hewlett Packard and 3M encourage the product champion who is an "inside the company entrepreneur." These people are totally dedicated to their new ideas and will use all the resources at their disposal to implement them. For these people to function, a culture that encourages risk taking and tolerates failure is a necessity.

Rewards

In addition to encouraging risk taking, successful technology companies reward their superior technical performers. At IBM a senior technical person may attain the level of an IBM Fellow which confers special status and rewards including a year of funded independent research. This is the highest position on the dual career ladder. At Intel high level people also become company Fellows. These are very prestigious positions in the company. At Intel superior performance may merit the highly valued Intel Achievement Award which does not pay a large sum of money but instead rewards the recipient with a pin which all award winners proudly display. As James Brian Quinn sees it: "Recognizing the many demands entailed by successful programs, innovative companies find special ways to reward innovators. Sony gives a small but significant percentage of new product sales to its innovative teams. Pilkington, IBM, and 3M's top executives are often chosen from those who have added successful new product entries. Large companies do not have to make their innovators millionaires, but rewards should be visible and significant. Fortunately, most engineers are happy with the incentives that provide widespread recognition to do a job well done and the right to play in the next exciting game."[45]

Open Communication

Another feature of technology companies is open communication in the company. At Intel, anyone in the company is encouraged to present his or her ideas to the top management of the corporation. As Mr. Robert Lyon described it "Information is valued by its quality, not by who provided it."[46] At Intel the culture values communication throughout all levels of the corporation. Executives and engineers all have half-wall partition offices and perquisites that isolate management from the rest of the company, such as executive lunch rooms and parking spaces, don't exist.

At Intel the number of levels between the President, Andrew Grove, and the lowest level in the organization is deliberately kept at seven. As the organization grows new units are added horizontally to preserve "the seven levels to the top" communications path. Another interesting concept in corporate communications used by Intel is the company encourages the taking of courses given internal to the company. A certain number of courses are taught by top level management. This practice helps to encourage communication between top level management and all levels in the corporation.[47]

Wide Latitude for the Project Group

In successful technology firms the project groups are given a wide range of freedom. Top management sets the broad challenging goals but decisions are made at the lowest level closest to the information. At Intel, for example, a series of councils operate to resolve technical and organizational problems. These councils are made up of working level people. At Intel sending a problem up to upper management for resolution is not allowed by the corporate culture. Top management providing challenging goals coupled with latitude for the project group is seen as stimulating creativity. "A Honda City* design engineer recalled: 'it is incredible how the company called in young engineers like ourselves to design a new car and gave us the freedom to do it our way. Mr. Kawashima, then President of Honda, promised at the outset that he would not intervene with the City project. Yes, we've given them freedom, commented Mr. Kawamoto, Vice President of Honda in charge of development, but we've also transferred a strong sense of responsibility to them." Mr. Kawamoto, remarked "At times management needs to do something drastic, like setting the objective, giving the team full responsibility and keeping its mouth shut."[48] This same pattern was seen at Data General where a group of young engineers were given the assignment by management to develop the next generation mini-computer and then given wide latitude in designing the machine.[49]

*City is a Honda model designation

4.2.4. Organizational Learning

Another interesting aspect of technology companies is using the product development process to try out new ways of doing business and institutionalizing parts of the product development process that result in success. As an example, Intel does extensive post mortems on projects. Successful portions of the project system are used to change and update how the company does business. As Allen Baldwin describes it, "We never do it the same way twice."[50] This notion is very prevalent in the writings about Japan. Imai, et al., write "From management's point of view, a new product development project offers an ideal springboard for creating a group of employees with broad skills and knowledge, and an organizational climate conducive to bringing about change." Lawrence and Dyer describe this as follows: "It is true that members of an organization cannot only learn as individuals, but can transmit their learning to others, can codify it and embody it in the standard procedures of the organization."[51]

An interesting concept closely allied to the use of the product development process as a mechanism for change is what is termed multi-learning by the Japanese. This refers to giving a project group wide exposure across functions and across levels in the organization. This concept will be described in detail in the section on technology transfer. The basic premise is that the project group becomes familiar with all phases--design, development, test, manufacturing, etc., necessary to bring a product to market. "The constant encouragement to acquire diversified knowledge and skills also helps to create a versatile team capable of solving a wide range of problems in a relatively short period of time." Imai, et. al., write "We also witness Japanese companies treating learning in breadth or learning across functional lines as the cornerstone of their human resources management program."[52]

This concludes the discussion of practices used by successful companies to improve the technology development process. In summary the following points have been made:

- At successful technology companies top management concerns itself with technology and financial issues. Top management is committed to long range planning and resource allocation for the firm.
- Successful technology firms encourage risk taking, reward risk takers, provide open communication between all levels in the organization, and give individuals and groups wide latitude in carrying out project assignments.

- Successful technology companies use the product development process as a way to try out new business concepts and use the process to institutionalize these concepts.

This concludes the section on successful practices to enhance technology development. The next section of this paper discusses in-depth practices to improve the technology transfer process.

4.3 Technology Transfer

In discussing techniques to improve technology transfer it is necessary to define the term and then briefly understand why the transfer of technology is frequently difficult. Technology transfer as used in this thesis is defined as "the application of technology to a new use or a new user."[53] Specifically, the thesis is interested in the development of technology and transfer to a new user within a firm.

Many theories attempt to explain why technology transfer is a difficult process. One theory which explains technology transfer difficulties in terms of organizational role can best be understood using a model developed by Allen.[54] In this model, (shown in figure 3), knowledge and information are inputs to the organization and new products, processes, and services, are outputs from the organization.
The organization typically has many sequential units in place to span from the knowledge input to the product, process, or service output.

Research organizations tend to be described as input coupled, that is, organized and managed to most effectively couple knowledge and information into the organization. Frequently these activities are organized by discipline, for example electrical engineering, to enhance the coupling of knowledge into the organization.

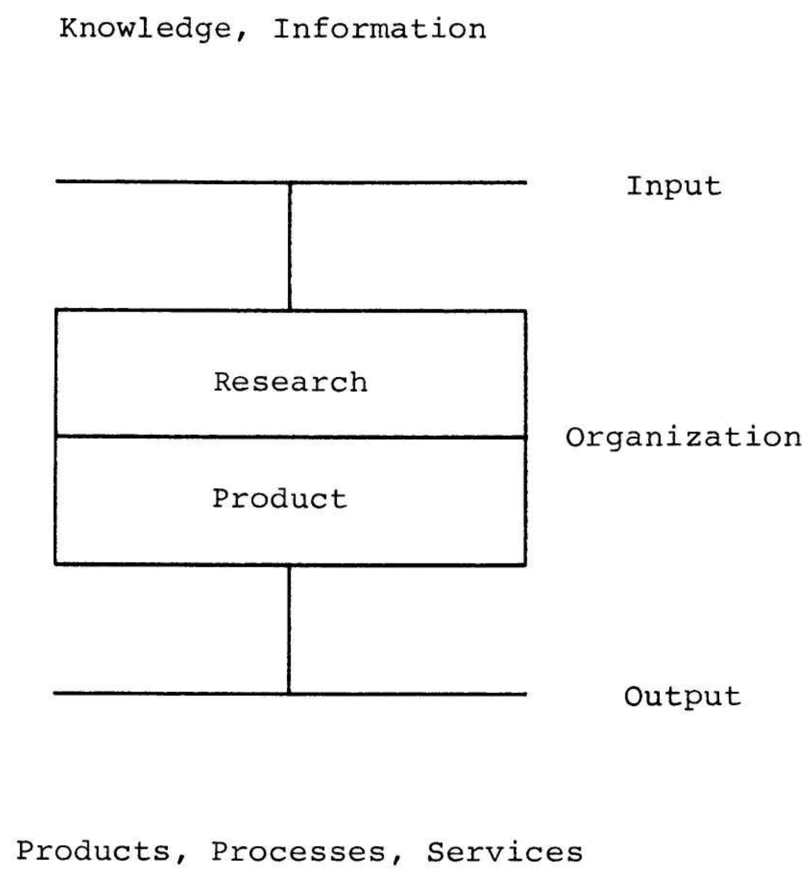

Figure 3

Organizations closer to the output are frequently output coupled or organized to get a product, process, or service to the market. The input and output coupled organizations view their activities from very different perspectives which can lead to barriers to technology transfer.

Rosenbloom and Wolek describe this phenomenon as follows: "In central laboratories which tend to be well coupled to the dynamic world of science and technology, the problem is made manifest as one of maintaining contact with the real needs of the organization. In operating units which tend to be well coupled to the real world on needs and capabilities, empirical success in making something work can seem more important than understanding why it works."[55]

Successful technology transfer practices will seek to build bridges between input coupled and output coupled organizations. Technology transfer practices are described in four categories: transfer of people, human bridges, organizational aspects, and proceedures.

