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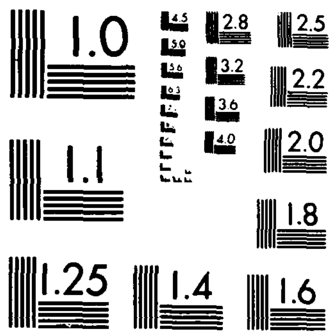

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AN EXPLORATORY STUDY OF DOMESTIC TECHNOLOGY TRANSFER CONCEPTS, FEDERAL INFRASTRUCTURE, AND PROCESS MODELS

THESIS

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THESIS

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

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Master of Science in Logistics Management

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The contents of the document are technically accurate, and no sensitive items, detrimental ideas, or deleterious information is contained therein. Furthermore, the views expressed in the document are those of the author and do not necessarily reflect the views of the School of Systems and Logistics, the Air University, the United States Air Force, or the Department of Defense.

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Paul A. Dawson

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Abstract

This report provides a narrative review of concepts and issues related to domestic technology transfer. Six investigative questions are posed which form a framework for analysis. First, what definitions of technology, innovation, and technology transfer have been advanced, and what other concepts are relevant for understanding the subject matter? Second, what factors have been identified as promoting or impeding technology transfer? Third, what important roles do individuals fulfill in technology transfer? Fourth, what is the Federal infrastructure for promoting technology transfer? Fifth, what is DOD's role in promoting domestic technology transfer? Sixth, what models have been advanced to portray the technology transfer process? The literature review indicates that innovation research provides a large body of knowledge related to factors influencing technology transfer, and factors can be grouped as pertaining to management involvement or the source - user relationship. In the Federal infrastructure for technology transfer, there are notable active systems, but funding appears to be a continuing problem. Although technology transfer from DOD to other sectors is predominantly passive, a trend toward active programs is observed. A complete working model of the process does not appear to be available, however, a variety of descriptive models contribute to understanding technology transfer processes.

AN EXPLORATORY STUDY OF DOMESTIC TECHNOLOGY TRANSFER CONCEPTS, FEDERAL INFRASTRUCTURE, AND PROCESS MODELS

I. Introduction

Increased investment in research and development (R&D) and improved industrial productivity resulting from applications of new technology were major factors contributing to economic growth in the United States from the late 1940s to 1970. During the 1970s, the rate of increase in industrial productivity declined in comparison to past rates and in comparison to the rates of foreign competitors. Improved transfer of the results of federally funded R&D to the private sector has been considered one approach to enhancing national productivity and competitiveness. (O'Brien and Franks, 1981:73-74)

The findings stated in Public Law 96-480 indicate national recognition of the importance of technology transfer:

> (1) Technology and industrial innovation are central to the economic, environmental, and social well-being of citizens of the United States.
> (2) Technology and industrial innovation offer an improved standard of living, increased public and private sector productivity, creation of new industries and employment opportunities, improved public services and enhanced competitiveness of United States products in world markets.
> (3) Many new discoveries and advances in science occur in universities and Federal laboratories, while the application of this new knowledge to commercial and useful public purposes depends largely upon actions by business and labor. Cooperation among academia, Federal laboratories, labor, and industry, in such forms

as technology transfer, personnel exchange, joint research projects, and others, should be renewed, expanded, and strengthened (U.S. Congress, 1980:Sec.2).

Public Law 96-480, cited as the Stevenson-Wydler Technology Innovation Act of 1980, also states that scientific and technological developments resulting from federally funded R&D should be accessible to state and local governments as well as private industry (U.S. Congress, 1980:Sec.2.(10)).

Technology transfer and technological innovation can be viewed as aspects of the larger subject of how to better manage the nation's technological resources (Gee, 1974:31). Assuming that expenditures for R&D are representative of technological resources, the national "resource" was estimated to be about $60 billion in fiscal year 1980. The Federal portion of this expenditure was estimated to be about one-half of the national total. (O'Brien and Franks, 1981:74) The substantial involvement of the Federal government in R&D presents a "prima facie case" for the necessity to understand the process whereby the results of federally sponsored R&D are transferred (Doctors, 1969:163).

Problem Statement

One of the initiatives of the Stevenson-Wydler Act to promote technology transfer is the requirement that "Each Federal laboratory shall establish an Office of Research and Technology Applications" (U.S. Congress, 1980:Sec.11). Section 11 of the Stevenson-Wydler Act, in addition to stipulating functions of the Research and Technology Applications

Offices (ORTAs) and reporting requirements, also specifies that laboratories with budgets exceeding $20 million will commit at least 0.5% of their R&D budget to support the technology transfer functions (U.S. Congress, 1980:Sec.11).

The Department of Defense (DOD) accounts for a significant amount of Federal R&D activity. For fiscal year 1980, approximately one-half of Federal R&D expenditures were estimated to be defense related (O'Brien and Franks, 1981:74). In a 1984 GAO survey of ten agencies accounting for a total of 263 laboratories, DOD's 75 laboratories represented the largest number of facilities operated. The agencies surveyed were: the Departments of Agriculture, Commerce, Defense, Energy, Health and Human Services, Interior, and Transportation; the Environmental Protection Agency, the National Aeronautics and Space Administration, and the National Science Foundation. (General Accounting Office, 1984:4) Although not reflective of the 0.5% funding requirement for technology transfer functions previously mentioned, DOD laboratory ORTA funding amounted to $2,922,500 in FY 1982. Despite the substantial size of defense related R&D expenditures and the large number of DOD research facilities operated, this expenditure was considerably dwarfed by the following agencies (General Accounting Office, 1984:7):

National Aeronautics and Space Administration	-	$52,486,000
Department of Health and Human Services	-	21,091,300
Department of Energy	-	13,245,400
Department of Commerce	-	10,589,000

Department of Defense guidance in support of the Stevenson-Wydler Act is provided in the Domestic Technology Transfer Program Regulation. One of the policy statements listed in the regulation is:

> Support the domestic technology transfer process as an integral part of the research and development effort and incorporate domestic technology objectives into the mission of each appropriate R&D activity (Department of Defense, April 1985:1-1).

Whereas Doctors (1969) states the case for understanding the technology transfer process is "prima facie", the DOD regulation and public law provide explicit requirements for the need to understand the process. Doctors (1969) also maintains that

> In considering any program of technology transfer, it is important to have in mind a working model of the process. Such a model has not yet been advanced by leading researchers... (Doctors, 1969:36).

Obviously, a number of years have passed since Doctors's statement. The problem, therefore, is to determine if an adequate model has been advanced.

Research Objective

The research objective is to ascertain if an existing model portrays the domestic technology transfer process by identifying technology transfer concepts, factors influencing the process, Federal and DOD transfer mechanisms, and previously advanced models.

Investigative Questions

The following investigative questions guide the research:

1. What definitions of technology, innovation, and technology transfer have been advanced, and what other concepts are relevant for understanding the subject matter?
2. What factors have been identified as promoting or impeding technology transfer?
3. What important roles do individuals fulfill in technology transfer?
4. What is the Federal infrastructure for promoting technology transfer?
5. What is DOD's role in promoting domestic technology transfer?
6. What models have been advanced to portray the technology transfer process?

Scope

The 75 laboratories within the DOD consist of 35 Army laboratories, 25 Navy, 14 Air Force, and one laboratory directly under DOD (General Accounting Office, 1984:14-16). A list of the laboratories is provided in Appendix A. The DOD laboratories estimated that 1,237 requests for technical assistance were received from state and local governments in FY 1982 (General Accounting Office, 1984:9). An approach to the research problem and objective would be to survey the population of DOD laboratories to determine what models, if any, had been adopted to portray the technology transfer process. The requests for assistance could then be analyzed as case studies for best fit to the models described. Such a detailed approach is well beyond the scope of this research effort.

For purposes of narrowing the research, the focus will be on the conceptual process of technology transfer with specific examples or case studies cited as necessary to support or illustrate concepts rather than attempting to enumerate or analyze numerous situations wherein transfers of technology are effected. Identification of technology transfer models will be through the review of pertinent literature.

This paper does not explore issues related to technology transfer in the international context of matters pertaining to arms export regulation and control. Research or studies on technology transfer inclusive of international considerations will be cited to the extent that the source purports to be equally applicable to domestic technology transfer.

Value of the Research

"Innovation and the transfer of technology are economic phenomena that managers can, should and must manage" (Fischer, 1984:7). When managers think that technological change is something that happens to their organization rather than something they can control and have work for them, it becomes a self-fulfilling prophecy (Fischer, 1984:3). Another problem with management misconceptions about technology is unrealistic expectations which have kept "...technological capability on a roller coaster of corporate funding" (Steele, 1983:133). Support by companies and public opinion for technological innovation has ranged from "virtually universal" to innovation being seen as ineffective and socially unresponsive. Nevertheless, "...companies must innovate in order to survive" (Steele, 1983:140).

The requirements of the Stevenson-Wydler Act and supporting DOD policy may seem to indicate that only Air Force managers directly involved with R&D management need to be concerned with domestic technology transfer. Technology and technological change, however, are pervasive facts of life for all Air Force managers. An example of the widespread importance of technology is the Air Force's interest in improving reliability and maintainability (R&M). Increased R&M will have a positive effect on three areas affecting mission capability: available manpower, costs of spare parts inventories, and combat effectiveness of weapon systems.

Achieving significant improvements in R&M will depend on developing and applying technology (Russ, 1985:122-125). In this environment, managers need to understand principles relating to technology transfer just as much as principles relating to such business functions as personnel, production, and finance. Therefore, the value of this research is to contribute to the ability of a manager to understand technology transfer.

Background

Digman's (1979) literature review of research pertaining to technical information systems provides nine specific findings which represent an overview of thoughts concerning technology transfer:

1. Technology transfer is an important, complex, and poorly understood process.

2. Innovations are spread or diffused according to the rules of diffusion theory.

3. There is a lack of communication and unity of purpose between the developers of technology and the users of technology.

4. Successful transfer depends more on the personal factors than upon formal dissemination means.

5. There is a myriad of government and industrial programs concerned with information dissemination, especially technical information.

6. The information activities of government agencies seem preoccupied with goals such as maximizing transfer, whether or not this is possible or even desirable.

7. In spite of various Federal agencies' attempts to increase the transfer rate, the rate of utilization is not high.

8. Organizational structures and practices affect the innovation process, but no single organizational model offers a master solution to the problem of innovation.

9. Innovators are the key elements in the innovation process. (Digman, 1979:38-39)

Digman's findings suggest an organization for this thesis. Regarding the first finding, another perspective on technology transfer is that it is one aspect of the larger process of technological innovation (Creighton et al, 1972:1). The larger process of technological innovation is itself a large, multidisciplinary body of knowledge. Disciplines contributing to the field of innovation research include economics, political science, sociology, industrial engineering, and even geography and anthropology. One of the problems resulting from this multidisciplinary characteristic is different terms of analysis and methods. (Tornatzky et al, 1983:13-14) The following section, therefore, examines definitions of technology, innovation, and technology transfer and explores the relationship of technology transfer to the large, complex field of innovation research.

Digman's second, third, and eighth findings concerning the spread of innovations, lack of communications, and organizational structures suggest the first section of the literature review in the next chapter -- factors which have been identified as influencing technology, both favorably and unfavorably. The second section of the literature review examines the role of individuals in the technology transfer process. Digman's fourth and ninth findings indicate the importance of individuals in technology transfer, therefore, the role of individuals is discussed separately from the factors in the first section. The fifth, sixth, and seventh findings concerning government agencies provide the impetus for the third and fourth sections of the literature review which examine the Federal infrastructure relating to technology transfer and DOD's activities. The last section of the literature review relates to the research objective of this thesis -- models of technology transfer are considered.

Concepts and Definitions

Technology. "The concept of technology transfer is not a simple one to define, for the meaning of the phrase seems to depend upon the audience considering it and the point in time" (Doctors, 1969:3). To explore the concept of technology transfer, a necessary step is to consider the idea of technology (Gee, 1974:32). Machines and physical tools are common referents for technology (Doctors, 1969:3-4; Tornatzky et al, 1983:1-2), however, such a view is an inadequate "nineteenth century notion" (Doctors, 1969:4).

Schon (1967) offers a broader definition of technology as

> ...any tool or technique, any product or process, any physical equipment or method of doing or making by which human capability is extended (Schon, 1967:1).

This definition is also accepted by Doctors (1969) and Tornatzky et al (1983), although in Tornatzky et al's quoted reference to it, the words "any product or process" are deleted (Tornatzky et al, 1983:1).

Simpler definitions of technology can be found. For example, technology is "...the means or capacity to perform a particular activity" (Gruber and Marquis, 1969:255), and "Technology has been defined simply to be the application of science" (Gee, 1974:32). Gee (1974) argues that the "application of science" definition is inadequate, using the example of dropping a pin as applying science (law of gravity) but not technology. His argument would seem equally applicable to Gruber and Marquis' definition. Dropping a pin is a particular activity. Holding it between two fingers and releasing it is certainly a means to perform the activity, but such a means is not likely to be considered technology. Applying the pin drop example to Schon's definition, the holding/releasing activity can be viewed as a technique or method of doing and the dropping as a process. The example fails to qualify as technology, however, by virtue of the "by which human capability is extended" criteria.

Gee (1974) posits that "The imprecise nature of technology ... rules against a precise definition" (Gee, 1974:32). Gee explains technology by contrasting it with science.

> Whereas science is concerned with the increase of knowledge and understanding, technology is directed toward use ... the output of technological activity is a product, process, technique, or

> material developed for some specific use. Technology ... can incorporate inventions ... Patents are more commonly the outgrowth of technology rather than of science (Gee, 1974:32).

Comparing Gee's comments with Schon's definition, a convergence of terms - product, process, techniques apparent. Also, Gee's emphasis on "use" is similar to Schon's "method of doing or making." Schon's definition of technology appears to be an adequate conceptualization of this variable.

Invention. Gee's comments noted above introduce the next variable to consider - inventions. For inventions, Doctors (1969) adopts the "narrow sense of the patent definition, "any new and useful process, machine, manufacture or composition of matter" (Doctors, 1969:5). Another definition is

> ...the first creation of a piece of hardware (or software), usually in prototype or demonstration form, which proves the feasibility of an idea or concept ... a subset of the idea generation/commercialization process (Jervis, 1975:19).

The keywords in these definitions are "new" and "creation". Inventions, as products or processes, embody technologies which may or may not be new. To be an invention, however, the manifestation of the technology must be new. The idea of "newness" also introduces a longitudinal dimension into the study of technology transfer, i.e. the concept of technology over time. A technology does not cease being a technology due to the passage of time. A more important notion may be Jervis's description of an invention as "a subset of the idea generation/commercialization process." The concept of innovation seems to represent the larger process of which invention is a subset.

Innovation. Whereas the definition of invention is fairly unambiguous, conceptualizations of innovation seem to follow two themes. One theme is an extension of the invention definition and emphasizes commercializing the invention. The second theme is somewhat broader in that the characterization relies on the perception of the user.