4.3.1 Transfer of People to Transfer Technology

Successful transfer of technology involves transfer of people. This conclusion is reached by the bulk of the authors in the field. Thomas Burns writes "The mechanism of technology transfer is one of agents, not agencies; of the movement of people among establishments rather than of the routing of information through communication systems."[56] George White, writing about technology transfer successes, discusses the people issue. In the development of the transistor, White cites Texas Instruments' hiring of a key Bell Lab scientist, Gordon

Teale, as a major factor in solid state technology transfer to TI. White attributes Boeing's successful entrance into the commercial airliner business to transfer of people from the military aircraft activity to the commercial side.[57] A conclusion of the Denver Conference on the Environment and Action in Technology Transfer, 1970-1980, was that "further development of technology transfer systems should focus more on people than hardware."[58]

In U. S. industries a sequential, non-overlapping development process is frequently used. Design, development, and test are performed by separate groups often with little interaction. After each phase a review is planned and the product then goes to the next phase. At the end of the cycle, the product is turned over to manufacturing to design a process for the product.

A new model, which is in use at IBM, Intel, Japanese firms, and others, seeks to use the people transfer concept to improve the technology transfer process. This concept employs a single team from initial concept through manufacturing. This concept is desirable for a number of reasons.

1) Less Redesign-With each transfer there is a tendency for the new group to view the product from a different perspective. Lacking familiarity with the original technology, the new group may fall back on familiar ways

to solve problems which may involve redesign. The initial project team moving through the process to manufacturing will use the original concepts in seeking problem solutions and thereby minimize redesign.

2) Shortened Product Design Cycle-With the pace of technology accelerating companies are increasingly concerned with reducing the design cycle time. With each transfer a new group of people must spend time learning the new technology. This process takes time. With the initial group following the project through to production, relearning time is minimized. Dr. Richard Pashley, Director of Technology Development at Intel, estimates that each handoff from one group to another, causes Intel a one year delay in bringing a new product to market.[59] In a fast moving business the window of opportunity will be closed by the time the product is ready for market.

3) More Design Margin-When the designers become responsible for the design from initial concept through manufacturing the designs tend to be more conservative. Dr. Pashley of Intel describes this by stating that "Designers who are responsible for integrated circuit design through pilot yields, provide designs that will have more design margin."[60]

4) Multi-Learning-The Japanese discuss the single project team as a way to implement what they describe as

multi-learning, learning across specialties and across levels of the organization. When the design team reverts back to research, advanced engineering, or manufacturing, each person returns with a perspective of the problems of the other groups in the process. This leads to consideration of these potential problems at the outset of future designs and improves the design process for the next iteration. This process also helps to build human bridges among the people in various functions in the organization.

5) Pride of Ownership-The new product development process is a tortuous path, and there is a low probability that any idea will result in a product. However, with the initiators following the product into production, the sense of ownership keeps the project group solving problems which a group with less vested interest might give up on.

6) Simultaneous Engineering-The concept of the initial group moving through to production includes the concept of simultaneous engineering or designing the product and process at the same time. Personnel from manufacturing, service, and downstream activities are involved early in the design process to minimize later redesign.

Group From Initial Concept Through Manufacturing: Examples

An example of this concept was described by Mr. Paul Calhoun, Silicon Gate Manufacturing Engineering Manager at the IBM Corporation General Technology Division in Burlington, Vermont.[61] When IBM made the decision to produce the 1 megabit dynamic random access memory (DRAM) chip, 38 people from the development organization were transferred into the manufacturing engineering group. Although the development and manufacturing people often see a problem from different perspectives the two groups were successful together in getting the chip into production. IBM considers this a very successful effort that shortened the manufacturing cycle time.

Dr. Richard Pashley related that Intel is now transferring engineers from the product groups, for example microprocessors, to the manufacturing group at the start of the design cycle. This group of product and process engineers stays together right through until manufacturing yields are obtained. Pashley calls this the "modularization" of the design process.

This process is very visible in Japanese companies. Imai, et al., write that "the sequential approach, is typified by the NASA type phased program planning system, adopted by a number of U. S. companies. Under this system, a new product development project moves through different phases, e.g. concept, feasibility, definition, design, and production, in a logical step-by-step fashion. But such segmentation works against the grain of a loosely coupled system where the norm is to reach out across functional boundaries as well as across different phases.[62] Fuji Xerox used the concept of a single team from initial concept through manufacturing to shorten the design time from 38 months for an equivalent product to 29 months for its FX-3500 copier .

Honda uses what is called the rugby approach to product development, explained by Mr. Wantanabi. "I always tell my team members that work cannot be done on the basis of a relay race. In a relay race, someone says my job is done, now you take it from here. But that's not right, everyone has to run the entire distance. Like in Rugby, every member of the team runs together, tosses the ball left and right, and dashes toward the goal. The important point to remember here is that the critical problems occur most frequently at the relay points within the sequential approach. The Rugby approach smooths out the process by involving everyone in the development project."[63]

Another example of transferring people to transfer technology is described by Roberts[64] as upstream-downstream transfers of people. As previously mentioned, many companies are organized sequentially from research to the final product or service. This sequence is often referred to as transition of the product from upstream to downstream organizations.

An example of this would be to transfer people from the manufacturing group into the development group during the development phase and to transfer development people to manufacturing during the manufacturing phase. This approach functions in a similar manner to the group from initial concept through manufacturing, helping to promote continuity of the product development process.

A third approach of transferring people to encourage technology transfer relates to the use of rotational programs in the company. Here a person develops a wide communications network in the company.

This plan also helps to break the Not Invented Here syndrome, which is the tendency of a group to reject ideas that were not developed within the group. Katz and Allen[65] have related the Not Invented Here syndrome to project group stability and tenure. Rotation plans tend act against the stability of project groups. Japanese companies use this practice extensively.

Imai, et al., write that Honda has a so-called practical training program in which all department managers are asked to select a functional area in which they have never worked before and to spend one week every two years getting their hands dirty. NEC enhances mobility across functional lines by transferring technical people from its R&D center to its division. As Mr. Miya, Director of R&D noted, "When a researcher starts producing results the division comes to us and says give us that person. NEC's rotation plan calls for a transfer of more than half of the newly recruited researchers from R&D to the divisions at the end of about ten years and more than 80% after twenty years."[66] Rubinger writes, "At Toyota, the firms' emphasis on job rotation and group oriented research efforts foster interdisciplinary R&D."[67]

Up until this point this section has focused on the transfer of technology where the end result is the embodiment of the technology in new products.

Technology transfer also involves the transfer of new knowledge. Here a new method of problem solving based on technology and the experience of a professional are being transferred. Examples of this might be new CAD/CAM or VLSI layout tools, computer models and simulations, and other computer aided engineering. Here again the evidence supports the conclusion that transferring technology is done most effectively by transferring people.

A criticism of this approach is that an advanced degree researcher, say in computer science will not want to transfer to an applications division and develop the use of CAD/CAM software. One possible way to solve this problem is to transfer a person to a new group long enough for the new users to learn the new technology and then transfer the researcher back to his or her home area. Transferring the researcher back to their research unit also prevents the researcher from becoming completely disconnected from the technology.

4.3.2 Human Bridges[68]

The use of the internal communications networks in the company can improve communication among groups in the company and thereby pave the way for improved transfer of technology.

Allen[69] studied the communications path in research and development organizations and found that there were certain individuals with high technical competence who communicated both within and outside the organization at a much higher level than average. These "gatekeepers" are highly influential individuals in different areas of the company. Gatekeeper networks in the company can often speed up information dissemination in the company. Whereas there might be a high psychological cost and organization charter problem with an individual from one group approaching a member of another group, an informal communications network unfettered by organizational boundaries can assist in a flow of information. This acts to improve the coupling between organizations and thereby improve the technology transfer process.

Research indicates that R&D laboratories should have some form of marketing input to determine what are the downstream user needs. Gatekeepers are in close communication with their peers throughout the organization. As a result gatekeepers at a research lab, are in an ideal position to supply the research activity with information on downstream user needs, and can be valuable in developing goal congruence between research and product organizations.

Gatekeeping links can be encouraged by promoting in-company activities that overlap organizational boundaries. Examples of these might be in-company professional societies, such as an electrical engineering society, or an in-company new product show, such as the new product show used by 3M Corporation.

Up to this point the paper has dealt with the people aspects of technology transfer. The next section addresses one theory on how to organize for technology transfer.

4.3.3 Organizational Aspects of Technology Transfer

Organizations that facilitate technology transfer have been discussed by Jack Morton.[70] Morton developed this theory while a Vice President of Research at Bell Telephone Laboratories.