Examples of definitions which stress new commercializations include the following:

> ...the application of a new technique (hardware or software) which increases performance at existing or lower costs (Doctors, 1969:5).

> ...the series of activities which in effect delivers an invention or idea to its first acceptance and use ... Innovation is by no means confined to the technological sphere but exists also in the arts and in education, social, and political circles ... (Gee, 1974:31).

> ...the technical, industrial, and commercial steps which lead to the marketing of new manufactured products and to the commercial use of new technical processes and equipment (Jervis, 1975:19).

The definitions offered by Gee and Jervis introduce the dimension of "series of activities" or "steps" to the discussion of innovation. As contrasted with "invention", innovation is more likely to be viewed as a process than a singular event. All three definitions incorporate the dimension of "application" or "use". Thus, an invention for which there is no use does not constitute an innovation.

Several concerns may be expressed concerning these definitions. First, in Doctors's view, an economic benefit is required (existing or lower costs). This stipulation seems to mitigate against situations wherein performance is increased, but at a higher cost. A requirement for increased performance may warrant an innovation even if the cost is higher. Gee's comments imply that the "technological sphere" is something different than the arts, education, social, and political spheres. Given Schon's broad definition of technology, all the spheres could be characterized as having their own technologies, i.e. techniques and methods of doing things. Therefore, a separate definition for "technological innovation" appears to be an unnecessary redundancy inasmuch as innovations are inherently technological.

Examples of the second theme in which innovation definitions are broadened include the following:

> ...the application of a technology, idea, or concept to a new use or a new user where the application is embodied in a new product or process developed for a specific purpose (Jones, 1983:14).

> ...a technology new to a given organization. By this definition, not all technologies are innovations; only those recently introduced into a setting are ... (Tornatzky et al, 1983:2).

> ... an idea which is perceived by the individual to be a new method, means, or capacity to perform a particular activity (Creighton et al, 1972:1).

> Innovation is not a technological advancement. Innovation is the process of applying a given technology to areas other than those for which it was originally designed (Sullivan, 1980:10).

From these definitions and comments, the shift of "newness" from the technology to the application is apparent. Another perspective on innovation is provided by Jolly (1980) who distinguishes between the noun and verb components of innovation. The noun component refers to the "device, technique, or procedure" and "The concept of newness need only apply to the user" (Jolly, 1980:76). The verb component, on the other hand, refers to "...the sequence of events that commonly occur when an institution, company or industry innovates" (Jolly, 1980:77).

One criticism of these definitions centers on Sullivan's statement that "Innovation is not a technological advancement." From the discussion so far, the statement "...not necessarily a technological advancement" appears more appropriate. This is only a minor criticism, however. The second set of innovation definitions generally represents the conceptualization of innovation that is necessary for understanding technology transfer. Changing the newness concept from the device, technique, or procedure to the user introduces the idea of movement or transfer from one setting to another. Thus, this paper accepts the definition offered by Tornatzky et al that innovation is technology new to an organization.

Vertical and horizontal transfer. Before investigating the definitions that have been advanced for technology transfer, the idea of vertical and horizontal movement should be noted. Whether or not vertical and horizontal transfer are both considered subsets in particular definitions of technology transfer is not usually specifically addressed, suggesting perhaps that the distinction is not important.

Doctors (1969) cites the work of Brooks (1968) in explaining vertical transfer as when

> ...a general principle is applied to produce a new product, device, or process within a given scientific or technical discipline, and, generally within an organizational entity such as a single corporation or government agency (Doctors, 1969:6).

A more succinct explanation is that "...the vertical flow of technology..." is "...from a laboratory to a given application, in a given discipline..." (Essoglou, 1975:5).

Horizontal transfer, on the other hand, can be described as

> ...secondary applications, wherein technology which originates in one sector (such as aerospace) is used in another sector (such as urban transportation or health... (Linhares, 1976:13).

Doctors (1969) again draws on the work of Brooks (1968) to offer the definition that horizontal transfer is when

> ...one technology is adapted to a different area of application, generally across institutional lines. An example ... might be seen in... the use of a new metal alloy developed for a rocket engine in a boiler for a steel mill (Doctors, 1969:6).

Research and development. R&D can be defined by detailing its separate components as follows:

> Basic Research - an increase of knowledge or understanding in science by gaining a fuller knowledge or understanding of the subject under study.

Applied Research - the practical application of scientific knowledge or understanding for the purpose of meeting a recognized need.

Development - the systematic use of scientific knowledge and understanding directed toward the production of useful materials, devices, systems or methods including design and development of prototypes and processes. (Newton, 1980:9)

Technology transfer. Gee (1974) contends that the phrase technology transfer "suffers from ambiguity" partly because of the question raised of from what source to what user. Sources and users do not necessarily have to be in the same technical discipline, and the activity may involve existing technology or new technology. (Gee, 1974:32) The definitions of technology transfer in the literature reviewed present three views on technology transfer: (1) the activity involves movement of technology after some type of adaptation, (2) the activity involves the movement of technologies both with and without adaptation, and (3) the activity involves the movement of technology; adaptation is not stipulated in the definition. Another characteristic introduced in the definitions is technical information.

Definitions of technology transfer which represent the first view include:

> ...the process whereby technical information originating in one institutional setting is adapted for use in another institutional setting ... more than the mere dissemination of technical information, it implies the adaptation of new technology through a creative transformation and application to a different end use (Doctors, 1969:3).

> ...the process of employing a technology for a purpose other than that for which it was developed ... tech transfer focuses on the utilization of previous research (Foster, 1971:111).

The second view that technology transfer involves the movement of technology both with and without adaptation appears to be widely accepted. Examples and comments incorporating this view include:

> ...the utilization of an existing technique in an instance where it has not previously been used. The transfer may be merely the acceptance by a user of a practice common elsewhere, or it may be a different application of a given technique designed originally for another user (Gruber and Marquis, 1969:255-256).

> When scientific or technical information generated and/or used in one context is reevaluated and/or implemented in a different context, the process is called technology transfer (Bar-Zakay, 1970a:3).

> ...the application of technology to a new use or user. It may be a direct application or may include the need for adapting or tailoring the technology to its new use or user (Gee, 1974:32).

> ...an effort to bring the results of research and development to new users... Technology transfer calls for the transformation of research and technology into products, processes, or services; or to the application of research developed for one purpose to a secondary purpose (Myran, 1978:10).

> ...the diffusion of a technology or technological information from a source to a user, in the same or a different organization, that results in an innovation (Jones, 1983:14).

Examples of technology transfer definitions representing the third view wherein adaptation is not mentioned may be considered to implicitly recognize transfers both with and without adaptations inasmuch as technology is still technology whether or not an adaptation is employed in the new setting. Definitions and comments reflecting this view include:

> ...a purposive, conscious effort to move technical devices, materials, methods, and/or information from the point of discovery or development to new users... It is the planned and rational movement of technology... It must be distinguished from the more general process of technological diffusion: the historic, unplanned movement of technical or social items from one user to another without any focused effort to actively transfer the particular item (Creighton et al,1972:2).

> The movement of technical ideas and know-how from a conceiving organization (the seller) to a user organization (the buyer) is technology transfer - at any stage of research and development (Evans, 1976:26).

> ...a process which involves the linking of technologies at one extreme with expressed or innate needs at the other and by means of a complex brokerage system (Gartner and Naiman, 1976:25).

> ...the successful dissemination of technical information (technology) to a potential user, resulting in some form of utilization of the technology by the user; therefore, successful technology transfer depends upon the existence of some sort of technical information system (TIS) (Digman, 1979:37).

The definitions offered by Doctors (1969) and Foster (1971) appear to be too narrow by considering technology transfer to be only applicable to adaptations. Given the frequent references to technical information, however, Doctors's comments deserve particular emphasis. The dissemination of technical information by itself does not constitute technology transfer.

After reviewing the definitions, another observation is that technology transfer appears to be predominately a horizontal transfer activity. To simply define technology transfer as the horizontal movement of technology, however, would result in the same limitation as imposed by Doctors and Foster, i.e. a restriction to secondary application. Myran's (1978) definition represents a view that technology transfer has both vertical and horizontal components.

One obvious conflict in the definitions is between Jones (1983) and Creighton (1972). The use of the term "diffusion" by Jones contradicts Creighton's statement that technology transfer is separate and distinct from diffusion. Concerning technology transfer versus the diffusion of innovation, Chakrabarti and Rubenstein (1976) explain that

> Spencer and Woroniak (1967) brought out the distinction between the terms "diffusion of innovations" and "technology transfer" by attributing an element of planning and purposiveness in the latter (Chakrabarti and Rubenstein, 1976:21).

Technology transfer studies and diffusion of innovation studies represent two main traditions of research on the movement of technical information, emphasizing "point to point" mechanisms and patterns of "spreading" over time, respectively (Chakrabarti and Rubenstein, 1976:20-21). These comments support Creighton's statement, therefore, Creighton's definition is considered to be superior to Jones's. Creighton's definition also adequately represents most of the views expressed on technology transfer definitions reviewed herein, assuming that his comments implicitly recognize movements of technology both with and without adaptation.

In relating the concept of technology transfer to the Federal sector, Tornatzky et al (1983) note that "...most government programs to promote the spread of technology are not characterized as "dissemination"; the term technology transfer is usually applied" (Tornatzky et al, 1983:161). Linhares (1976), on the other hand, comments that Federal technology transfer interests are wide ranging and include activities not only defined as technology transfer, but also technology utilization and diffusion. He also emphasizes that there are both vertical and horizontal components in Federal technology transfer. (Linhares, 1976:13-14)

Based on the review of concepts and definitions, a broad view of technology permits investigations into a wide range of tools, techniques, products, and processes as suitable subjects representing technology. The range of investigation in the subject of innovation, however, is affected by which type of definition one accepts. Defining innovation from the perspective of commercialization of inventions is more limiting than defining innovation on the basis of user perception. Technology transfer presents an even more difficult subject on which to focus because of varying perspectives on the scope of activities included in the concept. In some views, technology transfer seems almost synonymous with innovation; in others, technology transfer is viewed solely as horizontal or secondary applications of technology. In fact, neither of these views is acceptable. In general, technology transfer is a subset of innovation dealing with the movement of technology both with and without adaptation from the source to the user. The source to user context is in contrast to the more generalized process of diffusion or spreading of innovation.

An important observation on technology transfer and innovation diffusion is that

> ...the two processes are not mutually exclusive; a researcher working in one tradition must draw on the knowledge available in the other (Chakrabarti and Rubenstein, 1976:21).

In the following literature review, therefore, research and discussions on innovation adoption, R&D output utilization, and commercialization of innovations are all considered valid sources of information concerning factors and considerations in technology transfer.

II. Literature Review

Factors Influencing Technology Transfer

Chakrabarti and Rubenstein (1976) conducted research on 73 cases of adoption of NASA innovations in 65 organizations. The 73 cases were divided into two categories, process and product, with 28 and 45 cases in each group, respectively. Based on their review of technology transfer literature, twelve propositions relating to techno-economic and organizational factors were developed:

Techno-economic Factors:

1. The degree of general connection of the technology to the firm's existing operations will affect the degree of success of adoption.

2. The specificity of the relationship between the technology and some existing and recognized problem will affect the degree of success of adoption.

3. The degree of urgency of the problem to which the technology was related will affect the degree of success of adoption.

4. The quality of information received from the source about the innovation will affect the degree of success of adoption.

5. Maturity of the technology will affect the degree of success of adoption.

6. Availability of personnel to implement the technology will affect the degree of success of adoption.

7. Availability of financial resources to implement the technology will affect the degree of success of adoption.

Organizational Factors:

8. The degree of top management interest in the piece of technology will affect the degree of success of adoption.

9. The degree of success of adoption will be influenced by the dimensions of organizational climate of the adopting organization.

10. The degree of success of adoption will be higher in organizations where the use of confrontation in joint-decision making is higher.

11. The degree of success of adoption will be higher in organizations where the use of smoothing in joint-decision making is lower.

12. The degree of success of adoption will be higher in organizations where the use of forcing in joint-decision making is lower.

Support was found in process cases for all seven techno-economic factors. The results in the product cases supported propositions 1, 2, 3, 6, 7 and 8. Chakrabarti and Rubenstein noted that "The adoption of process innovations seems to be related to a firm's immediate problem-solving needs" (Chakrabarti and Rubenstein, 1976:32). Adopting product innovations, on the other hand,

> ...seems to be a more complex process requiring both the commitment of a greater amount of resources and a higher level of top management participation than is the case in process adoption situations (Chakrabarti and Rubenstein, 1976:32).

Reporting on research results from a study of attempts to market products, Jervis (1975) indicates that five major areas were identified to distinguish innovations achieving commercial success:

1. Strength of management and characteristics of managers

2. Understanding user needs

3. Marketing and sales performance

4. Efficiency of development

5. Effectiveness of communications

These conclusions were among the results of Project SAPPHO, a study carried out at the University of Sussex, wherein 70 similar innovations in the chemical and instrument industries were matched into 35 "pairs" of successful and unsuccessful commercialization attempts. (Jervis, 1975:19-21)

Also in the context of commercial innovation is Jones's (1983) discussion of technology transfer success factors as being related to three general areas:

1. Organizational factors
2. Communication factors
3. Technology maturity factors

Regarding organizational factors, Jones contends that "Goal compatibility and congruence determine the extent to which technology transfer is likely to happen" (Jones, 1983:28). The differences in goals between university R&D and commercial organizations are cited as an example wherein a general interest in theory may not foster a transfer relationship to firms more concerned with the financial benefits of commercial applications (Jones, 1983:26-31). Communication factors are important in technology transfer because

> In-house personnel are usually concerned with short term incremental product improvements, cost reduction, quality control, and other internal needs. This observation reinforces the need to communicate with outside sources of information in order to keep track of technology trends and opportunities (Jones, 1983:30).

Technological maturity refers to the "gap" between basic research and readiness for commercialization.

Increased maturity implies less risk and uncertainty for the commercial adopter, and, therefore, greater probability of successful technology transfer. (Jones, 1983:31-32) "The more mature the technology, the more likely is the firm to attempt to transfer and commercialize it" (Jones, 1983:32).

Linhares (1976) discusses technology transfer factors in the context of utilization of Federal R&D output, whether the user is private industry or governmental agencies at the local, state, or Federal level. Six factors are cited as appearing to be critical:

1. Technical community awareness of user community needs/desires
2. Technical knowledge and sophistication of user community
3. Technical knowledge and sophistication of supplier community
4. Risk aversion environment
5. Market disaggregation
6. Federal program coordination.

Regarding the first factor, Linhares notes that Federal R&D is often perceived as being undertaken without relation to real problems and needs. Involving the market sectors in addressing needs and problems could improve the probability of technology transfer as R&D moves away from basic research. The second factor is a problem for state and local governments, according to Linhares, inasmuch as budget constraints often preclude staffing for scientists and engineers. By the term "supplier community" in the third factor, Linhares refers to "suppliers of products", not the source of technology in the sense of a source - user relationship (Linhares, 1976:18-19). The suppliers of products are themselves a user or market in that they must make innovation adoption decisions regarding their products. The source of the technology transfer may be internal or external.