Morton was faced with the problem of transferring technology from the Bell Telephone Laboratories, the company's primary research organization, to Western Electric the development and manufacturing group for the Bell System.

The theory originated by Morton is an attempt to manage the the thin line that separates research from development. On the one hand Bell Laboratories sought to maintain the independence of the laboratories to prevent all its resources from being consumed by current development or production problems. On the other hand, Bell Laboratories did not want the isolation between the groups to be so strong as to preclude the transfer of technology.

The theory Morton developed is known as "the bond and barrier" theory of organizations. Morton reasoned that research groups and development groups could be coupled closely together by the use of bonds. The two principal bonds are organizational, common reporting path, and spatial, common location. If either of these bonds is missing it is termed a barrier.

Morton reasoned that if the two groups are coupled too closely together then the research, or long term activity, will gradually be consumed by the development activity. Morton concluded that if two bonds exist, an organizational bond and a location bond, long term research would suffer.

He developed the theory that a organization optimized for technology transfer between research groups and development groups will contain one bond and one barrier. If two groups are physically bonded by co-location they should report to different organizations; if two groups are bonded by organization they should be at different locations.

In Morton's experience groups that had double barriers, different reporting paths and geographical separation, had a difficult time transferring technology.

At the time the theory was developed the Bell Laboratories were geographically centralized primarily in New Jersey; Western Electric facilities were located throughout the country. In this case the two organizations had double barriers, separate reporting paths and separate locations.

As a result of Morton's work Bell Laboratories placed satellite research facilities on-site at Western Electric locations. This philosophy is also very effective in establishing communications channels between research and development and providing user need information into the research process.

4.3.4. Procedural Aspects of Technology Transfer

Roberts[71] described one technique for facilitating technology transfer, joint planning of R&D projects by the research group and the downstream user activity. This concept was discussed at length with respect to goal congruence obtained with a technology strategy. Joint planning makes the project more relevant and recognizable to the downstream activity. It also tends to develop a stakeholder relationship with the downstream organization and tends to establishes a natural owner when the time comes to transfer the technology. This relationship was seen in the Bendix Case.[72]

Roberts described a joint appraisal of results used to determine where the transfer process can be improved. This process must be treated very carefully because if projects resulted in a failure, joint appraisals can be a very difficult situation. For successful projects, it may be a way to continue the success with minor improvements.

This concludes the section on successful practices for technology transfer. In summary the following points have been made:

- the transfer of technology is most effectively done by transferring people.
- technology transfer is effectively done when a single group takes an idea from the initial concept through to manufacturing
- upstream-downstream transfer cf people helps to transfer technology.
- bond and barrier organizations can improve technology transfer
- human bridges can improve technology transfer; gatekeepers are helpful in building human bridges
- rotation plans can build human bridges and help reduce the Not Invented Here syndrome which often opposes the transfer of technology.

The next section of the thesis examines in-depth the General Motors Technical Staffs. The practices developed in this section will be applied to the General Motors Organization.

CHAPTER 4

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CHAPTER 5

THE GENERAL MOTORS TECHNICAL STAFFS

5.1 General Motors Corporation Overview

Before discussing the activities of the General Motors Technical Staffs it is appropriate to give a brief overview of the General Motors Corporation. General Motors is a large multiproduct, multinational, corporation with 1985 sales revenue of 96.4 billion dollars and net income of 4 billion dollars.[73] The sales revenue figure represents a 15 percent increase over the 1984 sales revenue figure of 84 billion dollars.

For the 1985 model year General Motors sold 6.3 million cars and trucks domestically and 1.3 million overseas.[74] In addition to passenger cars and trucks, General Motors Corporation manufactures locomotives, turbine engines for aircraft, military vehicles, guidance and navigation computers,[75] as well as supplying military electronics (GM Hughes) and computer services (GM EDS).

A part of the organization chart for the corporation is shown in Figure 4. Operations report to the President and Chief Operating Officer, and the staffs report to the Vice Chairman. The Passenger Car Groups, Truck and Bus, Electrical Components Group, Mechanical Components Group, Power Products and Defense Operations, Quality and Reliability, and Overseas activities fall into the

PARTIAL ORGANIZATIONAL CHART-GENERAL MOTORS

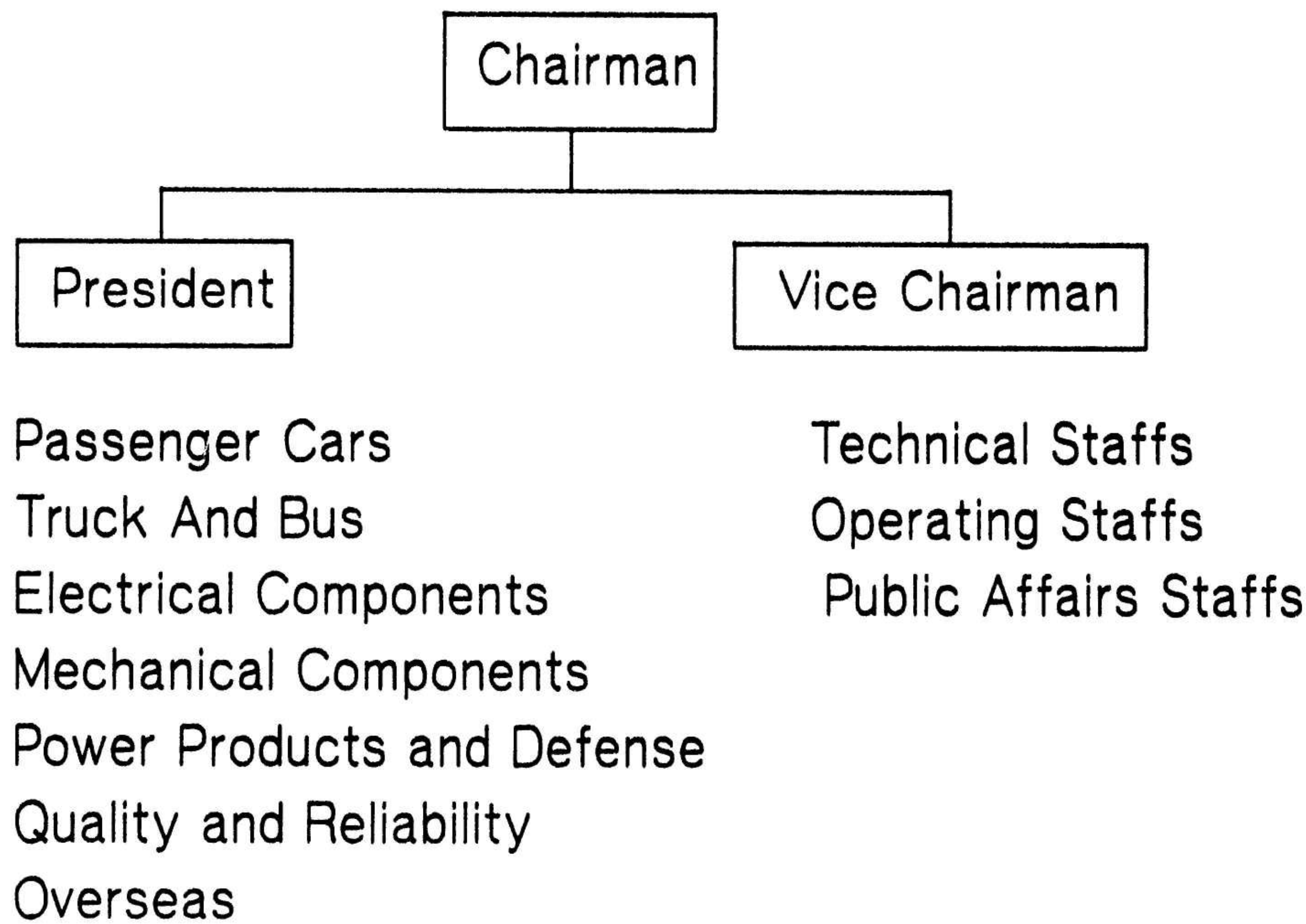

Figure 4

operations group. The staff organizations, reporting to the Vice Chairman, are the Technical Staffs, the Operating Staffs, and the Public Affairs Staffs.

Passenger car operations are organized into two groups: a Buick-Oldsmobile-Cadillac Group (BOC), and Chevrolet-Pontiac-G.M. Of Canada Group (CPC). The passenger car groups and the Truck and Bus Group are the major system manufacturers who are responsible for the design, development and manufacture of the major product, motor vehicles.

The Mechanical and Electrical Components groups are component and sub-system manufacturers that support the passenger car and Truck and Bus groups.