The fourth factor, risk aversion, relates to innovation adoption decisions. Linhares contends that in the public sector the tendency is to avoid risk due to concerns for criticism from voters and a focus on near term issues and improvements (Linhares, 1976:19-20). Market disaggregation, the fifth factor, occurs in the public sector because even though the market may appear large for a product, each customer may impose unique specifications, thus preventing economies of scale which would facilitate technology transfer. Federal program coordination as a factor refers to the potential problem of an agency supporting R&D for a product which is not compatible with the objectives or regulations of another agency. "Cross-program knowledge" is important (Linhares, 1976:20).

From the four authors reviewed above, two general themes seem to emerge for discussing factors that influence technology transfer. One broad theme is management involvement. Chakrabarti and Rubenstein's proposition concerning top management interest specifically recognizes this theme. Their propositions concerning the availability of personnel, the availability of financial resources, and organizational climate can also be considered to be management related factors. Jervis also specifically cited management as a major area influencing innovation success, and his other major areas of marketing, development efficiency, and communication effectiveness can be considered to be in the domain of management involvement. The second general theme relates factors to the source - user relationship. Chakrabarti and Rubenstein's propositions concerning problem recognition and problem urgency, and Jervis's major area of understanding user needs highlight this theme. Linhares's factors on awareness of needs, user knowledge, and supplier knowledge also are examples of elements of a source - user relationship. The related issues of risk aversion and technological maturity, as discussed by Linhares and Jones, are examples of factors which can be barriers to a source - user relationship. Additional literature concerning factors influencing technology transfer is reviewed in the following paragraphs under the sub-headings of management involvement and source - user relationship.

Management involvement. D.B. Hertz wrote in 1965 that there was a growing awareness among executives that innovation was not just desirable, but was a condition of survival. Hertz also noted that research findings had found that deep involvement of top management in the research process was associated with successful R&D operations (Hertz, 1965:49). More recently, global competition and the impact of technological change are cited as challenges requiring executive skills in the management of innovation (Fischer, 1984:2; Leonard-Barton and Kraus, 1985:102). Two factors that management must influence in order to promote effective performance by innovative groups are "...the ability to anticipate technological progress within a field and the need to establish an appropriate setting for a creative group" (Fischer, 1984:3).

Myers and Sweezy (1978) reported on results of "a study of 200 innovations that passed initial screenings but failed after entering the commercialization pipeline" (Myers and Sweezy, 1978:41). In their study, five broad categories accounted for most of the failures:

Market	27.5%
Management	23.5%
Capital	15.0%
Technology	11.5%
Laws and regulations	17.5%

Management, as a category, included errors such as developing a welding torch for repairing automobile bodies, but discovering after it did not sell that the torch was a fire hazard with the upholstery in place (Myers and Sweezy, 1978:41-42). Management, in general, was related to the other categories as well. For example, Myers and Sweezy noted that in the marketing category "...management often plunges ahead without trying hard enough to minimize that risk" (Myers and Sweezy, 1978:41). In the area of laws and regulations, management is described as "conservative" by rejecting products or processes which might be susceptible to patent or anti-trust problems. In the capital category, management tended to underestimate the funds required to complete the innovation process. The involvement of management should be to "...ask the right questions at the right time" in order not to overlook things easily forgotten and to "...force an appraisal of the assumptions and ideologies that underlie every innovation" (Myers and Sweezy, 1978:46).

In contrast to the private industry and commercialization context of the discussion on management involvement so far, Driver and Koch (1981) describe conditions which can help transfer research results into management practice based on experience in the Federal sector (U.S. Forest Service). Driver and Koch contend that a manager must be involved with the researcher in several ways. First, the problem and significance must be agreed upon. Both parties must have a personal and mutual interest in the problem, and the research effort must be a cooperative effort with the manager involved in the early phases. The manager and researcher must also establish and maintain "...mutual respect and trust" (Driver and Koch, 1981:33-35).

Source - User Relationship. Management involvement includes managers of both sources and users in the technology technology transfer relationship. The distinction between source and user does not necessarily mandate an interorganizational relationship. Interorganizational relationships, however, are often the context of literature concerning technology transfer. Such is the case with literature reviewed in this section.

The source - user relationship can also be characterized as seller - buyer. Evans (1976) uses this terminology in describing sellers as typically consisting of inventors, universities, or research institutes, and buyers as typically being an industrial organization. The ability to transfer technology between seller and buyer, according to Evans, is a function of attitudes held by each party. The differences in attitudes can constitute a "transfer gap" to be overcome if the relationship is to successfully promote technology transfer. Evans's "technology gap" raises issues similar to those posed above by the questions of technological maturity and risk aversion. (Evans, 1976:27-29) In particular, the transfer gap consists of six elements:

1. The gap between idea and prototype.
2. The communications gap between organizations.
3. The disparity between the buyer's concept of worth of new technology and the seller's opinion of its value.
4. The refusal of buyers to recognize that outside technology can be valuable to them.
5. A biased interpretation of the risk versus return axiom.
6. A tendency on the part of many organizations to discourage the sale of a technology even when it would be to their benefit to do so (Evans, 1976:29-30).

The transfer gap makes technology transfer difficult because attitudes are difficult to change. To overcome these problems, Evans suggests that sellers provide "reassurance that the technology is practical" with working models of products or small scale tests of processes. For buyers, Evans suggests that the risk-taking on new technology be uncoupled "from the marketing, production, and R&D departments" by assigning responsibility for new products or processes to a special group. (Evans, 1976:31-32)

Evans's suggestions can be related to an earlier article by Foster (1971). Foster commented that

> Ideally, a company should build a tech transfer team that operates in the new business department, although, of course, the team will interface with the R&D, marketing, and manufacturing functions (Foster, 1971:111).

Foster recommends that organization for technology transfer be based on pairing problems and customers. Thus, in his example, a company with a new technology such as composite materials should identify specific customers in aerospace, building construction, or other appropriate industries. The transfer teams can then proceed with implementation plans addressing particular needs. Foster stresses that the tech transfer team should not be located in either the R&D or marketing department. (Foster, 1971:116-117)

A generalization from Foster (1971) and Evans (1976) seems to be that special provisions in organizational structure may have to be made to facilitate the source - user relationship. Gartner and Naiman (1976) present a similar argument in the context of Federal technology transfer by positing "...for a complex technology transfer to be successful, an explicit structure is needed" (Gartner and Naiman, 1976:27). Gartner and Naiman describe technology transfer by characterizing the environment as comprised of two general systems: the R&D General System and the Company General System. The R&D General System can be a Federal, university, or private laboratory. The Company General System represents the user to whom technology is to be transferred. Departments and divisions within the laboratory or company represent the subsystems of both general systems, and elements in both cases are the people involved in transfer and utilization. (Gartner and Naiman, 1976:22-23) Barriers have been identified as listed below:

Between the General Systems

1. No formal transfer policies
2. Cost barriers
3. Time horizon conflict
4. Infringement problems

Between Subsystems

1. Inertia barrier
2. Lack of an incentive structure
3. Cost barrier
4. Communication barrier
5. Time barrier
6. Geographic distance
7. Non-existent transfer management structure
8. Technology barrier

Between Elements

1. Lack of an incentive structure
2. High risk of being blamed for failure
3. Insecurity of retaining job if not successful
4. Mutual disrespect
5. Unique requirements of each subsystem
6. Updating of technology needs
7. Time barrier

8. Lack of transfer organization managers

Bortman (1977) describes the barriers between the Federal and private sector, in particular, as being "bigness" and "appropriateness". Bigness refers to the problem of being able to penetrate the Federal bureaucracy "...to find the right person and the right solution to a problem" (Bortman, 1977:77). The appropriateness problem relates to the nature of Federal sector technology.

> Quite often, the "high" technology being developed by DOD, NASA, and other labs is totally unsuited to local problems (Bortman, 1977:80).

To overcome barriers to Federal technology transfer, Gartner and Naiman recommend the creation of a specific organization in the Federal sector to be known as the Technical Extension Service (TES). In their opinion such an agency could facilitate source - user relationships by putting information into usable form, advising Federal agencies on actions to improve technology transfer, connecting technical know-how with capital resources, and developing long run interface relationships among governmental, university, and industrial personnel. (Gartner and Naiman, 1976:26-27)

Roles of Individuals

Whereas Gartner and Naiman suggest a new organizational structure to facilitate technology transfer from the Federal sector to other sectors, the literature on innovation often suggests that barriers to technology transfer "...are frequently overcome through the presence of individuals who play certain roles or who possess particular characteristics" (Jervis, 1975:19). References to individuals and technology transfer also cite the importance of interpersonal relationships. Doctors (1969), for example, noted that the experience of the NASA Technology Utilization program was that "Personal contact is significantly more important than mere dissemination of literature" (Doctors, 1969:41). Another expression of this view is that

> ...the mechanism of technological transfer is one of agents, not agencies; of the movement of people among establishments, rather than of the routing of information through communication systems (Burns, 1969:12).

The influence of this thinking is apparent in a 1974 statement by the National Referral Center, a service operated under the Library of Congress:

> The center heartily subscribes to the conviction that scientific and technical information is most effectively transferred from person to person, not from media to people (Timmons, 1978:34).

Roles which have been identified include technical manager, entrepreneur, bureaucratic entrepreneur, boundary spanner, gatekeeper, product champion, purchasing agent or user, technical innovator, innovation manager, and chief executive. (Tornatzky et al, 1983:102; Jervis, 1975:21-22) The fundamental function performed by various roles is to provide a link between sources and users. In their study of knowledge dissemination and utilization, Havelock et al (1969) provide a thorough discussion of linking roles. The premise of the need for linking roles is that between researchers and practitioners there is a knowledge gap which is effectively bridged by additional persons or groups. Havelock et al offer a typology for classifying linker roles as conveyer, consultant, trainer, leader, innovator, defender, knowledge builder, practitioner, and user. (Havelock et al, 1969:7-1 - 7-4a)

The conveyer is typified by the county agent in agriculture's Cooperative Extension Service. The consultant category includes linking roles of facilitators or outside change agents. The trainer category overlaps the conveyer and consultant category with the distinction being that the receiver of the knowledge is in a formal education environment rather than a work setting. The leader category represents individuals inside the user group. Havelock notes that the gatekeeper concept is related to this category in that formal leaders (administrators, supervisors, directors, presidents) may also be the "gate" controlling access to receivers. Also in the leader category and distinct from formal leaders and gatekeepers is the role of opinion leaders, those who influence the adoption of new ideas by others. (Havelock et al, 1969:7-3 - 7-13)

Havelock et al characterize innovator as a linking role because an innovator may be a latent opinion leader, can serve as a demonstrator for real opinion leaders, and may provide advocacy for an innovation. The defender category includes those who have negative roles in linkage, although Havelock et al note that this can be of value when user systems are too open to change and do not consider the pitfalls of an innovation. The knowledge builder category recognizes that sources themselves have linking roles. Expert scientists can be viewed as gatekeepers to the world of science, and R&D managers provide visible linking roles. (Havelock et al, 1969:7-13 - 7-19)

Including practitioner and user as separate categories in their typology is at first somewhat confusing in that "practitioner" was the term Havelock et al used in describing the knowledge gap (i.e. gap between researchers and practitioners). The notion of practitioners in a linking role, however, takes into account the fact that practitioners do not necessarily represent ultimate users. Users themselves are categorized as having linking roles because the user is the only one who can determine need and, therefore, usefulness of knowledge transferred. (Havelock et al, 1969:7-20 - 7-21)

Technological Gatekeeper. The discussion on the linking role typology of Havelock et al mentioned the gatekeeper concept briefly in relation to leaders. The concept is relevant to technology transfer and should be discussed further. The "gatekeeper" construct can be traced to communication research with Lewin (1947) conceptualizing the term "as one who controls a strategic portion of a communication channel" (Brown, 1979:23). The diffusion of information in a multi-step pattern with "gatekeepers" as a moderating influence is a major finding from literature on mass communication research. Allen (1966) developed the term "technological gatekeeper" in research on the flow of technical information into R&D laboratories. Research by Allen and others found that certain individuals are sought out by their colleagues for technical advice, have more contact with external information sources, and have effective communications with each other. (Brown, 1979:23-24) Gatekeepers create awareness of new products and processes by their ability to absorb complex information and translate it into more understandable form not only for their colleagues, but also for top management (Tornatzky et al, 1983:107).

Gatekeepers make up "no more than 15% of a typical development-engineering or applied research group" and bear a disproportionate burden of maintaining new information flow into an organization because most engineers tend to stop keeping up with new theoretical developments after graduation from college (Fischer, 1984:7). Brown's (1979) research on six firms in three different industries identified 10 individuals as gatekeepers out of a sample of 124. Brown used a methodology developed by Taylor (1972) to identify gatekeepers. To fit the definition, an individual had to both be named by others as a choice for technical discussions and have greater technical contacts outside the organization (Brown, 1979:25). In comparing preferences for information sources between gatekeepers and non-gatekeepers, Brown found the higher preference by gatekeepers for information from vendors and customers to be statistically significant ($p<.001$), while higher preferences for literature and outside friends as sources approached significance ($p<.08$, $p<.07$, respectively). Brown also noted that the gatekeeper variable was significantly and positively associated with supervisory status. According to Brown, previous research had raised the question of whether an individual is a gatekeeper because he is a supervisor or individuals become supervisors as a result of their higher performance as gatekeepers. Frost and Whitley (1971) supported the former proposition while Taylor (1972) supported the latter. Brown concluded that the question required more research, although he felt the proposition that gatekeepers tend to become supervisors was more plausible due to performance being an intervening variable. (Brown, 1979:30-34)

Linker. Another significant representation of the role of individuals in technology transfer is the "linker" concept advanced by Creighton et al (1972). Creighton et al (1972) noted that in Havelock et al's typology of linking roles the linker was generally depicted as a third party to the source - user relationship and was separated from the user by gatekeepers. In their conceptualization of the linker, Creighton et al assumed that the linker "...operates within the organization which receives the knowledge" (Creighton et al, 1972:10). In comparison to Havelock et al's typology, this restriction reduced the linker to include the roles of leader, innovator, and early knower of an innovation. Creighton et al (1972) rejected Havelock et al's inclusion of the user in the linking role typology because if the user were to consistently exhibit linking role behavior, the user should then be categorized as an early knower or adopter of an innovation (Creighton et al, 1972:10). In addition to Havelock et al's work, Creighton et al (1972) were influenced by the works of Allen and Farr on technological gatekeepers; Lazarsfeld and Katz on opinion leaders; and most importantly by Rogers and Shoemaker (1971) on generalizations regarding opinion leaders, early knowers, and early adopters (George et al, 1978:52). Rogers and Shoemaker's generalizations on individual characteristics were developed from a content analysis of "...approximately 1200 empirical and 300 non-empirical reports from a variety of disciplines" (George et al, 1978:52). Thirty-two generalizations regarding early adopters of innovations are provided at Appendix B.

The hypothesis of the research by Creighton et al (1972) was that individuals functioning as linkers within an organization "...would exhibit similar traits and characteristics as those of the gatekeeper, opinion leader, innovator, and early knower of an innovation" (Creighton et al, 1972:11). To test their hypothesis, a self-designating questionnaire entitled the Professional Preference Census (PPC) was developed and administered to officers in the Naval Civil Engineering Corps (n=1128). As a result of their analysis, the hypothesis was supported, and 41 linkers

(3.6%) and 132 potential linkers (11.7%) were identified (Creighton et al, 1972:13-40).

The PPC was also administered to civil service employees of the Naval Facility Engineering Command in 1973 by S.H. Claasen (n=1598) and to Navy Chief Radiomen in 1975 by C.R. Fontz and M.P. Shoemaker (n=1143). In these studies, the percentages of linkers identified were 4.3% and 3.8%, respectively. A conclusion from the studies was that individuals with linker characteristics are not unique to a select population (George et al, 1978:55-58).

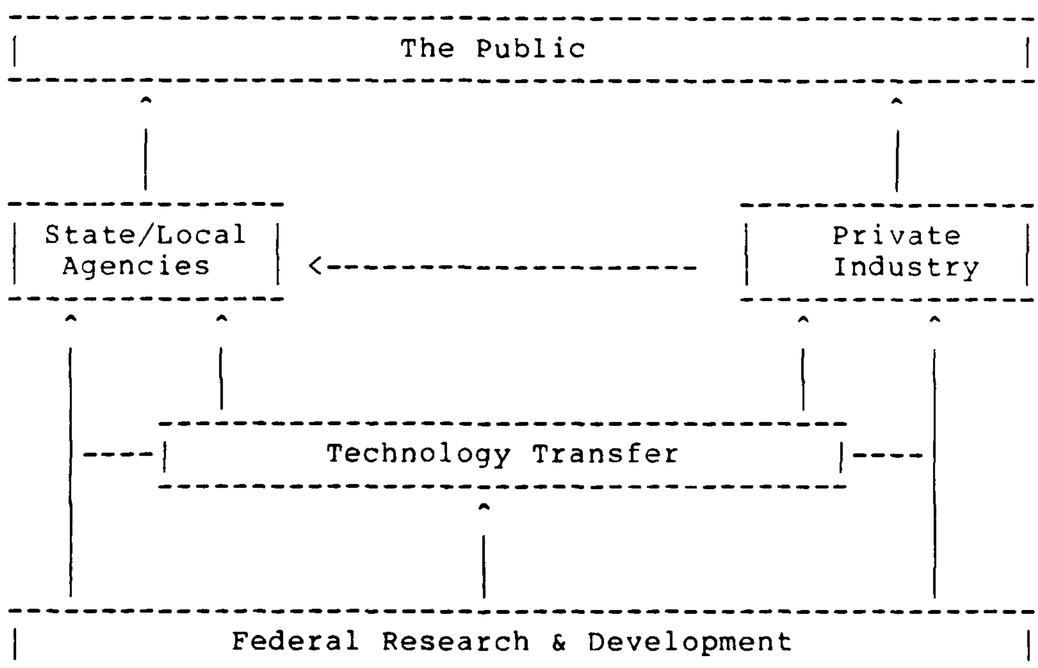
Federal Infrastructure

Promoting domestic technology transfer was not of major interest in the Federal government until the middle 1960's, with the notable exception of the agricultural extension program (Tornatzky et al, 1983:162). The agriculture program dates back to 1887 when the Hatch Experimental Station Act established agriculture experiment stations in connection with Land Grant Colleges. In 1914, legislation was passed establishing the Cooperative Extension Service which functions to transfer research and development results to users (Doctors, 1969:176-177). The agricultural extension program represents "The classic version of a technology transfer system..." and "...is perhaps the most complete of any of the existing technology transfer programs" (Tornatzky et al, 1983:162). The large increase in productivity of American farm workers is considered to be indicative of the success of the agricultural program (Doctors, 1969:177). Research on the agricultural extension system has defined eight major aspects of the program:

1. A critical mass of new technology
2. A research sub-system oriented to utilization
3. A high degree of user control over the research utilization system
4. Structural linkages among the research utilization system's components
5. A high degree of client contact by the linking sub-system
6. A spannable social distance across each interface between system components
7. Evolution as a complete system
8. A high degree of control by the system over its environment (Tornatzky et al, 1983:163)

Since the mid sixties, the interest of Federal agencies in promoting domestic technology transfer increased in part due to greater competition for tax revenues. The competition created a climate wherein interest and commitment to technology transfer became common in agencies with research support programs. Federal technology transfer systems now in operation can be characterized on the basis of their mode of communication as either active or passive. (Tornatzky et al, 1983:162-164) Active systems are those wherein "...transfer agents interact between researchers and clients often interpersonally or face-to-face (e.g., the county extension agent)" while passive systems are those which rely on formal or impersonal media with the user being wholly responsible for access to the research (Tornatzky et al, 1983:164). Most Federal technology transfer programs are passive (Gartner and Naiman, 1976:23). Passive systems are cheaper to maintain and operate but "...do not work very well when results are judged by volume of technology transferred through the system and eventually implemented" (Tornatzky et al, 1983:167).

The major clients or user groups in transfer systems are portrayed by Linhares (1976) as follows:



According to Linhares, the citizens of the country are the ultimate beneficiaries of the output of Federal R&D. Lines are shown from the Federal R&D base both directly to private industry and state/local agencies as well as to technology transfer because some research and development activities are funded directly. Linhares also maintains that some transfers are aimed at private industry "...to be subsequently supplied to a state or local agency in their provision of public services " (Linhares, 1976:15). The transfer of R&D products to state and local governments can be grouped into those which are general purpose oriented and those which are functionally or mission oriented. Functional relations tend to be the most prominent with Federal organizations, such as the Department of Transportation, dealing primarily with their counterpart organizations. (Linhares, 1976,:16-17) In order to further examine the Federal infrastructure, Federal R&D must be investigated.

Examining the Federal R&D structure is complicated by the facts that "Almost all Federal government agencies engage in research and development" and "...no Federal budget for research and development exists, as such" (Timmons, 1978:17-18). Federal laboratories and research centers receive about 35% of the Federal government's research and development budget with the remainder representing contracted R&D to universities, private industry, and non-profit organizations (Timmons, 1978:19). Federal laboratories can be categorized as special mission, civil mission, and Federally Funded Research and Development Centers (FFRDC's). The DOD and NASA account for the "vast majority" of special mission laboratories. Civil mission laboratories, unlike the special mission, "...have an inherent need to work closely with state, local, and other Federal government units..." (Timmons, 1978:19). Civil mission laboratories operate under such agencies as the Departments of Transportation; Commerce; Health, Education, and Welfare; and Agriculture. FFRDC's can be financed by one or more Federal agency and may be an industrial firm, university, or non-profit institution which manages or performs research and development. (Timmons, 1978:19-20) An example of a FFRDC is the Lawrence Livermore Laboratory, administered by the University of California (Newton, 1980:16). To provide an indication of the scope of R&D carried out by Federal laboratories, Timmons (1978) provides a 16 page list of areas and research subjects ranging from aeronautics to space technology (Timmons, 1978:Appendix C). His point is that "...the Federal research and development capability is both awesome and difficult to comprehend" (Timmons, 1978:22).

Just as there are numerous Federal agencies involved in research and development efforts, there are also numerous agencies and subdivisions involved in technology transfer. Some of the organizations involved in technology transfer are described in the following paragraphs.

The National Technical Information Service (NTIS). Established in 1970, the NTIS operates under the Department of Commerce. It was formerly known as the Office of Technical Services with its beginnings traced to 1946 when it served as a channel for moving captured German and Japanese technology to U.S. industry. "NTIS is the only central source of research reports and other analyses that are developed by the vast Federal network of departments, bureaus, and agencies" (Timmons, 1978:26).

Smithsonian Science Information Exchange (SSIE). Timmons (1978) reported that the SSIE was a non-profit corporation operated by the Smithsonian Institute and filled a particularly critical gap by providing information on ongoing research (Timmons, 1978:28-29). Allison (1982) noted, however, that the SSIE "...has now vanished, its mission to be picked up by the National Technical Information Service, which is not being given any funds or manpower spaces for the purpose" (Allison, 1982:15).

National Referral Center (NRC). The NRC operates in the Library of Congress as a function of the Science and Technology Division and refers questions on any subject to sources of authoritative information. NRC publications are available through the U.S. Government Printing Office, but the NRC considers putting people in touch with people to be its most important activity (Timmons, 1978:31-34).

NASA Technology Utilization Program (TUP). The NASA TUP has been described as "...the most ambitious Federal program to promote technology transfer" with the exception of the Department of Agriculture program (Doctors, 1969:61). Some of the elements of this program include NASA Tech Briefs, Industrial Application Centers (IAC's), the Computer Software Management and Information Center, Public Sector

Application Teams, and Technical Application Programs. The NASA Tech Briefs announce innovations believed to have commercial potential. (Timmons, 1978:47) IAC's are located at seven universities to provide assistance to industrial clients in applying technology and matching problems to appropriate NASA expertise. The Computer Software Management and Information Center, located at the University of Georgia, makes computer programs of NASA and other government agencies available at low cost. Organizationally, technology utilization is a major program of the Technology Transfer Division in the Office of Space and Terrestrial Applications at NASA. (Allison, 1982:11-12)

> Well-funded and supported, the NASA Technology Transfer Program appears to have earned a secure place in the agency. It also appears to be meeting, to the satisfaction of agency officials, its two major goals: Transferring space technology to terrestrial applications and maintaining support for NASA (Allison, 1982:12).

Federal Laboratory Consortium for Technology Transfer (FLC). The FLC is an informal organization (Timmons, 1978:48) whose beginnings can be traced to 1971 with the formation of the Department of Defense Technology Transfer Laboratory Consortium (Richards, 1982:3). The DOD Technology Transfer Consortium had evolved from periodic meetings of individuals from west coast Navy facilities "...in what became known as the Navy Technology Transfer Consortium" (Akin et al, 1980:22). The DOD consortium was expanded to include members from all Federal laboratories in 1974. The organization has a membership of over 300 R&D laboratories and centers from 11 Federal agencies (Federal Laboratory Consortium, undated:1).

The FLC emphasizes person to person contact by maintaining a national network of designated transfer representatives who are also usually responsible for their laboratory's ORTA. The FLC is also divided into six regions managed by Regional Coordinators to provide easier access to the system by users. Within the system, ten technical specialty coordinators assist in making sure requests go to appropriate laboratories. (Richards, 1982:4-5) "In addition to answering specific requests for help, Consortium members organize meetings of technology transfer experts and potential users to stimulate interchange of information" (Allison, 1982:13).

Technology transfer agents were the subject of research by Lennon (1982). Questionnaires were were submitted to agents at 123 Federal laboratories and agencies, 100 of which were FLC members. Sixty responses were returned. Lennon does not specify how many of the sixty responses were FLC members. Presumably, the ratio would be rather high and the responses would characterize views of transfer agents in the FLC. Information gathered from the survey included the following:

1. 42% of the transfer agent positions were full-time.
2. The average numbers of full-time assistant and part-time assistants were 5.2 and 4, respectively.
3. The most common methods by which users learned

about technology transfer activities at the laboratory (as perceived by the agents) were through personal contacts and attending conferences, workshops, and seminars.

4. One-on-one technical assistance was the most frequent method of interaction with users with face-to-face and telephone discussions representing the most highly used communications.

5. Most frequently cited as constraints by the agents were time and lack of money for the technology transfer office.

6. 67% felt that there was an adequate communication network among transfer agents.

7. 60% of the agents felt that less than 30% of the laboratory's projects were transferable to state or local governments, or private industry. (Lennon, 1982:10-30)

Users participating in eleven FLC technology transfer projects were surveyed by Herdendorf (1982). Thirty-four questionnaires were mailed and 22 returned, so the sampling is rather small. Among the determinations, nevertheless, were that personal contact was the most common method of interacting with technology transfer agents, users were very satisfied with response times, and users felt that the agents were effective. (Herdendorf, 1982:2-15)

The efforts of the Federal Laboratory Consortium and the NASA Technology Utilization Program are also particularly significant because they have served as models in developing congressional policy mandating active technology transfer programs in Federal laboratories. In particular, the Stevenson-Wydler Technology Innovation Act of 1980 has provided this mandate. (Allison, 1982:10,14) Congressional initiatives and actions have obviously had significant impacts on the Federal infrastructure for technology transfer. Initiatives since the mid-1960's have included:

State Technical Services Act of 1965

Intergovernmental Cooperation Act of 1970

National Science and Technology Policy Organization and Priorities Act of 1976

Federal Program Information Act of 1978 (O'Brien and Franks, 1981:75)

The need for policy guidance and coordination among organizations has also been reflected in the creation of the National Science Foundation's Intergovernmental Science and Public Technology program, Experimental R&D Incentives Program, and the Intergovernmental Science, Engineering, and Technology Advisory Panel. (O'Brien and Franks, 1981:75) Despite all the interest and actions,

> The Federal technology transfer enterprise has been generally characterized by deficiencies in: Interagency program consistency, cooperation and coordination of efforts, agency commitment of non-mission resources, and formal evaluations to determine the effectiveness of technology transfer activities. (O'Brien and Franks, 1981:74)

In congressional hearings by the House Subcommittee on Science, Research, and Technology in mid-1979, "Witness after witness argued that the potential for increased technology transfer was great, but that formal policy requiring active technology transfer was inadequate..." (Allison, 1982:10). The Stevenson-Wydler Act addresses such concerns with the requirement in Section 11 of the Act for ORTA's to be established and funded from laboratory budgets (O'Brien and Franks, 1981:75).

Section 11 of the Act also established in the Department of Commerce a Center for the Utilization of Federal Technology which, among other duties, would coordinate the ORTA activities. Other provisions of the Act required the establishment of an Office of Industrial Technology under the Department of Commerce (Section 5); authorized grants and agreements for Centers for Industrial Technology (Section 6); required the Secretary of Commerce and National Science Foundation to obtain the advice and cooperation of other departments and agencies (Section 9); and established a committee to be known as the National Industrial Technology Board (Section 10). Section 14, Authorization of Appropriations, provided $229 million over five years for Section 6 and $66 million over five years for carrying out other provisions. (U.S. Congress, 1980) Lennon (1982) notes, however, that "Virtually all funds under the Act for the Commerce Department were eliminated by the Reagan budget makers" (Lennon, 1982:9).

The Stevenson-Wydler Act symbolizes the concern of Congress and the administration over "getting our money's worth out the national labs", but "more galvanizing" was the "sharply critical 1983 report on the labs by a presidential commission" (Brody, 1985:40). The panel, chaired by David Packard, "...accused the labs of working without clear purpose..." (Brody, 1985:40). Increased cooperation among the labs themselves as well as with industry was urged with the panel recommending labs be eliminated if not required. An outgrowth of the report is the "steel initiative" for which labs will cooperate with steel industry companies to seek "leapfrog" technological advances to restore international competitiveness. (Brody, 1985:40-41)

DOD Role in Technology Transfer

"DOD is mission oriented and has little or no interest in promoting technology transfer" (Doctors, 1969:49). Similar views to this can be found in technology transfer literature. An example is the statement that "The DOD ... has a rather parochial outlook and restrictive, limiting policy toward technology transfer to the civilian sector" (Hughes and Olson, 1976:36). These comments may be somewhat extreme when one considers that DOD laboratories fall in the special mission category described earlier. "The mission of the DOD and its agencies is to provide for the national security" (Timmons, 1978:41). The concept of national security can be debated, of course, with national interest being considered to equate with national welfare. Thus, under a broad interpretation it is appropriate for special mission labs to be concerned with solving problems in other sectors.