The General Motors Corporation mission is as follows:

- "The fundamental purpose of General Motors is to provide products and services of such quality that our customers will receive superior value, our employees and business partners will share in our success, and our stockholders will receive a sustained, superior return on their investment."[76]

5.2. The Technical Staffs

The Technical Staffs are composed of the Research Laboratories, the Advanced Engineering Staff, the Current Engineering and Manufacturing Services Staff, the Design Staff, and the Patent Section.

5.2.1 The Research Laboratories

The General Motors Research Laboratories was organized in 1920 under the direction of Charles F. Kettering. It was the first of its type in the auto industry. The Research Laboratories is headed by a General Motors vice president and has approximately 1600 employees. About 600 of the staff are professional scientists and engineers with about 400 holding Doctoral degrees.

The organization is divided into 6 areas each assigned to a director. These directors are responsible for 19 departments. The 19 departments are shown below:

Analytical Chemistry	Fuels and Lubricants
Biomedical Science	Mathematics
Computer Science	Metallurgy
Electrical Engineering	Physical Chemistry
Electro-chemistry	Physics
Electronics	Polymers
Engine Research	Power Systems Research
Engineering Mechanics	Societal Analysis
Environmental Science	Transportation Research
Fluid Mechanics	

Most departments are organized according to academic discipline such as Electrical Engineering and Physical Chemistry. A few departments are organized by system such as Power Systems Research, Transportation Research, Societal Analysis, and Engine Research. A director is responsible for interdisciplinary programs. The organization functions in a matrix fashion for projects where researchers are drawn from their specialty to support a project need.

The Mission of the Research Laboratories is as follows:

- To anticipate technologies of the future and to become expert in them.
- To generate new knowledge and new technology that will be of value to General Motors.
- To evaluate technical advances developed elsewhere for possible application at General Motors.
- To serve as a reliable source of scientific information.
- To provide consulting services to other General Motors units and staffs.

For 1984 the Research Laboratories devoted 13 percent of its activity to Basic Research, 37 percent to Short Range Applied Research (less than five years), 41 percent to Long Range Applied Research (greater than five years), and 9 percent to Product Development.

Interviews With General Motors Research Laboratories

The divisions have strategic business plans, however, it is difficult for the staff activities to learn of the details. General Motors Research Laboratories has its own five year plan which is a technology development strategy. The Research Laboratories' five year plan is developed by a "bottom up" approach; general areas for research are defined by the directors. Specific areas of research within the general area are defined by the scientists. Working level scientists may suggest areas for future research programs based on ideas from university contacts, literature, and General Motors divisional contacts suggesting short range and long range needs.

As an example, one director sees increasing use of electronics on vehicles, and that interconnect technology is a weak link in the system. The director may set a priority to investigate reliable interconnect technology that is easy to manufacture, assemble, and service. Once the interconnect area of technology is defined as a priority, senior researchers will define and work on promising ideas they have which fall into this broad category. Other examples of areas of interest to the corporation in electronics include VLSI design automation, high voltage transistors, antennas, and displays. The Research Laboratories works in these areas on projects that have unique application to General Motors rather than general application.

Some advanced projects are used to determine technology needs. As an example, a research project may determine that a concept may be feasible if several technical problems are solved. Knowledge of where technical roadblocks exist suggest new areas for research.

As part of its technology strategy and its mission is "to evaluate technical advances developed elsewhere for possible application at General Motors," the Research Laboratories has recently been instrumental in developing strategic alliances with small firms. Currently strategic alliances have been formed with various machine vision and artificial intelligence companies including Applied Intelligent Systems, Automatrix, Diffracto Limited, Robotic Vision Systems, and View Engineering. These strategic alliances provide General Motors with a "window on technology."

Research Laboratories technology is transferred in a number of ways. The Research Laboratories documents research results with written reports which receive distribution throughout the corporation. Verbal communication of new ideas is encouraged both by individual researchers and through the use of conferences which bring together people working in the same area throughout the corporation.

Technology is also transferred by transferring people. This type of transfer is rare for several reasons. Differences between the salary scale at the General Motors divisions and the Research Laboratories inhibit transfer.

A doctoral level scientist may earn a salary that is at the upper end of the management salary scale at a division. This acts as a barrier to transferring people.

Another barrier to people transfer from the Research Laboratories is the "cultural gap" between the sending and receiving organizations. A technically specialized individual may have many colleagues who share his or her level of expertise at the Research Laboratories while there may be few people with similar levels of expertise at the divisions.

Another barrier to transfer of personnel is the lack of a career path for individuals who want to remain on the technical side of the activity. Higher technical levels (dual career ladder positions) do not exist at the divisions.

In spite of these barriers successful transfers of people have been accomplished. Recently a head of the Electronics Department at the Research Laboratories was transferred to head the semiconductor operations at Delco Electronics Division; several researchers have been transferred to the CPC Group. A senior researcher was transferred to The Fisher Body Division. A whole group was transferred from the Research Laboratories to the Advanced Engineering staff. Although transfers have been made from the Research Laboratories, very often technology transfer is not the primary objective; most frequently the career progression of the individual is the reason for the transfer.

An additional barrier to the transfer of people from the Research Laboratories is headcount constraint. Each unit receives a headcount budget that it must not exceed. The downstream organization must somehow be able to absorb the additional headcount for the transfer to occur.

The Research Laboratories have instituted a new technology transfer program to improve the transfer process. In this program the various General Motors divisions select critical technology areas for transfer. The divisions and the Research Laboratories jointly recruit college graduates who will come to the Research Laboratories for a one to two year research and development program in the area of technology that the sponsoring division desires. After the training program the individual is transferred to the sponsoring unit. This program has been very successful; to date approximately 25 people have graduated from it.

This program builds bridges from the divisions to the Research Laboratories that can help to reduce the Not Invented Here syndrome. Another similar approach is for the Research Laboratories to sponsor a large project and develop a stakeholder relationship with the interested divisions. This takes the form of having supporting divisions provide personnel to work jointly with the Research Laboratories staff and to be able to return to their home division with the technology and a communications network to the Research Laboratories.

From the Research Laboratories perspective there is no formal product development process. New concepts from the Research Laboratories are taken to various groups that could potentially have an interest in the new concept. The Research Laboratories operates in the "technology push" mode having to "sell" the potential advantages of the new concept. If the advantages of the new concept are attractive to the divisions or other staffs, a downstream organization may become interested in the possibilities.

The Research Laboratories see that there is a gap in the technology development and transfer process in the corporation. Before proceeding two terms must be defined. <u>Design</u> is the activity where concept feasibility is proven; <u>development</u> is the activity where a design is turned into a product, process, or system, that meets all the required specifications including performance, function, reliability, quality, manufacturability, safety, etc. and is ready for commercialization. The Research Laboratories design new products, processes, and tools but feel that there is no group in the corporation with the responsibility for development.

Barriers to Technology Development and Transfer at The Research Laboratories

The following barriers to technology development and transfer have been developed from interviews from the Research Laboratories:

- There is no overall plan jointly agreed to by the user divisions and the Research Laboratories that forms the basis for the Research Laboratories' technological agenda for the future.
- As a result of the lack of a plan, the Research Laboratories sets its technological agenda internally and operates in a "technology push" mode trying to generate interest for new technology among potential users.
- In the past there was not a well defined development function. Both the CPC and BOC organizations have recently established advanced engineering groups responsible for the development function. For new tools, techniques, and systems, there still is no formal development function.
- Transfer of technology by transferring people from the Research Laboratories is difficult because of administrative constraints such as salary differentials, headcount constraints, and career paths at other locations.
- Gaps in the level of technological sophistication exist between the Research laboratories and the divisions.

5.2.2 Advanced Engineering Staff

The Advanced Engineering Staff is comprised of approximately 1,500 scientists, engineers, designers, mathematicians, technical specialists, mechanics and support people. The Advanced Engineering Staff identifies "future products, tools, and technologies, and develops these to the practical application stage.[77]

The mission of the Advanced Engineering Staff is as follows:

- The fundamental purpose of the Advanced Engineering Staff is to support the GM corporate mission by identifying, developing, and demonstrating new and improved, integrated product, manufacturing, and system technologies and by assisting GM's operating units in implementing those technologies to insure the corporation's sustainable competitive advantage.[78]

The Advanced Engineering Staff consists of Advanced Product Engineering, Manufacturing Engineering and Development, Computer Integrated Systems, Machine Intelligence Technology Implementation, and Special Projects.

Advanced Product Engineering develops and demonstrates concepts for future General Motors vehicles. Work covers all aspects of vehicle engineering: fuels, engines, power transfer, braking and suspension, body and components, performance, durability, emissions, electronics, acoustics, interior environment and safety.

The Manufacturing Engineering and Development activity develops and assists in the implementation of new manufacturing technology including tools, materials, processes and systems that can improve product quality and increase productivity.

Computer Integrated Systems is a group of engineers and computer professionals who specialize in advancing the technology in computer-aided design and computer-aided manufacturing (CAD/CAM). This group seeks the development of a corporate wide system of standardized tools, hardware, languages, and databases for new computer-aided technologies.

The Machine Intelligence Technology Implementation group is working to accelerate General Motors' use of intelligent machines. This group works with machine vision and artificial intelligence companies General Motors has purchased an equity interest in.

Interviews with Advanced Product Engineering

Advanced Product Engineering is one of the groups that comprise the Advanced Engineering Staff. The mission of Advanced Product Engineering is as follows:

- Identify, develop, and demonstrate new product ideas and assist the divisions in their production implementation. Improve the efficiency of the design process.[79]

Advanced Product Engineering does not think that the corporation's technical effort is driven by an overall technology strategy. Rather, the technical efforts of the corporation are seen as being driven by two factors: responses to the external environment and top management.

The external environment drives technology primarily through the market demand and legislation. Advanced Product Engineering sees external factors tending to drive technology in response to a crisis situation. Examples of this include the market demand for fuel efficiency which resulted from the oil shocks of the mid-1970s, and the federal exhaust emission regulations which resulted from increased environmental awareness.

Top management also drives the technical effort through sponsorship of new technology. As examples, former General Motors President Edward N. Cole is credited with sponsoring the development of the catalytic converter, the major after treatment device used by almost all car manufacturers to control exhaust emissions. General Motors Chairman Roger B. Smith is credited as sponsoring the transfer of a high permeability magnet technology from the Research Laboratories into the product.

Advanced Product Engineering sees the most effective technology transfer occurring in the corporation in response to one of these two factors, top management support for technology or a crisis in the external environment.

In the absence of these two factors Advanced Product Engineering often finds it difficult to transfer technology to the car groups. The car groups place a premium on the experience gained in developing a product and releasing the product to the manufacturing organization. Advanced Product Engineering personnel do not have this experience. The perception by the car groups of the importance of divisional experience in the product development process, acts as a barrier to the transfer of technology from Advanced Product Engineering to the car groups.

The technical agenda for Advanced Product Engineering effort is shaped from two principal sources. Top management requests project work from the Advanced Engineering Staff. An example of this type of project is the new General Motors Saturn Project. This is a project to re-think the automotive design and manufacturing process from a clean sheet of paper perspective. This project was initiated by Alex Mair, Vice President of the Technical Staffs. General Motors Chairman Roger B. Smith has sponsored this project.

The second source for projects is a new idea or discovery that comes about in the course of doing project development work. Here an engineer will have a new idea on how to apply a technology presently being developed to a new area or applying a newly discovered phenomenon to solve an existing problem.

Advanced Product Engineering sees its role as being more hardware oriented. The Research laboratories is seen to have a more analytical orientation. The development process may be sequential for some projects where a concept comes from the Research Laboratories and moves to Advance Product Engineering, or the two groups may be working on the same problem simultaneously.

<u>Barriers To Technology Development and Transfer at Advanced Product Engineering</u>

The following barriers to technology development and transfer have been developed from interviews at Advanced Product Engineering:

- The car groups place a premium on the experience of developing and releasing of a product. The perception by the car groups that this type of experience is necessary for product development acts as a barrier to the technology transfer process, and is viewed as part of the Not Invented Here syndrome.
- As with the Research Laboratories there is no overall plan agreed to by users and Advanced Product Engineering, that sets the Advanced Product Engineering technical agenda for the future. As a result, in absence of top management or the external environment driving technology transfer, Advanced Engineering Staff operates in a

technology "push" mode trying to interest the divisions in new technology.

5.2.3 Current Engineering and Manufacturing Services Staff

The Current Engineering and Manufacturing Services Staff contains both engineering and service functions. Among the service activities are General Motors Air Transportation Service, General Motors Photographic, and General Motors Facilities. The engineering organization in Current Engineering and Manufacturing Services Staff is Current Product Engineering.

The Mission statement for Current Product Engineering is as follows:

- "Assist the vehicle and component groups in product design, development, test, validation, certification, investigation, and analysis, by providing centers of specialized technical expertise and unique engineering facilities.

Current Product Engineering is composed of six centers of technical expertise: General Motors Proving Grounds, Technology Support, Electrical Engineering Center, Engine Emission Control Center, Field Product Engineering, and Technical Center Operations.

Current Product Engineering's mission is tied directly to the vehicle and component groups. The needs of these users is a primary input into the Current Product Engineering project agenda.

Interview With Current Product Engineering

Current Product Engineering interfaces and transfers technology on a regular basis with the vehicle and component groups. A drawback to the practice of transferring people to transfer technology is that the transferred individual sometimes quickly moves on to a new assignment which doesn't require the technical expertise of the individual. Technology transfer by transferring individuals is only seen to be successful if the individual remains in the assignment long enough to transfer the technology.

Current Product Engineering has had experience with one of the successful technology transfer practices discussed in Chapter 4, maintaining a group from initial design through manufacturing. This project was the corporate tire program where a Current Product Engineering group established the specifications for a new corporate tire, worked with vendors to develop the tire, then followed the tire into production, maintaining responsibility for quality and reliability. This program was very successful in bringing a new radial tire technology to General Motors Corporation. Current Product Engineering has less difficulty with the car group interface because much of Current Product Engineering's role is defined by the car divisions. However, the issue of who should control the resources, Current Product Engineering or the car groups, comes up frequently.

5.2.4 The Design Staff

The General Motors Design staff is responsible for the styling of most General Motors' vehicles, interior as well as exterior. The job of The Design Staff is to give the vehicles in General Motors their basic divisional identity. The exterior shapes must be attractive and the interiors must be functional and protect the occupants.

The Design Staff has a total of 1,400 professionals including designers, sculptors, engineers, and skilled craftsmen. The Design Staff is divided into eighteen engineering departments and thirty four design studios. Tools used to design new vehicles include CAD/CAM systems, 3-D graphics, clay models, and designers' sketch pads.

The Design Staff's strategic planning group works with divisional planning activities to develop design goals for future products based on marketing inputs. The advanced design studios begin to develop design concepts for future vehicles. The output from the Design Staff is a clay model that is reviewed by management and approved, and a digitized representation of the surface of the vehicle.

The Design Staff was not interviewed for this thesis.

5.3 Interviews with Executives Outside The Technical Staffs

A number of General Motors executives responsible for technical activities, who are not part of the Technical Staffs organization, were interviewed regarding the problems of technology development and transfer at the

Technical Staffs. The technical executives had common concerns regarding the development and transfer of technology by The Technical Staffs. These concerns were grouped into the following areas:

Technology Strategy

All of the technical executives interviewed agreed that General Motors Corporation does not have a technology strategy for the firm as a whole; some units have their own technology strategies and some units do not. As a result the technology strategy for a unit is internally consistent but may not utilize the natural synergies and interdependencies available through an overall plan.

Examples of technology strategies at the unit level include the Research Laboratories five year research plan that includes a window on technology outside the firm in the areas of machine vision and artificial intelligence. Robert J. Schultz, who was President of the Delco Electronics Corporation, and now Vice President and Group Executive in charge of The Chevrolet-Pontiac-General Motors of Canada Group, indicated that Delco Electronics was doing technology planning, and the acquisition of Hughes Aircraft was primarily to fill some of the holes identified by the technology plan.

Chapter 4 discussed the importance of a technology strategy in driving goal congruence between users and providers of technology. Lack of goal congruence was the second area of concern among the executives.

Lack of Goal Congruence

Most of the non Technical Staff executives interviewed felt that there was a lack of goal congruence between the areas that the product groups want the Technical Staffs to work in, and the research agenda of the Technical Staffs. These executives felt that there needed to be more support for the product groups by the Technical Staffs.

The issue of lack of goal congruence was brought into focus during the interviews. The non Technical Staff executives viewed the Research Laboratories and the Advanced Engineering Staff as forming project agendas with too little input from users of technology. This position is supported to some extent by the interviews which suggest that the technological agendas of both the Research Laboratories and Advanced Product Engineering are set internally by their managements. However, interviews at the Research Laboratories discussed the difficulties encountered in obtaining information on future technology needs from users.

An area where the executives felt that goal congruence is lacking is in the styling area. The Design Staff is responsible for the aesthetics of the vehicle. Sometimes the appearance and the engineering objectives are at odds with each other; this lack of goal congruence acts as a barrier to technology development.

The non Technical Staff executives had two proposals for developing better goal congruence between technology users and the Technical Staffs. The first proposal was to have more sponsored research at the Technical Staffs. This would entail a certain portion of the Research Laboratories and Advanced Engineering Staff budget being funded directly by users for specific projects. The need for a certain amount of unsponsored research and development was recognized by the executives, but they felt it should be at a much lower level than now. One executive felt that the Advanced Product Engineering group should concentrate almost entirely on end user development for the car groups.