(Timmons, 1978:42) Regardless of such a philosophical debate, it should be noted that the Mansfield Amendment of 1969 to the Military Procurement Act "...required all defense research projects to have a direct relationship to a specific military project" (Allison, 1982:14). Timmons (1978) states that the Mansfield Amendment is overrated as a barrier because non-federal agencies can reimburse labs for costs incurred (Timmons, 1978:44).

DOD's principal efforts in technology transfer have been in the area of passive activities (Allison, 1982:4). A formal regulation on the dissemination of information is the Scientific and Technical Information Program (STIP) found in DOD Directive 3200.12 (November, 1985:1). The STIP was established in 1962 (Hughes and Olsen, 1976:183), and the directive encourages information dissemination not only among DOD but also to the national scientific and technical community as well. The Defense Technical Information Center (DTIC) is the major repository for Defense technical information. Reports and other information are also provided to NTIS for dissemination. In addition to providing information through DTIC and NTIS, publications in journals and technical presentations represent two major efforts of all three services. (Allison, 1982:4-5)

An important means of technology transfer from DOD "...occurs through the normal operations of private industry, particularly through companies that are defense contractors" (Allison, 1982:5). Allison notes that defense contractors can build technical facilities at government expense and subsequently utilize the resources for secondary application in other markets. Also acknowledging this type of technology transfer are the comments of Gansler (1980):

> The federal government makes defense R&D even more attractive by allowing a firm to retain patent rights for any potential civilian work... This has the desirable feature of encouraging transfer of government-sponsored R&D into the civilian sector (Gansler, 1980:97)

Technology transfer through defense contractors may be DOD's most effective mechanism. Also contrary to a negative outlook on DOD technology transfer is the contention that transfer from DOD has been successful because about 75% of DOD's R&D is performed by universities and industrial organizations. The results of the R&D, therefore, are in commercial domains which can best seek civilian applications. (Allison, 1982:5-6)

Despite the history of passive involvement in technology transfer, active programs are increasing in importance in DOD (Allison, 1982:3). The Stevenson-Wydler Act has contributed to this shift in emphasis not only by requiring specific activities, such as the ORTA's, but also by providing enabling legislation to allow the legitimate use of military funds (November, 1985:3). One of the problems for the ORTA's, however, is that "This function is often overwhelmed by the magnitude of the task to transfer technology" (November, 1985:3). An initiative by the Naval Ocean Systems Center to address this problem is to create a Technical

Assistance Program, as authorized by Stevenson-Wydler, utilizing the services of technically skilled retirees (November, 1985:1-2).

> With an active retiree force serving as technology brokers, problems like frozen fire hydrants could be referred to a laboratory that just created a "paint" to prevent ice adhesion. In another example, problems with electric wheelchair traction can be presented to world-renowned military traction experts. The use of retirees, as eyes and ears in the community increases the R&D exchange. (November, 1985:3)

Another example of active technology transfer versus passive is an initiative that links the ORTA at the Aeronautical Systems Division (AFSC) laboratories at Wright-Patterson AFB, Ohio, with the Ohio Technology Transfer Organization (OTTO). In 1984, Ohio Governor Richard Celeste and the Commander of the Aeronautical Systems Division signed a Memorandum of Agreement which "...established the first working relationship in the country between a statewide technology transfer network and a federal Office of Research and Technology Application" (OTTO, undated:inside cover). During 1984, 51 OTTO clients were assisted by resources at Wright-Patterson AFB. A case cited to illustrate the type of assistance provided was the problem of billboard paint adhesion for a local manufacturer. An expert in paint adhesion at the base contacted the company and was able to recommend specific quality control steps which greatly reduced the company's problem. (OTTO, undated:13)

In testimony before the House Subcommittee on Science, Research, and Technology in 1979, Dr. George Milburn, Technical Assistant to the Deputy Under Secretary of Defense for Research and Advanced Technology, stated:

> I think the Defense Department today has a very proper appreciation of technology transfer. I think we are well aware of it. We do, however, have to respond to our basic mission requirements, which are in support of the Military Service. (Allison, 1982:14)

In the past, DOD reluctance to commit resources to active technology transfer efforts was due in part to pressures to reduce personnel. Increasing the active transfer effort was seen as eroding available manpower and creating a justification for further cuts. While Stevenson-Wydler creates a positive mandate for active programs, Congress has not reduced the pressures on the labs because no new personnel or funding has been provided for increasing active technology transfer. (Allison, 1982:14-15)

Evolution of Technology Transfer Models

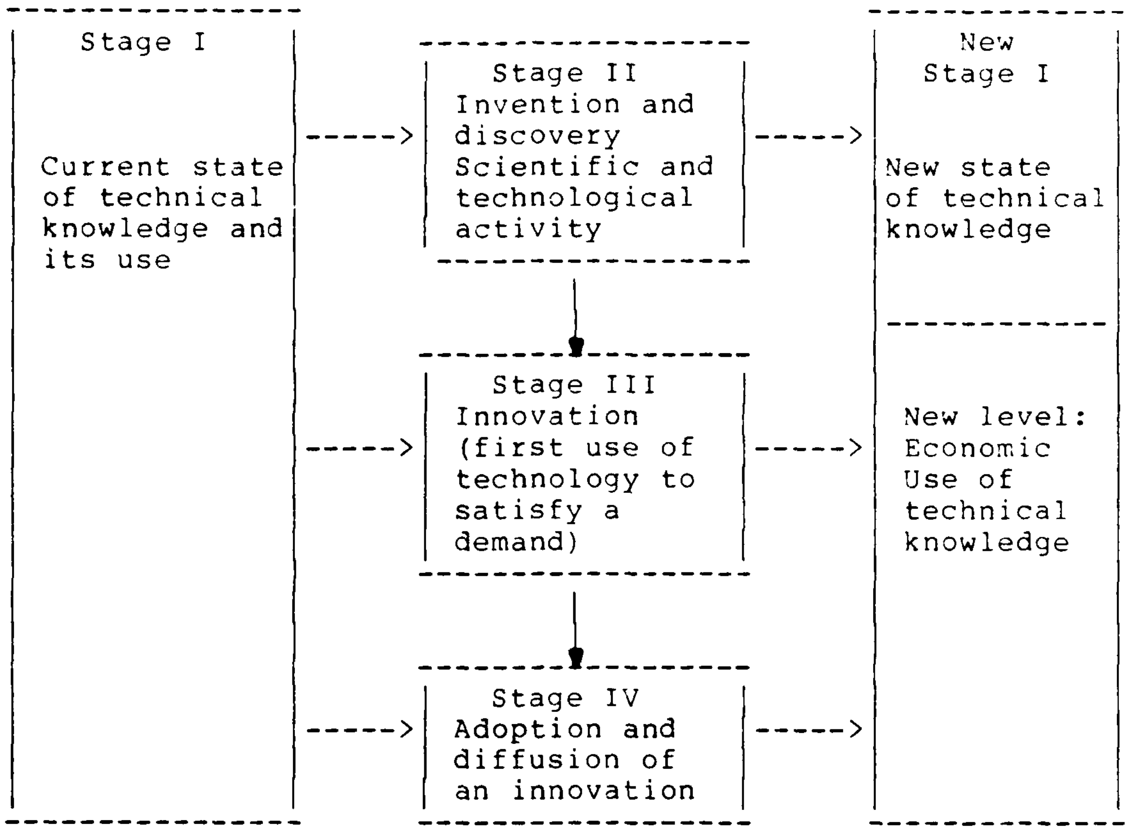
At the beginning of this chapter, factors influencing technology transfer were developed by drawing on the field of innovation research. Examining models of technology transfer proceeds in the same fashion. One of the fundamental approaches for studying innovation is based on the premise that "Innovation is a process of many discrete decisions and behaviors that unfold slowly over time" (Tornatzky et al, 1983:17). The decisions in the process are not all overt and explicit, however, and the decision makers can also be hard to identify. "It is rare that a single decision by a single decision maker can explain technological change in an organization" (Tornatzky et al, 1983:18). To organize the numerous decisions that comprise the innovation process, the concept of stages is used as an analytical tool even though it may distort reality. "There is nothing inherent in a stage conception which implies that individuals actually involved must agree on or even realize just what stage they are going through" (Tornatzky et al, 1983:19). Stages are usually described from the point of view of either the producer (source) or user of the technology. The stages used by researchers are generally variants of the following (Tornatzky et al, 1983:19-22):

Stages and Processes in Technological Innovation

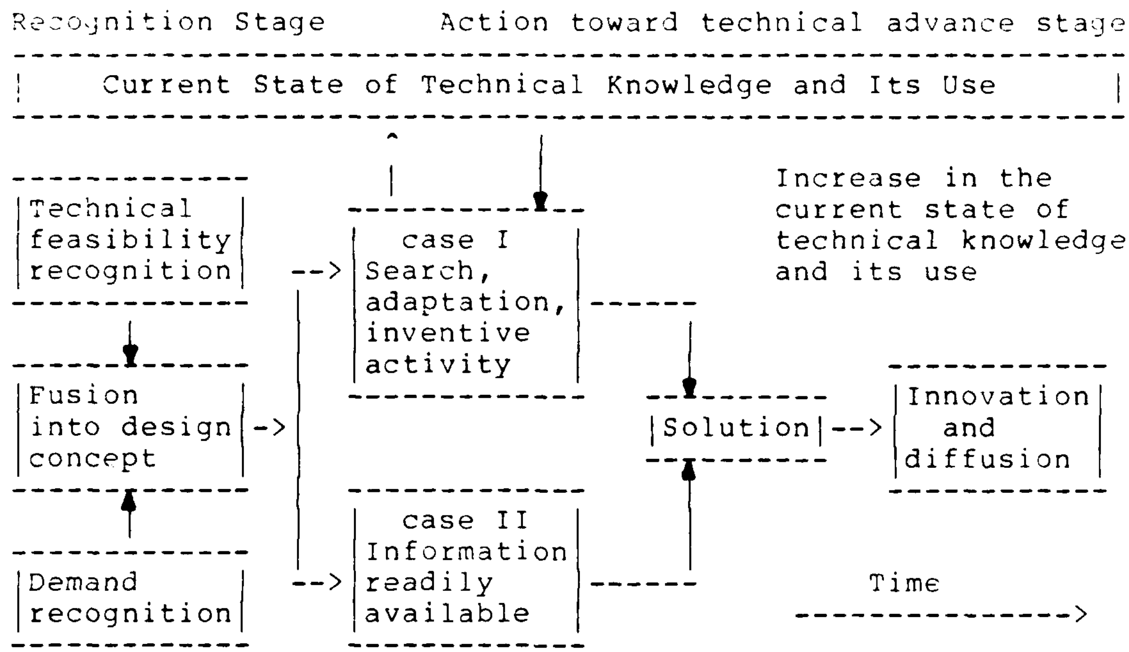
Producer	User
Basic Research	Awareness
Applied Research	Matching/Selection
Development	Adoption/Commitment
Testing/Evaluation	Implementation
Manufacturing/Packaging	Routinization
Marketing/Dissemination	

Problems with stage models include difficulties in defining adoption of innovations and difficulties in levels and units of analysis. Adoption has been used by some researchers as synonymous with the entire innovation process, although from the user perspective it is usually "...the point which divides the organization's not having the technology from its having it" (Tornatzky et al, 1983:24). The value of the adoption construct has been questioned on the basis of the difficulty in naming the specific decision which in fact constitutes the dividing point mentioned and also on the basis that whether or not adoption has occurred is generally determined in retrospect by the "weight of the evidence". "In general, stage models are most useful for organizing a body of empirical information about a sequence of decisions rather than for defining adoption" (Tornatzky et al, 1983:25). The problem with levels and units of analysis arises because stages of the innovation process generally categorize the entire organization as being in a given stage at a given time. Many studies, however, point out that "...innovation is usually carried out by small groups or individuals" (Tornatzky et al, 1983:25) and at a given point different parts of the organization are involved in different stages. "It is ... important to remember that stage models of innovation are at this point in their evolution essentially descriptive and diagnostic tools for looking at interconnected decisions, not predictive tools in any real sense" (Tornatzky et al, 1983:25). Given that technology transfer is a subset of innovation as previously discussed, the statement by Tornatzky et al is a consideration to keep in mind when reviewing literature on innovation and technology transfer models.

Gruber and Marquis (1969). Two models are presented by Gruber and Marquis to assist in their analysis of technology transfer. The first represents a macro view of the technical advance process.



This four stage process recognizes that the level of technical knowledge can increase with no resulting transfers or economic value, i.e. technology can transfer from Stage I to II and not necessarily result in an innovation. Reaching Stage III represents transfers of technology which attain economic value while the activity in Stage IV determines "...the macro economic value of the technology transferred..." (Gruber and Marquis, 1969:257-258). The ability and willingness to utilize existing technical information is an important factor influencing Stages II, III, and IV. The process of utilizing technical information is reflected in the following microlevel model of technical advance:



Recognition--->Fusion--->Action--->Solution--->Economic Use

In this model, achieving technical advance is not only a function of ability/willingness, but also demand recognition and technical feasibility recognition. The model is related to the first in that the current state of knowledge is the same concept and movement from State I to III in the macrolevel is similar to case II in the microlevel where needed information is available. (Gruber and Marquis, 1969:261-265) Grubber (1976) cites this model, with slight changes, as being "...one of the often referenced concepts of the technical innovation process" (Grubber, 1976:16) and it is also mentioned by Newton (1980) as being illustrative of the technical innovation process (Newton, 1980:54).

Bar-Zakay (1970b). Regarding the presentation of stage models as either producer or user centered, Tornatzky et al

(1983) note that "It is difficult to combine these two perspectives into a single sequence" (Tornatzky et al, 1983:23). A model advanced by Bar-Zakay (1970b) attempted to provide a combined perspective. Bar-Zakay's model (figure 1) was developed to stimulate thinking on international technology transfer issues, but he also maintained that "...the forces involved in the process of technology transfer are the same, whether it takes place within a country or between countries..." (Bar-Zakay, 1970b:2). In Bar-Zakay's model the producer or source is labeled "Donor" and the user is termed "Recipient". The activities of each are described as occurring simultaneously within the stages. The activities and concerns listed for each are not necessarily mutually exclusive, and some activities must be carried out by both. The four decision points noted are only the major ones -- decisions could be made to terminate a project at many other points. As decisions are made there is also a feedback process, but it is not expressly shown in the model. Bar-Zakay contends that although providing proper attention to the activities increases the probability of successful transfer, frequently the sequence is not followed. (Bar-Zakay, 1970b:4-9)

Stipulating an "unrecognized" technology transfer opportunity to begin the Search stage indicates it is important for the participants to have a recognition capability. The policies established by donors and recipients can act as

Stage	Donor	Both	Recipient
Search		Unrecognized TT Opportunity	
	Identify capabilities		Identify Needs
	Establish policies & priorities		Establish policies & priorities
	Develop incentives to search for needs		Develop incentives to search for capabilities
	Provide channels for contact		Provide channels for contact
		Establish viable contact	
		Decision: Go/No Go	
Adaptation		Formulate TT project	
	Learn environment of recipient		Evaluate socio-economic implications
	Evaluate adaptation requirements		Evaluate effectiveness
	Evaluate cost		Evaluate other alternatives
	Evaluate feasibility		Evaluate desirability
		Analyze cost effectiveness	
		Decision: Go/No Go	
(Implementation)			

Fig. 1. Bar-Zakay Technology Transfer Model (Bar-Zakay, 1970b:3)

Stage	Donor	Both	Recipient
(Adaptation)			
	Decision: Go/No Go		
Implementation		Recruit Resources	
	Consider capital and hardware		Consider people and emotions
	Overcome predjudice		Build cohesive organization
	Provide training		Provide supporting elements
	Overcome resistance to change		Ensure bureaucratic support
		Run pilot operation	
	Decision: Go/No Go		
Maintenance		Run full-scale operation	
	Delegate authority		Ensure compatibility with supporting elements
	Assist in trouble-shooting		Evaluate side effects
	Identify diversification possibilities		Perform concurrent R&D
	Evaluate net benefits		Evaluate net benefits
		Evaluate success	
	Decision: Go/No Go		

Fig. 1. Bar-Zakay Technology Transfer Model (continued) (Bar-Zakay, 1970b:3)

incentives to attract one another. Channels established should provide for interdisciplinary groups representing the donor and recipient inasmuch relying on individuals with limited knowledge and interests is less efficient. The Adaptation stage begins with project selection. Evaluating adaptation requirements is listed as a donor activity because the donor is better able to perform the necessary technical analysis, but the recipient must also evaluate adaptation needs. The lack of evaluating skills by the recipient regarding alternatives and desirability can lead to purchases of inappropriate technology. Recruiting resources in the Implementation stage refers to both capital and human resources. Training can be a prominent factor in this stage. The supporting elements, or available infrastructure, can also determine the success or failure of the technology transfer. "Since several years may elapse between the Adaptation and the Implementation Stage, the importance of long-range planning is indicated in the model" (Bar-Zakay, 1970b:14). The Maintenance stage represents full-scale operation of the technology transfer project. Decisions and conclusions are drawn continuously throughout the stages, but the conclusions at the Maintenance stage are the most important because they will assess the relative importance of mistakes and how mistakes affected the project outcome. If the evaluations are not performed, ineffective projects may linger on instead of being canceled quickly. (Bar-Zakay, 1970b:6-22)

Creighton et al (1972). "In simplified terms, a program of technology transfer must include a mechanism which effectively links or couples the sources of the knowledge with the eventual utilization of that knowledge" (Creighton et al, 1972:3). The process represented by this view was shown by Creighton et al as:

```
-------------                              ---------------
| Source      |          Linking           | Utilization  |
|   of        |<------------------------>  |     of       |
| Knowledge   |         Mechanism          | Knowledge    |
| (Supplier)  |                            | (User/       |
-------------                              | Receiver)    |
                                           ---------------
```

To explicate the "rather vague concept of a linking mechanism", a model (figure 2) with nine factors was advanced (Creighton et al, 1972:4). The model was entitled the Predictive Model of Technology Transfer (PMTT) and the factors were described as follows:

Factor	Description
ORGA	the formal organization of the receiver of information and his perception of his position within it
PROJ	the selection process for research and development projects undertaken by the source, and the receiver's contribution to that process
LINK	the number of informal linkers in the receiving organization
DOCU	the format, organization, or presentation of the technology being transferred
DIST	the physical channel through which technology flows
CAPA	a wide spectrum of traits involving the capacity to assemble and invest resources

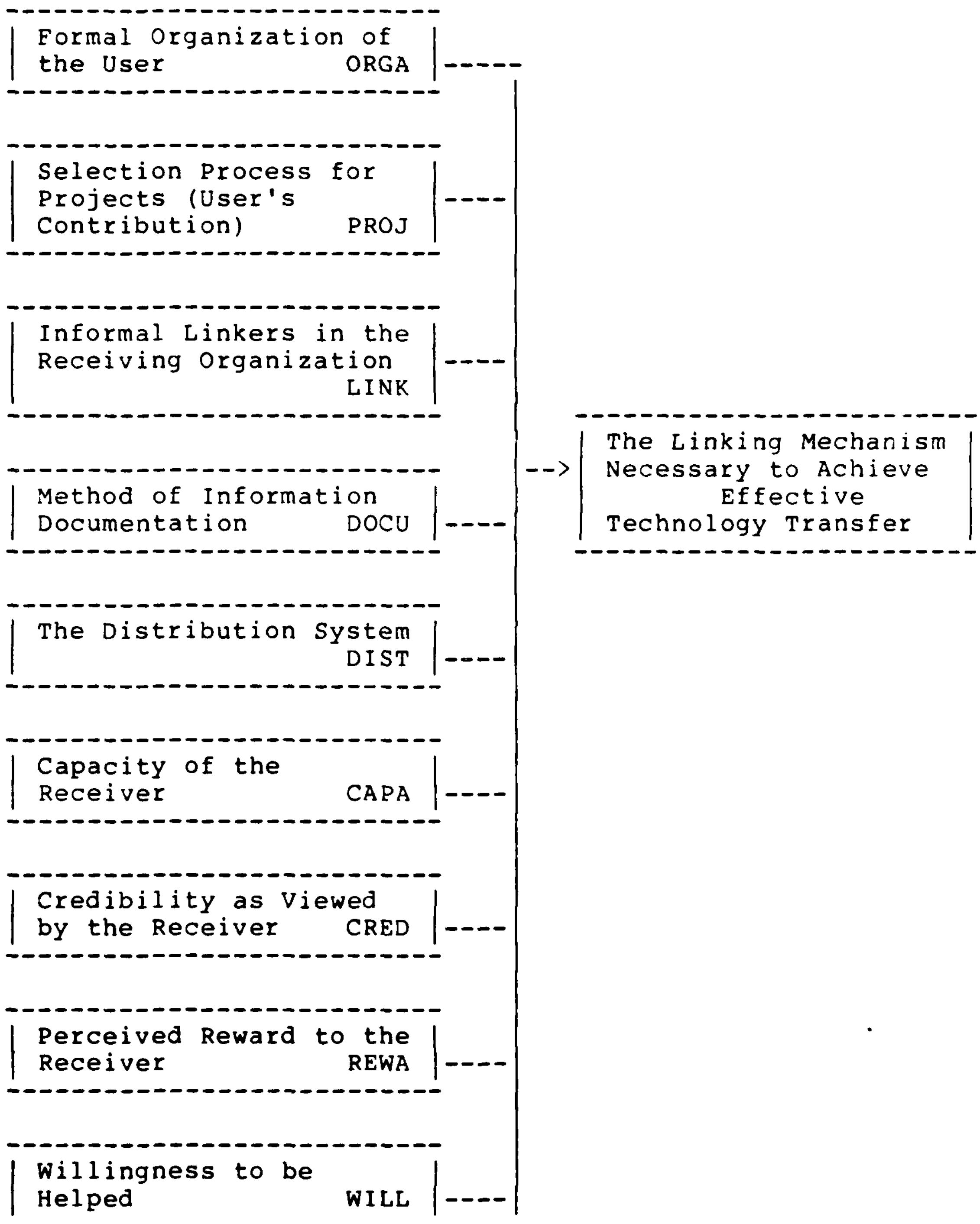


Fig. 2. Predictive Model of Technology Transfer (Creighton et al, 1972:5)

CRED	an assessment of the reliability of the information as perceived by the receiver
REWA	the perceived and actual recognition of innovative behavior in the social system of which the individual is a member
WILL	the individual's ability and/or desire to accept change in the organization of which he is a member (Creighton et al, 1972:4-6)

The model was called "predictive" based on the idea that coefficients could be developed for the factors such that "the degree of transfer within the user organization" could be predicted (Creighton et al, 1972:4). In discussing the PMTT, Essoglou (1975) pointed out that Jolly had divided the factors into formal and informal. The revised model as presented by Essoglou (1975) is shown in figure 3.

Grubber (1976) observed that the factors of the PMTT were similar to the results of a 1972 National Institute of Mental Health study which provided a distillation from available literature of innovation characteristics affecting adoption probability. The NIMH distillation included relevance, compatibility, relative advantage, observability/communicability, complexity and feasibility, reversibility, divisibility, trialability, and credibility. The most significant difference of the PMTT was the inclusion of the linker factor (Grubber, 1976:57-59).

Jolly et al (1978) presented the PMTT with greater detail on the literature supporting the nine factors in the model. Jolly et al contended that there were an "abundance" of models dealing with technology transfer, but few which

```
                       FORMAL FACTORS
                       ---------------------------
                       | Method of Information    |
                    ---| Documentation       DOCU |---
                    |  ---------------------------   |
                    |                                |
                    |  ---------------------------   |
                    |  | The Distribution System  |  |
                    |--|                     DIST |--|
                    |  ---------------------------   |
                    |                                |
                    |  ---------------------------   |
                    |  | Formal Organization of   |  |
                    |--| the User            ORGA |--|
                    |  ---------------------------   |
                    |                                |
                    |  ---------------------------   |
                    |  | Selection Process for    |  |
                    |--| Projects (User's         |--|
                    |  | Contribution)       PROJ |  |
Source              |  ---------------------------   |   Utilization
  of                |                                |     of
Knowledge-->        |  INFORMAL FACTORS              |-->Knowledge
(Supplier)          |  ---------------------------   |   (User/
                    |  | Capacity of the          |  |   Receiver)
                    |--| Receiver            CAPA |--|
                    |  ---------------------------   |
                    |                                |
                    |  ---------------------------   |
                    |  | Informal Linkers in the  |  |
                    |--| Receiving Organization   |--|
                    |  |                     LINK |  |
                    |  ---------------------------   |
                    |                                |
                    |  ---------------------------   |
                    |  | Credibility as Viewed    |  |
                    |--| by the Receiver     CRED |--|
                    |  ---------------------------   |
                    |                                |
                    |  ---------------------------   |
                    |  | Perceived Reward to the  |  |
                    |--| Receiver            REWA |--|
                    |  ---------------------------   |
                    |                                |
                    |  ---------------------------   |
                    |  | Willingness to be        |  |
                    |--| Helped              WILL |--|
                       ---------------------------
```

Fig. 3. Predictive Model of Technology Transfer, Reorganized into Formal and Informal Factors (Essoglou, 1975:6)

incorporated the widely held notion that understanding technology transfer requires a user perspective. Research conducted in 1966 which revealed a low rate of transfer for NASA technologies was cited as an example of a research agency failing "...to perceive the multiplicity of the problem involved in identifying and fulfilling potential user needs" (Jolly et al, 1978:2). An advantage of the PMTT versus other models, therefore, was its development from the users standpoint. (Jolly et al, 1978:2)

Newton (1980) discussed the PMTT and noted that it is known as the Technology Transfer Process Model (the title of the Jolly et al (1978) work). According to Newton, the model represented a distillation of other models and research was being conducted to validate the factors and develop coefficients. (Newton 1980:41)

> The principle utility of the TTPM [Technology Transfer Process Model] lies in its awakening of the planner/manager to the resources available for implementing technology transfer both internally and externally to the organization (Newton, 1980:43).

Hughes and Olson (1976). Hughes and Olson depict the technology transfer process in terms of a basic stage-process model which they term a "Gauntlet Model". The stages are considered to be a series of open switches through which an innovation must pass in order to move from need to use as follows:

(open switches)

Perception of need --------->|

Description of problem |

Search for solutions |

Awareness of ideas |

Evaluation of alternatives |

Selection |

Motivation to implement |

Mobilization of support |

Commitment - decision |

Development |

Adaptation |

Steady use <-----------------|

The "gauntlet" reference alludes to their premise that the failure to "close any switch" in the process results in project attrition or no transfer (Hughes and Olson, 1976:148-149).

Jones (1983). A stage-process model is presented by Jones (credited to Roberts & Frohman, 1978) to illustrate the relationship between innovation and technology transfer. Jones contends that technology transfer is the "link between the innovating organization and the R&D environment" (Jones, 1983:19). The model, therefore, is portrayed as follows:

```
-----------------------------------------------------------
| Market      |     Stage 1                   | R&D          |
| Environ-    |   Recognition of       <------ Technology    |
| ment        |   Opportunity                 | Environ-     |
|             |                               | ment         |
|             |     Stage 2                   |              |
|             |   Idea Formulation            |              |
|             |                               |              |
|             |     Stage 3              <-----              |
|             |   Problem Solving        ----->              |
|             |                               |              |
|             |     Stage 4              <-----              |
|             |   Prototype Solution          |              |
|             |                               |              |
|             |     Stage 5                   |              |
|             |   Commercial Development      |              |
|             |                               |              |
|             |     Stage 6                   |              |
|       <-----    Technology Utilization ----->              |
|             |   and Diffusion               |              |
-----------------------------------------------------------
```

In this model, technology transfer occurs at various stages and can be both to and from the firm and its environment. Transfer can range from providing technical opportunities in stage 1 to diffusion of technologies to the environment in stage 6. (Jones, 1983:19-21)

Other models. Grubber (1976) includes several models in his literature review, but does not discuss the thinking of the authors who originally formulated the models. In a technological innovation model (figure 4) credited to Goldhar, Bragaw, and Schwartz (1976), the influence of Gruber and Marquis can be seen by the inclusion of recognition of technical feasibility and recognition of potential demand as prerequisites which are fused into design concept. (Grubber, 1976:18,103) Grubber also cites two models from PH.D dissertations. One is from Alok Chakrabarti's 1972 work (figure 5). This model incorporates many of the