A second proposal to drive goal congruence between the two groups is to use the bonus incentive system to pay Technical Staff executives in proportion to the number of Technical Staff ideas that are implemented in the product.

Lack of Technology Representation with Top Management

Several of the executives interviewed were concerned with the lack of representation for technology at the top of the corporation. Because of this lack of representation, technology issues often do not get the level of attention that these executives felt was appropriate. One executive felt that a top level officer should be appointed to present technology issues to top level management. This executive pointed to the fact that Charles F. Kettering, the inventive genius of General Motors, and the first Director of The Research Laboratories, reported to the Board of Directors.

Narrower Research Agenda

One technical executive felt that the Research Laboratories should concentrate more on narrow, specific developments rather than trying to maintain such a broad-based level of technical competence. This executive pointed to a premier electronics company where 90 percent of the funding for R&D comes from the divisions and the research group works on areas specific to the next generation products.

An example of this is that the Research Laboratories designed a sophisticated three dimensional solid modeling computer software package that had significant potential for automotive packaging studies. The software package was not used by the car groups because it was not user friendly, and the Research Laboratcries could not invest the time to make the software user friendly without detracting from its broad based research effort.

5.4 Barriers to Technology Development and Transfer

From interviews with executives of the Technical Staffs and General Motors executives outside the Technical Staffs barriers to the technology development and transfer process at the General Motors Technical Staffs have been identified. These barriers, grouped into seven major categories, are listed as follows:

1) There is no overall goal congruence between the Technical Staffs and downstream users, that forms the basis for the research and development agenda for the Technical Staffs.
2) There is a lack of in-depth support for projects by the Technical Staffs due to the broad based research and development agenda maintained.
3) Technology issues are not well represented at the top management level.
4) The Not Invented Here syndrome exists between the car divisions and the Technical Staffs centering on the issue of releasing responsibility for products to manufacturing.
5) There is a limited amount of broad based learning at the Technical Staffs, car groups, and technology user organizations. Salary and career path differences, and headcount constraints contribute to the lack of broad based learning.
6) There is no formal product development process.
7) Level of sophistication barriers exist between the Technical Staffs and technology user organizations.

CHAPTER 5

FOOTNOTES

73. Smith, Roger, B., Chairman General Motors Corporation, Speech at the Chicago Auto Show, 2/17/86.

74. Smith Roger, B., op. cit.

75. General Motors Corporation, "Annual Report," 1984, p. 8.

76. Route, William, D., Director, Advanced Product Engineering, General Motors Advanced Engineering Staff, interviewed, Warren, Mi., 1/13/86.

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78. Route, William, D., op. cit.

79. Route, William, D., op. cit.

CHAPTER 6

TECHNOLOGY DEVELOPMENT AND TRANSFER RECOMMENDATIONS

The balance of this thesis is concerned with applying information presented in the first part of the paper regarding technology development and transfer practices used by other successful companies, to the seven barrier areas outlined in the previous chapter.

The Technical Staffs represent a significant resource to General Motors Corporation. The Technical Staffs employ approximately 8,000 people. While the breakdown of technical personnel as a percentage of this total is not available, at the Research Laboratories, for example, about 40 percent of the work force are engineers and scientists. The Technical Staffs can be seen to be a significant pool of talented people for the corporation. Techniques that can improve effectiveness of the technology development and transfer process used by the Technical Staffs, can, therefore, have a significant impact on the engineering effectiveness of the corporation.

The remainder of the thesis discusses ten recommendations to improve the technology development and transfer process used by the Technical Staffs. The recommendations begin with a discussion of techniques to improve goal congruence between the Technical Staffs and users of technology.

As has previously been discussed, when goal congruence exists between The Technical Staffs and downstream activities, such as when the President or the Chairman of the Board sponsor new technology, the technology development and transfer process proceeds relatively smoothly. Techniques that improve the goal congruence between the Technical Staffs and the user organizations will be seen to have a positive effect on technology development and transfer at General Motors Corporation. The development of a technology strategy is seen as a technique for making progress toward the objective of goal congruence between the Technical Staffs and the user groups.

6.1 Technology Strategy

The concept of a technology strategy, a definition of the technology needs for the future of the corporation and a plan for its development, was discussed in depth in Chapter 4. As indicated, a number of other successful companies including IBM Corporation, Intel Corporation, and Toyota use this planning concept.

The technology strategy has as its base the business strategies of the firm. Each business unit, whether a product or service group, will have defined the areas where it seeks to sustain a competitive advantage. The technology strategy is a list of technologies required by the business objectives and a plan for developing this technology. Technology needs are defined from this set of business objectives.

A technology strategy is seen as an ideal tool for managing technology to channel resources toward common business objectives. Several illustrations of the concept are presented below.

For example, at the low end of the automotive market segment a division might have as its strategy to be the value leader. Here the important attributes will be to deliver the same performance and quality at a lower price. Technology developments here might focus on process technology. Technology required may be robotics, artificial intelligence, vision systems, and factory communications to link "islands of automation."

A division at the upper end of the automotive market segment may choose to be the uncompromising feature/function leader. Here the important competitive thrust may be the rapid introduction of new feature technology. For this strategy product technology is seen to be of primary importance. In this example a list of potential new vehicle sub-systems will be compiled. Manufacturing systems would stress flexibility to allow the rapid introduction of new technology.[80]

The technique would be the same for another member of the Technical Staffs. For example, the Current Engineering and Manufacturing Services Staff may seek to be the world leader in testing technology. For the Current Engineering and Manufacturing Services Staff, this might mean the development of computer-aided vehicle testing systems.

Next, each group would study the competition. What is the competition planning? Hints can be obtained from literature and also by looking at trends developing from past products. For example, Japanese car makers are introducing more ceramic components on their vehicles; a logical extension may be a ceramic engine. Fiber reinforced metal parts are turning up in larger numbers, plastic exterior panels are being developed on some competitive vehicles.

The technology strategy must comprehend the competition. Competitive analysis will provide clues to where the competition is going; the technology strategy should support strategic response to competitive thrusts. For example, if the Japanese introduce a new ceramic engine technology, how will General Motors respond?

Next, a technology strategy will attempt to define how the technology is to be developed. Will technology be developed in-house, or cooperatively with other companies or by joint venture, strategic alliance with another company, contract research, acquisition, etc. along the range of possibilities defined by the Horwitch-Friar model?

The technology strategy defines the resources that will be committed to the technology development and a timetable for technology development. In this way progress toward goals can be assessed.

The technology strategy should define a technology transfer plan along with a technology development plan for the new technology. The downstream customer should be identified and involved as soon as possible. The downstream activity should be willing to incur some risk in working with the technology, so that the concept creating or developing organization is not in the "technology push" mode.

Advantages of a Technology Strategy

A technology strategy can have significant positive impact on the technology development and transfer process used by the Technical Staffs.

1. One of the primary advantages of a technology strategy for the Technical Staffs is to develop goal congruence between the The Technical Staffs and the requestors of technology. This process establishes a natural owner for the technology reducing the "technology push" mode of operation. In effect "market pull" or user demand is being stimulated.
2. A second benefit of a technology strategy is that the users and the Technical staffs can establish a technology transfer plan at the outset, defining which groups will receive the technology and how it will be developed. In effect this defines the new product or service development process for each new technology. This also allows the user groups to better prepare for the arrival of the new technology.

3. The user input will help to develop a stakeholder relationship and may encourage the user units to work more closely with the Technical Staffs during the initial phase of work, so that a team from initial concept to final product can be assembled or that an "upstream-downstream" transfer program can be implemented.
4. The development of a technology strategy provides a way of monitoring the progress of technology development. If technology development is taking an excessively long period of time management may make corrections.
5. The technology strategy provides a way to manage technology development along the three axis model dimensions.
6. The plan defines the resources to be committed to each task.

6.2 Top Management Support for Technology

When top management is concerned with technology and actively supports it, the technology development and transfer process goes on relatively smoothly. Examples of technology sponsorship by former General Motors President Edward N. Cole and current General Motors Chairman Roger B. Smith have been cited.

This pattern is repeated at many other companies. With top management support, projects develop smoothly. The example of the development of the IBM 360 had T. Vincent Learson as a sponsor; when Singer introduced the electronic sewing machine, Donald P. Kircher, the CEO, provided support for the idea.[81]

A technology development and transfer process that requires the CEO to sponsor projects will obviously be seen as ineffective as the CEO has a multitude of responsibilities, technology being just one of the them.

The concept that is being suggested here is for top management to indicate support for the technology process rather than sponsoring individual projects. Top management should help drive goal congruence among the units in the corporation by stressing the need for a technology strategy.

A way to accomplish this, I believe, is to use the model developed by IBM Corporation of having a senior technical executive reporting to the Chairman of the Board, with responsibility for the technology strategy of the firm. This establishment of this position in the corporation would do several things to improve the technology process in the corporation.

1) It would establish the importance of the technology planning process in the corporation.

2) The position of a chief technical executive reporting to the Chairman would help drive goal congruence between the users and providers of technology in the corporation.
3) This position would provide a vehicle for bringing important technical issues before the Chairman and provide for the representation of technology at top management levels in the corporation, including the Board of Directors.

6.3 The Reward System

Once goal harmony between the users and the Technical Staffs have been established via a technology strategy, the reward system should be used to maintain this congruence. The suggestion by one of the interviewees to make the Technical Staffs bonus awards contingent on how many ideas the Technical Staff contribute to the product will be seen to fail a basic test of a bonus system. In a bonus system a person needs to have control over what he or she is being measured on. If they don't have this control the system cannot drive the desired results. The Technical Staffs do not control what goes into the product, therefore, this type of bonus plan will not function properly. If, however, a technology strategy is established and goal harmony between product and downstream users is obtained, a bonus system which keys on performance to this plan will be successful.

Texas Instruments uses this approach. There is a formal planning process for the current year and the next ten years. The long term plan, called OST (objectives, strategies, and tactics), is reviewed yearly along with the short term plan. Managers at TI are rewarded on how well they meet current budgets and on the progress that is made toward meeting the long term plan.[82] This technique is seen as effective by TI in striking a balance between long term and short term goal attainment and in driving a harmony between the plan and each manager's goals and objectives.

The previous three recommendations, the development of a technology strategy, the appointment of a senior level executive to oversee the technical activities of the corporation, and a bonus plan to address long term performance to meet technology objectives, address the issue of goal congruence in the technology process. The next several recommendations address the issue of closer coupling of the Technical Staffs to the end users of technology.

6.4 Increased Support for Downstream Users

In the 1950-1960 time frame the traditional role played by a corporate research laboratory and an advanced development activity was to operate in a manner decoupled from the operating divisions. The research and development activities were working on future technology which would form the basis for new products. As an example of this, the RCA Research Laboratories in the 1950s and 1960s was creating concepts and developing new products with little association with the product divisions. As has been described, this type of research is defined as "technology push." The product is made because it is feasible to make it; little input is obtained from the market. The RCA Research Laboratories, however, working independently from the divisions, began to develop a series of products that were failures. These included the development of the video disc player, when the product divisions were requesting a technology that could both record and play back.[83]

A more current view of corporate research laboratories and advanced development activities is that they should support more directly the activities of the product and technology users. As an example of this the Bendix Advanced Technology Center played a big supporting role in the development of the Quantum 2000, a major new generation electronically controlled machine tool. The Bendix Advanced Technology Center provided application of new development testing tools and supported the product development. Because of its close association with the product groups, the project leader for the Quantum 2000 was chosen from the Advanced Technology Center and transferred to an operating division.[84]

Several successful companies are using this model. At Intel Corporation The Technology Development Group, which is the main corporate advanced development activity, works on the next generation of products.[85] At Hewlett Packard Laboratories, the corporation's central research and development organization, they develop and support new products. As an example, the new Hewlett Packard Precision Architecture for HP's new generation of 32 bit computers was developed at the laboratories.[86]

The Research Laboratories and the Advanced Engineering Staff of General Motors should work more on sponsored projects from the divisions and other downstream users. This is consistent with the new model of research and development activities which shows them to be most effective when supporting activities with market input.

This approach has a number of advantages. It helps develop goal congruence between the users and the Research Laboratories and Advanced Engineering Staff. The approach helps to build bridges between the activities via common interest projects, and the arrangement provides the market pull for the concepts from the Research Laboratories and the Advanced Engineering Staff. Most importantly, it provides the possibility of using a large number of highly talented resources to support the product and downstream users.

6.5 Narrowing the Scope of In-House Research

The idea of more support for downstream users includes the concept of more in-depth support. A case can be made for narrowing the scope of the research agenda to allow concentration in a few, highly important areas. The Research Laboratories maintains competence in a very broad range of areas. As a result of this, one techncial executive at the Research Laboratories described the difficulty in pursuing further commercialization possibilities without detracting from the research agenda. As an idea requires more effort to advance further toward reality, the manpower is not available without impacting the research agenda.

At Intel Corporation the central research activity uses contract research with universities, outside firms and research consortiums, to leverage the in-house technical effort. The role of the group is to monitor this research and determine which ideas appear most promising for the businesses that Intel is in. The most promising ideas are passed on to the Technology Development Group to pursue. As Alan Baldwin described it, "the research group is like a funnel passing on the most promising ideas to the Technology Development Group."[87]

The Research Laboratories can maintain a broad-based agenda and still provide more direct support to the divisions and downstream users by sponsoring outside research in order to maintain diversity and monitoring this activity to keep abreast of the technology. A narrower research agenda would allow The Research Laboratories to provide more direct customer support.

6.6 Group From Initial Concept Through Manufacturing

The practice of using a group from initial concept through manufacturing was discussed at length in Chapter 4. It has been used successfully by companies as diverse as IBM Corporation, Honda, Singer, and NEC, for example. The concept was also used effectively by Current Product Engineering in the development of a new corporate radial tire.

This concept is in contrast to the sequential development process where a group performs a particular function, for example design, and then "hands-off" the project to a downstream organization. As was pointed out in Chapter 4, the points of transfer from one group to another are typically where difficulties with the sequential process are manifest. The advantages of this concept are a speed-up of the development cycle and an improvement in quality by eliminating the downstream re-learning and re-engineering of the product or service.

Organizational mission statements also act to encourage the "hand-off" from one group to another. For example, each group in General Motors has a mission statement that defines the function the group is to perform and the areas in which it performs these functions. These mission statements tend to be non-overlapping. As soon as a group is performing in an area that is perceived to be outside its charter, the activity may be called into question. For example, researchers who were involved in taking a product further along the commercialization path than the concept stage were called into question by their management. There is a sense that remaining within the charter limits is more important than taking the process further along the path to commercialization. In other successful companies this risk taking is encouraged and rewarded.

A group from initial concept through manufacturing acts to break what Rosabeth Moss Kanter calls "segmentalism" or the practice of limiting the scope of an individual or a group's activity by job definition. "Segmentalism sets in when people are never given the chance to think beyond the limits of their job, to see it in a larger context, to contribute what they know to the search for better ways. The hardening of organizational arteries represented by segmentalism occurs when job definitions become prison walls and when the people in the more constrained jobs become viewed as a different and lesser breed."[88]

Segmentalism is the opposite of what has been previously described as multi-learning in Japanese companies. As activities become more familiar with the way other parts of the organization function, for example marketing, development, etc., early research can factor this knowledge into designs and avoid problems downstream.

An example of this concept in General Motors is the Saturn Project. General Motors Chairman Roger B. Smith is credited as being the driving force behind the project. In this project a group of Technical Staff personnel were involved in a totally new way to design and manufacture an automobile. This core group is moving with the project through the development phase and into manufacturing.

6.7 Transferring Technology By Transferring People

Technology transfer by transferring people has been discussed as difficult to implement because of salary constraints, cultural barriers, and career paths, and technical obsolescence. One way these objections can be overcome is by transferring the individual for a short period of time to the downstream organization. In this way the person would assist in on-site people-to-people technology transfer. After a period of time, from six months to one year, the researcher would have the chance to return to his or her former activity. Management should provide special incentives in terms of salary and bonus to encourage this process and should provide special dispensation for the family situation of the individual workers. Management should encourage these assignments. The advantages of this situation would be that the transferred person would bring the new technology into another organization and at the same time be able to build bridges between the new organization and the old organization; all the old supporting contacts would be available. The long term salary and career path planning would remain with the upstream organization. At the end of the transfer assignment the researcher would be given the opportunity to make the transfer permanent or to return to the originating organization. The returning researcher could then be placed back with his or her colleagues so that technological obsolescence does not set in. This model is consistent with the multi-learning concept. An example of this was seen in the IBM example were 38 researchers followed the product into manufacturing in the General Technology Division in Burlington, Vermont.

6.8 Rotation Programs

As another example of the multi-learning concept described by the Japanese broad-based knowledge is developed by rotating people through different disciplines in the organizations. This program has several positive aspects.

As with the group from initial concept to manufacturing approach, people in rotation programs develop a better feel for the problems of upstream and downstream organizations. For example, the product designer becomes more aware of the problems of manufacturing after having spent time in manufacturing. This program helps to break the Not Invented Here syndrome and helps to build communications bridges to other groups.