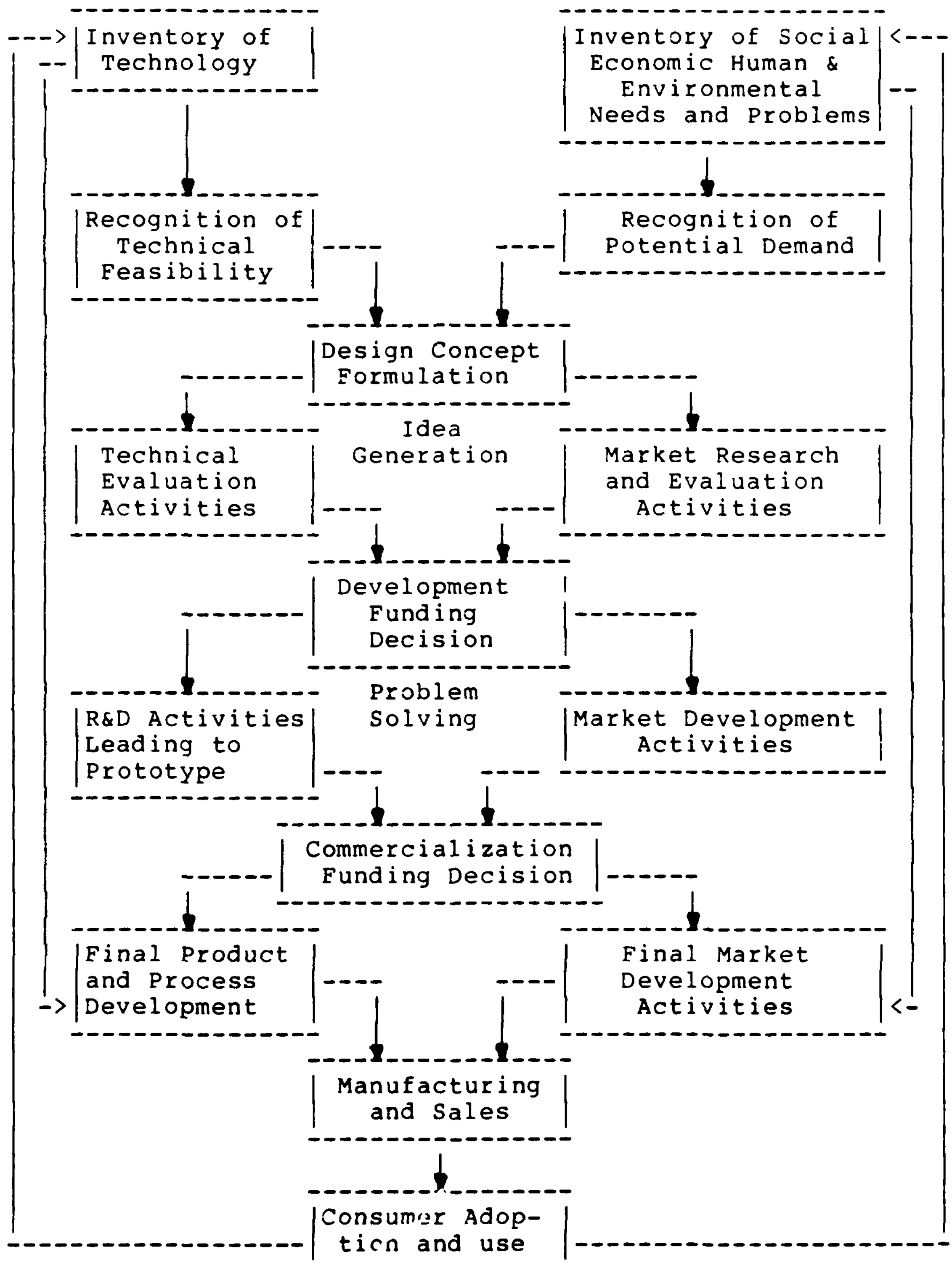


Fig. 4. Process of Technological Innovation - Goldhar et al (Grubber, 1976:103)

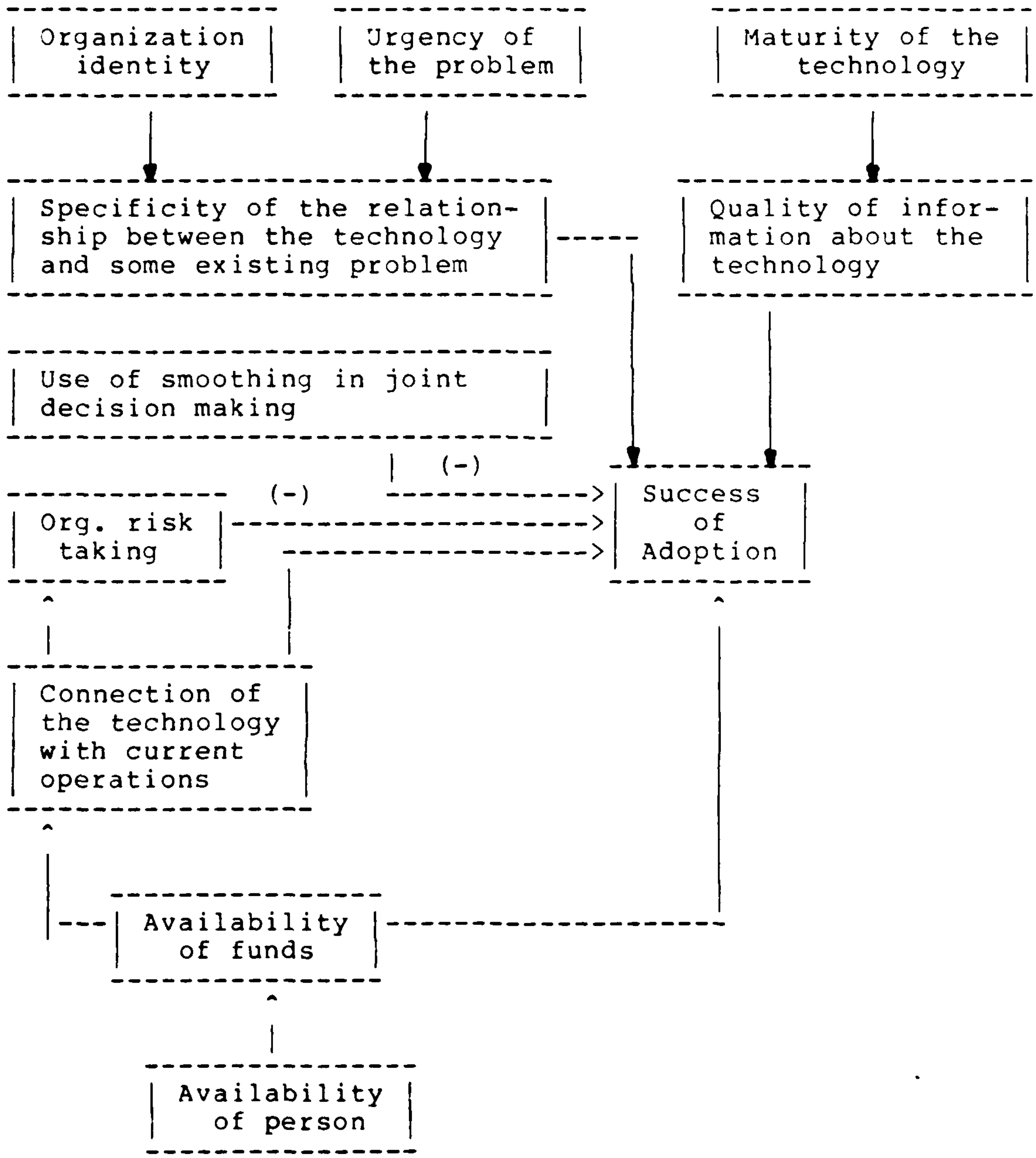


Fig. 5. Chakrabarti Model - 1972 PH.D Dissertation (Grubber, 1976:105)

propositions reported previously in this literature review in the discussion of research by Chakrabarti and Rubenstein (1976). The other is from E.C. Young's 1972 dissertation and emphasizes decision making that influences the stages of an adoption process (figure 6). Lastly, Grubber (1976) includes a technology transfer process model, but its derivation is not explained (figure 7).

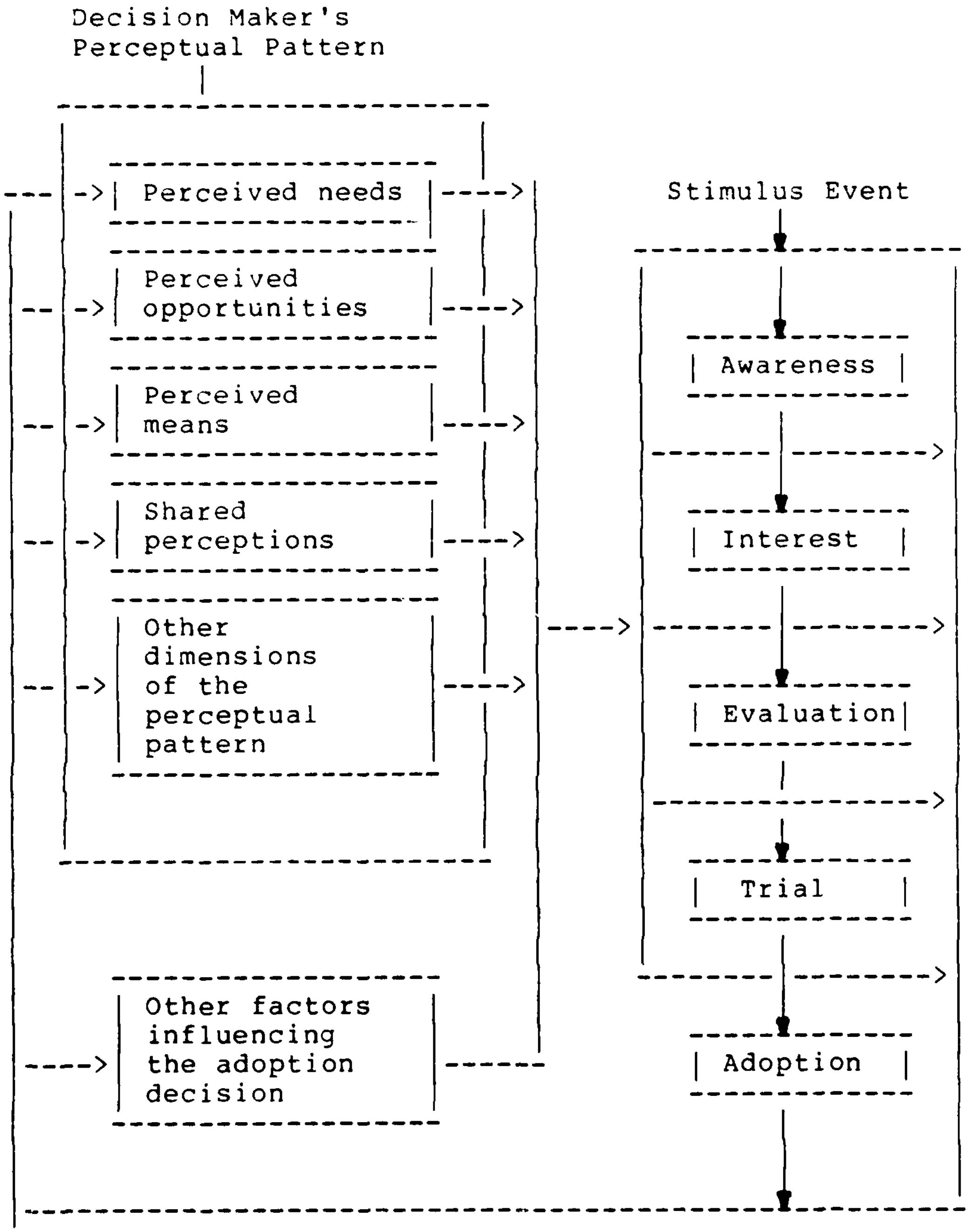


Fig. 6. Young Model - 1972 PH.D Dissertation
(Grubber, 1976:104)

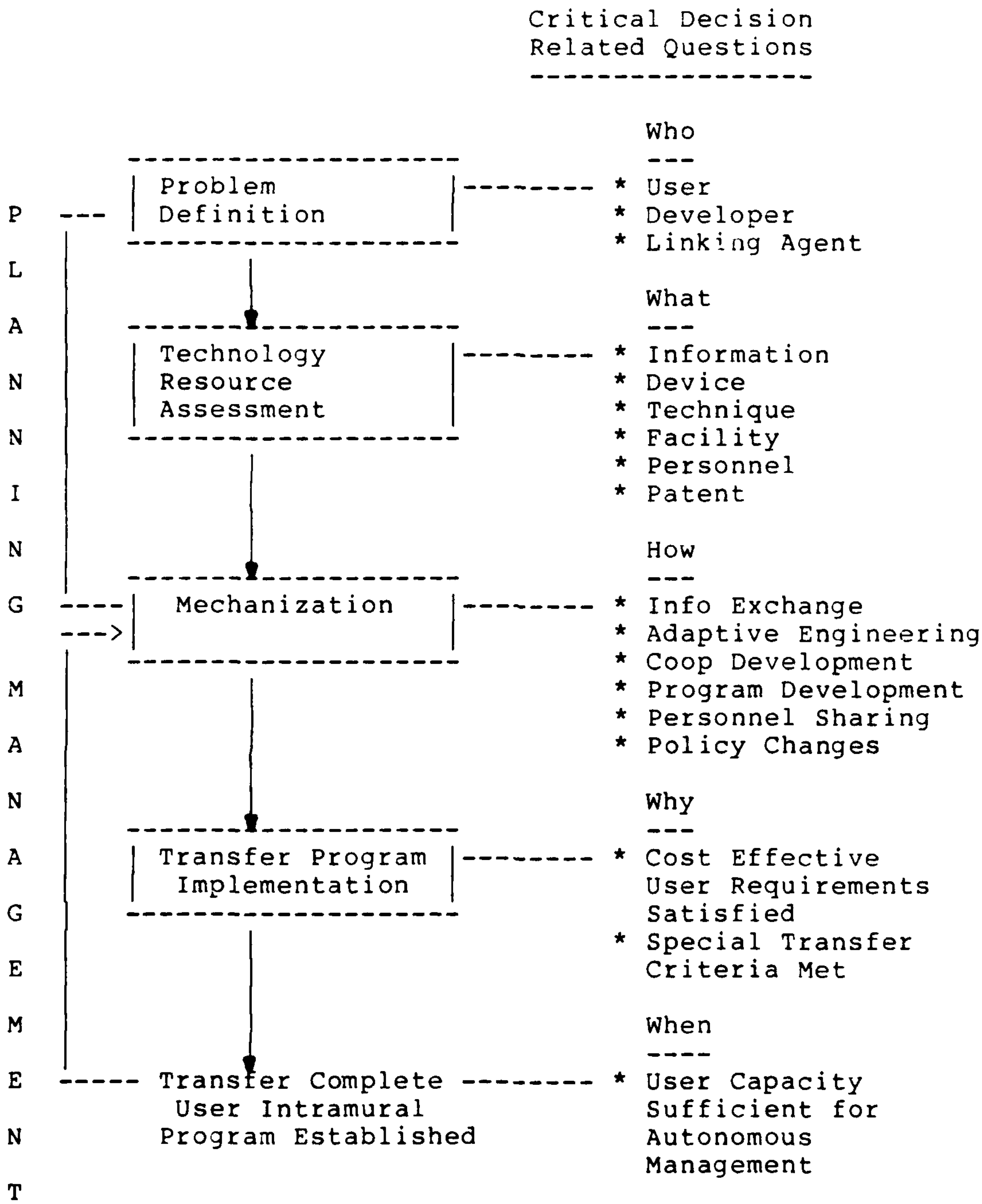


Fig. 7. Technology Transfer Process (Grubber, 1976:106)

III. Methodology

The research is an exploratory study using secondary data sources. Exploration is selected in order to gain an understanding of the problems and issues in the subject area which is one of the purposes served by such an effort (Emory, 1985:62). Emory notes that the value of exploration is underrated by researchers and managers.