Another advantage of rotation programs is that by assigning new people who have never had experience in an area to solve a problem, new creative solutions may be developed. In studying radical innovation it is found that radical innovation often comes from outside the established industry. This is because people in the industry tend to develop a pattern of thinking regarding certain problems and solutions. Allen and Marquis have found that people working in an area tend to carry over familiar solutions to new problems. Allen and Marquis have described this in the literature as "negative biasing sets."[89] One way to break this negative biasing set is to allow new people to attempt a problem solution.

In any organization a proper balance of experienced professionals with in-depth knowledge in one area and people with broad-based knowledge should be maintained. Rotational programs should maintain this balance by limiting the number of people rotated each year in a given activity.

6.9 Bond and Barrier Organizations

As previously discussed in Chapter 4 the use of bond and barrier organizations is a way to facilitate technology transfer, develop goal congruence among organizations, and to facilitate learning across functions. This concept was developed by the Bell Telephone Laboratories. Bell Laboratories was physically centralized in New Jersey and the development and manufacturing facilities for The Bell System were located at the Western Electric Facilities throughout the country. The concept of bond and barrier organizations originated in the Bell Laboratories attempt to manage the thin line that separates research from development and manufacturing. On the one hand, Bell Laboratories sought to maintain the independence of the laboratories to prevent all its resources from being consumed by current development work. On the other hand, Bell Laboratories did not want the isolation to be so strong as to preclude technology transfer.

In the Bell Laboratories and the Western Electric case there were two barriers separating the groups. Western Electric was geographically separated from Bell Laboratories and reported to a different organization. Bell Laboratories decided that since the organizational barrier existed it should be reinforced with a geographical bond. As a result, Bell Laboratories moved satellite research activities to Western Electric sites that were working on concurrent technology. This arrangement had several positive effects for both activities. The Bell Laboratories personnel became more familiar with the problems facing the Western Electric development and manufacturing people. The Western Electric commercialization group was able to influence the technology with their manufacturing and marketing expertise. For both groups the communications networks increased and there was increased learning across function.

The Advanced Engineering Staff and the car groups and downstream users operate in a double barrier environment. The Advanced Engineering Staff is organizationally and geographically separated from the car groups and some other downstream users. While arguments may be put forth that The Advanced Engineering Staff should be part of the car groups, this arrangement will be countered by the assertion that advanced resources might be consumed in current projects in the car groups.

The bond and barrier organization would be helpful in this situation. People from the Advanced Engineering Staff could work on site at the car groups to provide the bond to reinforce the organizational barrier.

With this approach the Advanced Engineering Staff would be closer coupled to the car groups so that the goal congruence can be improved and the effect of the Not Invented Here syndrome reduced. Both groups would learn as a result of the move.

This concept would be used when a division requested specific development work to be performed by the Advanced Engineering Staff. The development work could go on at the division's home location.

This mode of operation has been used at Toyota. Rubinger[90] writes that the Engine Number 1 group, which is the advanced engine group, and the Engine Number 2 group, which is responsible for commercialization, are located in adjacent areas in the same facility. Toyota encourages transfer between the two groups as a way to promote learning across functions.

6.10 Formalized Product Development Process

As was previously noted, there is no formal process for taking a new concept and converting it into a new product, tool, process, or system. There is no formal channel that relates the upstream organizations to a downstream user and identifies the in-between steps on the way to commercialization.

Although it may seem desirable to have a formal road map that refers product ideas down one path, process ideas down another, etc., this may be very difficult and limiting in a large organization.

The alternative proposed here is that a technology strategy establishes goal congruence between the Technical Staffs and the downstream users. Goal congruence leads to agreement between the users and the Technical Staffs as to the path the idea will take toward commercialization. This technology transfer plan should be an upfront activity for each project at the Technical Staffs. Congruence should be attained from downstream users as to the technology transfer plan. This would eliminate the problem of the Technical Staffs trying to locate a potential user for the technology after it has been conceived.

The Technical Staffs may want to pursue commercialization on its own. For example, smaller companies or contractors can be designated as the group to take a new technology and convert it into a product reality. An example of this might be the three dimensional CAD/CAM modeling system designed by the Research Laboratories.

In summary, this concept is to identify the path to commercialization at the outset of the project and to get agreement from the downstream users at the outset. This will provide the necessary path that links an idea to a product reality.

This concludes a discussion of the recommendations for improving the technology development and transfer process used by The General Motors Technical Staffs. The ten recommendations that have been discussed in sections 6.1 to 6.10 of this section are summarized below:

1) development of a technology strategy
2) a senior executive responsible for the development and implementation of the technology strategy
3) a reward system compatible with the technology strategy
4) increased support for downstream users
5) narrowed scope of in-house research
6) use of project groups from initial concept through manufacturing
7) transferring technology by transferring people
8) rotation programs
9) use of bond and barrier organizations
10) definition of the product development path

A matrix has been developed which summarizes the barriers to technology development and transfer discussed in Chapter 5, and relates the areas of contribution of each of the recommendations developed in Chapter 6. This matrix is shown in figure 5.

TECHNOLOGY DEVELOPMENT AND TRANSFER BARRIER AREAS IMPROVED BY RECOMMENDATIONS

THESIS RECOMMENDATIONS	BARRIER AREAS: LACK OF GOAL CONGRUENCE	LACK OF PROJECT SUPPORT	TOP MGMT CONCERN FOR TECHNOLOGY	NOT INVENTED HERE	LIMITED BROAD BASED LEARNING	NO PRODUCT DEVELOPMENT PROCESS	LEVEL OF TECHNOLOGY BARRIERS
TECHNOLOGY STRATEGY	X	X	X			X	
SENIOR EXECUTIVE FOR TECHNOLOGY	X	X	X				
REWARD SYSTEM KEYED TO STRATEGY	X	X				X	
MORE SUPPORT FOR USERS PROJECTS		X					
NARROWER RESEARCH AGENDA		X				X	
GROUP FROM CONCEPT TO MFG.	X	X		X	X		X
TRANSFER OF PEOPLE				X	X		X
ROTATION PLAN				X	X		X
BOND AND BARRIER ORGANIZATION		X		X	X		X
PRODUCT DEVELOPMENT PLAN						X	

FIGURE 5

CHAPTER 6

FOOTNOTES

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Chapter 7

CONCLUSIONS

This thesis has attempted to determine what the barriers to technology development and transfer are at the General Motors Technical Staffs and to develop a set of recommendations for how the Technical Staffs can improve the technology development and transfer process. This will enable the Technical Staffs to continue to contribute to the future success of the corporation.

The methodology used by this thesis is to first examine the premise that technology is important to the auto industry. After concluding that technology is a key success factor for the auto industry, the paper describes technology development and transfer practices from other successful companies. This information was obtained from in depth interviews with senior technical executives at IBM Corporation and Intel Corporation. Additional material was developed from library research and from coursework from the M.I.T Management of Technology Program.

After describing a list of technology development and transfer practices used by other companies, the paper presents a description of the General Motors Technical Staffs and the role and mission of the groups.

Key executives at the groups were interviewed and a list of barriers to technology development and transfer developed from each group interview. Key technical executives outside the Technical Staffs' organization were interviewed and from both sets of interviews seven general areas of barriers to technology development and transfer were developed. These problem areas in technology development and transfer are by no means unique to General Motors Corporation. Interviews with IBM executives pointed up similar problems.

Chapter 6 provides a set of ten recommendations for improving the technology development and transfer process at the General Motors Technical Staffs. A matrix (Figure 5) relates the contribution of each of the ten recommendations to the barrier areas.

A criticism that can be made of this thesis is that it suggests changes in the practices used by the Technical Staffs and other General Motors organizations, while maintaining the presumption that the organizational structure should remain unchanged.

This philosophy was adopted for three reasons. First, this author lacks the requisite knowledge to suggest changes in the organizational structure. The organizational structure is a result of a well thought out series of objectives of which technology development and transfer may be only one.

Second, it was felt that all parties to the process would be receptive to recommendations that could be tried out on an experimental basis within the present setting with minimal disruption. If these trial activities proved to be successful the concepts could be extended. If unsuccessful the practices would be eliminated with minimal risk. If organizational changes were required the risk of implementation would be high and the corresponding probability for adoption would be low.

Last, the issue of technology transfer was found to be largely an issue of people management. Much progress can be made in this area without changing the organizational structure.

The recommendations developed in this paper are presented as a way to improve the technology development and transfer process used by the General Motors Technical Staffs. These recommendations represent the best solutions from other successful companies, research, and ideas from the M.I.T. Management of Technology Program. It is hoped that these recommendations will be adopted and that the General Motors Technical Staffs will continue as a strong and vital force as General Motors moves forward in the future as a 21st century company.

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