> There are often strong pressures for quick answers to research problems. Too often it is "obvious" that exploration is "stalling around" ... A wiser view is that exploration ... should not be slighted (Emory, 1985:62).

Secondary data sources are "Studies made by others for another purpose..." while primary data sources represent original sources from which data is gathered for the task at hand (Emory, 1985:135). The advantages of secondary data sources are cost and length of time to gather information. The cost is low and collection can usually be accomplished quickly. Problems with secondary data sources, however, include differing definitions, difficulty in assessing accuracy, and the potential for irrelevancy by being out of date. (Emory, 1985:135-136)

The advantages of secondary data sources are considered to outweigh the problems for the purposes of this research. As mentioned in Chapter I, the focus of the research is on the conceptual process of technology transfer. A study of the conceptual process is in contrast to the possibility of a case study approach. With DOD laboratories having received over 1200 requests for assistance from state and local governments in FY 1982 alone (General Accounting Office, 1984:9), a substantial amount of data presumably is available for such an effort. Two problems, however, result in the conceptual approach being favored. First, the time and resources to collect and analyze a meaningful number of cases (perhaps 100) are simply not available. Secondly, the objective of the research is framed as determining if a working model of the technology transfer process has been advanced. The related investigative questions were developed to analyze issues in technology transfer from a general to increasingly specific level of detail. In order to progress through the investigative questions to the objective, an understanding of empirical research and substantive thought related to technology transfer is necessary. Such an understanding was not likely to result from a case study analysis. This approach, therefore, favors a study of published information. It has also been noted that "...secondary data may be used as the sole basis for a research study" (Emory, 1985:136).

The research design can also be characterized as ex post facto, descriptive, and cross-sectional. The ex post facto perspective is in contrast to an experimental design. An experimental design attempts to control the variables under study, whereas in an ex post facto design the investigator is not endeavoring to manipulate variables (Emory, 1985:60). A descriptive study is research "concerned with finding out who, what, where, when, or how much" as opposed to determining "how one variable affects another" (Emory, 1985:60). The cross-sectional perspective on design classifies research by the time dimension. A cross-sectional study is "carried out once", while a longitudinal study is repeated (Emory, 1985:61).

A literature search was conducted as the principal means of gathering the secondary data sources. Two inquiries were conducted through the Defense Technical Information Center (DTIC). The keywords for the first inquiry were "technology" (first level) and "management" (second level). The second inquiry was based on the keyword "technology transfer" (first level). The inquiries resulted in 65 and 263 titles, respectively. A search was also conducted through the Defense Logistics Studies Information Exchange (DLSIE) using the search title "Technology Coordinating Papers and Technology Transfer". The DLSIE search resulted in 150 titles for examination, although some were duplicated with the DTIC results. Given the subject matter of domestic technology transfer, documents listed in the DTIC and DLSIE report summaries were screened for applicability on the basis of titles and abstracts provided. The Naval Postgraduate School was determined to be a noteworthy source of information, as a result of this screening. Dr. J.W. Creighton was contacted by telephone, therefore, for further information. The reference books listed in the bibliography as published by the Naval Postgraduate School, as well several reports and theses, were obtained directly from Dr. Creighton as a result of this solicitation. One of the research reports obtained from Dr. Creighton noted that "It is safe to say that there are several thousand books and articles which deal directly with this subject [technology transfer and technology utilization]" (Creighton et al, 1972:49). This statement seemed to be supported by the fact that the bibliography in the work by Tornatzky et al (1983) contained over 600 titles itself. Faced with an apparently overwhelming number of sources, a problem was how to select a variety which could be reviewed within a reasonable time, yet which would provide sufficient breadth and depth of factors pertinent to domestic technology transfer issues. Among the reports and theses selected from the DTIC search, however, was a 1982 thesis by Lt Cmdr Claudia Lynn Bailey. This work became particularly useful in further guiding the literature search in view of its stated purpose:

> This thesis provides a compilation of pertinent selected works on technology transfer and addresses the foundations of technology transfer; the elements of the Predictive Technology Transfer Model; applications of technology transfer; and the associated public policy issues (Bailey, 1982:4).

The compilation included 126 abstracts on various publications. The abstracts were organized into related technology transfer subject areas. Thus, selecting articles from different groupings assisted in maintaining a balance among the source material as opposed to inadvertently concentrating too heavily on a single subset of the topic. A variety of periodical sources were suggested as a result. "Periodicals are often the best single source of information for the business researcher" (Emory, 1985:144).

In addition to the above activities, the collection of secondary data sources was assisted by traditional library card catalogue and reference work searches. Materials were obtained through the libraries of the Air Force Institute of Technology, Wright State University, the Dayton Public Library, and the Greene County District Library. Brochures noted in the bibliography were obtained from the Office of Research and Technology Applications (ORTA), Aeronautical Systems Division (AFSC), Wright-Patterson AFB.

The principal limitation of the methodology is that the design does not constitute empirical research wherein a hypothesis is formulated, data are collected, and the hypothesis is tested using techniques of statistical analysis. In addition, the experience survey method of exploration is not included. An experience survey seeks "...information from persons experienced in the area of study..." who can help "...secure an insight into relationships between variables" (Emory, 1985:63). Lastly, given the vast amount of literature on technology transfer, important references may have been omitted from the review on which this research is based.

IV. Findings and Discussion

The investigative questions advanced in Chapter I are the guide for this research. The findings and discussion, therefore, follow the sequence of these questions which are restated here for convenience:

1. What definitions of technology, innovation, and technology transfer have been advanced, and what other concepts are relevant for understanding the subject matter?
2. What factors have been identified as promoting or impeding technology transfer?
3. What important roles do individuals fulfill in technology transfer?
4. What is the Federal infrastructure for promoting technology transfer?
5. What is DOD's role in promoting domestic technology transfer?
6. What models have been advanced to portray the technology transfer process?

Question 1. The concept of technology is subject to misunderstanding due to its frequent association with objects or hardware. The technology definition of Schon (1967) offers a more complete perspective which is accepted by other researchers. Innovation includes both the first creation of new technologies (inventions) and the introduction of technologies into new settings (perception of newness). Introducing technologies into new settings raises the question of adaptation -- how must products or processes be modified to fit the new environment. Technology transfer is a dimension of the broader subject of innovation. Transfer implies a contrast to the notion of diffusion. A degree of specificity in terms of origin and destination is inherent in transfer whereas diffusion represents a gradual spreading over time.

Question 2. Because technology transfer is conceptually intertwined with innovation, the large body of information represented by innovation research is available for investigating factors which impede or promote technology transfer. Factors influencing technology transfer can be categorized as pertaining to management involvement or the source - user relationship. Management involvement relates to the willingness of management to provide resources necessary for technology transfer and the attitudes toward risk taking. The source - user relationship can be interorganizational or intraorganizational. Technology transfer represents a linking mechanism which overcomes barriers or gaps between the source and user. Two particularly relevant barriers to transferring technology from the federal government to state/local government and private industry are the appropriateness of federal technologies and the size of the bureaucracy which can hinder the identification of sources. Two fundamental characterizations of technology transfer systems are active and passive. Passive systems rely heavily on information dissemination. An argument can be advanced, however, that the dissemination of information does not constitute technology transfer inasmuch as a technology is not necessarily put into use by virtue of information acquisition. Given this reasoning, technology transfer systems would simply be active by definition and passive would not apply. Active systems emphasize specific organizational structures and person-to-person contact in order to promote technology transfer.

Question 3. Research at the level of analysis of the individual suggests a variety of roles which are significant in the technology transfer process. The gatekeeper construct which originated in 1947 communication research assists in the analysis of technology transfer relationships because the flow of technical information to and from the source and user is a critical element in the process. Information-active gatekeepers provide an interface between organizations at both ends of the linking mechanism. The related, but distinct, concept of the Linker developed at the Naval Postgraduate School by Drs. Creighton and Jolly illustrates research that has been applied specifically to a DOD organization. The term "linker" can also represent a general label for an entire range of technology transfer roles, such as those described in Havelock et al's research on knowledge dissemination and utilization.

Question 4. The Federal infrastructure for promoting technology transfer is described as mostly passive due to the emphasis on systems to collect and disseminate technical information. Notable active systems include NASA's Technology Utilization Program and the Federal Laboratory Consortium for Technology Transfer. Domestic technology transfer from the federal government is not a new phenomenon in view of the long and successful history of Department of Agriculture programs. A discernible shift in attitudes appears to have occurred, though, concerning the benefits of massive R&D expenditures by Federal agencies. In particular, confidence seems to have eroded in the assumption that R&D expenditures are justifiable in part due to secondary applications of new technologies in other levels of government and the private sector. Federal R&D is carried out by Federal laboratories, and is also contracted to universities, private industry, and non-profit organizations. Federal laboratories can be categorized as civil mission and special mission. DOD and NASA research facilities are prominent examples of special mission laboratories. Despite Congressional technology utilization concerns which resulted in the Stevenson-Wydler Innovation Act of 1980, funding for operating active transfer systems appears to be a continuing problem.

Question 5. DOD's role in domestic technology transfer appears to be largely passive, just as the Federal government's transfer role is generally characterized.

Active efforts, however, can be cited which tend to ameliorate allegations that DOD is unconcerned and pursues restrictive policies. Involvement in the creation and growth of the Federal Laboratory Consortium for Technology Transfer, and the relationship between Wright-Patterson AFB laboratories and the Ohio Technology Transfer Organization are examples of positive transfer efforts. DOD support for technology transfer is also cited by virtue of defense contractors being able to capitalize on opportunities for secondary applications of products and processes developed with defense funding, and by virtue of the fact that a large percentage of DOD R&D is conducted by universities and industrial organizations which can also capitalize on the results. In terms of technology transfer being a purposeful effort with specific origins and destinations, however, these contentions can be said to describe a process more appropriately characterized as innovation diffusion than a system of technology transfer.

Question 6. A variety of models of innovation and technology transfer have been advanced to relate researchers' and analysts' perspectives on process factors. The models appear to be predominantly descriptive rather than predictive. Innovation models generally depict stages through which new technologies pass in order to group related decisions. The depiction is convenient for analysis, but in reality innovation is not necessarily an orderly, sequential process in which decisions and decision makers are readily identified. Level of analysis seems to be a barrier to developing a complete working model of the technology transfer process. On one hand, the process requires an organizational perspective or at least the perspective of an adopting unit of organization wherein the technology is to be introduced. On the other hand, individuals are widely recognized as an important element of the process, and therefore, should somehow be represented. Innovation stage models provide conceptual overviews of the process within which technology transfer operates as a subset. Technology transfer recognizes a source - user relationship, however, which some stage models lack. The Bar-Zakay model is an example of a model which overcomes that deficiency. With models such as Bar-Zakay's, nevertheless, the contribution of the individual is unrecognized and the focus is weak on the mechanism which links the source and user. The Technology Transfer Process Model (Creighton et al) provides a useful framework which incorporates an important individual role (the Linker) and details other factors which have been widely recognized in innovation and technology transfer literature. The original premise of the model that it could, in time, become predictive has not been realized, but this does not detract from its explanatory utility.

V. Conclusions, Recommendations, and Implications for Future Research

"When first embarking upon this thesis, the subject of technology transfer appeared to be reasonably well bounded; however, in reality it is like trying to bound an explosion" (Hughes and Olson, 1976:57). The subject matter of technology transfer indeed covers a vast body of knowledge. An organizing framework is obviously essential to an endeavor to examine the subject. In this case, the research objective and investigative questions provide a hierarchy of inquiries which guide the research from the general level of concepts and definitions to the more specific considerations of DOD's role in technology transfer and models which have been advanced to explain the process.

The research objective is to ascertain if an existing model of technology transfer portrays the domestic technology transfer process. Based on the findings and discussion presented, such a model does not appear to have been advanced, although models of innovation and technology transfer do assist in presenting and analyzing various facets of the process which have been identified through empirical research and distillations of pertinent literature.

Recommendations and Implications for Future Research

This research provides a framework for future research efforts in the area of domestic technology transfer. As an

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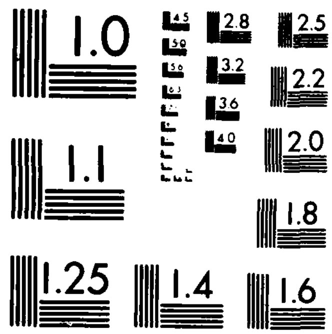
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exploratory study, it contributes to future research by providing an overview of domestic technology transfer which in turn enables the narrowing of the topic into specific, manageable segments. One area for additional research is the influence of Federal patent policy on technology transfer and utilization. The impact of patent policy was briefly mentioned in a quote from Gansler (1980). The ability of firms to retain patent rights resulting from Federally funded R&D was cited as a factor promoting technology transfer. The efficacy of Federal patent policy in domestic technology transfer could be developed as a thesis topic.

Further research based on replications of several of the empirical studies discussed in this thesis is also recommended. Lennon (1982) surveyed transfer agents in the Federal Laboratory Consortium for Technology Transfer (FLC). The FLC membership has increased since the Lennon survey, thus offering the potential for a larger number of respondents, and several additional years of experience with carrying out the requirements of the Stevenson-Wydler Act may provide additional insights regarding the benefits (or lack thereof) of the legislation. Herdendorf (1982) surveyed users in technology transfer projects, but only 22 responses were available for analysis. A survey of user perceptions with a larger sample may provide valuable insights into the benefits of promoting technology transfer. Lastly, it is recommended that the instrument developed by Creighton et al

(1972) to identify Linkers in Navy organizations be administered to an Air Force organization.

The Federal infrastructure for promoting technology transfer is comprised of numerous organizations with active or passive programs. Additional research should be undertaken to explore a single agency's efforts in detail. For example, an examination and assessment of the NASA Technology Utilization Program could be undertaken for thesis study.

Sources and users of technology can be located within the same organization, as previously explained, thus indicating that transfer mechanisms must also be operative at the sub-unit level. In particular, additional research is recommended to explore such processes within the Air Force. A worthwhile approach for an Air Force logistician would be to analyze the processes for promoting R&D for logistics and transferring the results thereof into use.

Research is also recommended in the area of network to network technology transfer arrangements. The Federal Laboratory Consortium for Technology Transfer and the Ohio Technology Transfer Organization are examples of networks which promote technology transfer. The working relationship established between the Aeronautical Systems Division's ORTA and the OTTO provides an excellent opportunity for research in this area.

Appendix A: DOD Laboratories Identified in 1984 GAO Survey

Department of Defense

Armed Forces Radiobiology Research Institute

Air Force

U.S. Air Force Wright-Aeronautical Laboratories
  Aero-Propulsion Laboratory
  Avionics Laboratory
  Flight Dynamics Laboratory
  Materials Laboratory
Air Force 6570th Aerospace Medical Research Laboratory
Air Force Armament Laboratory
Frank J. Seiler Research Laboratory
Geophysics Laboratory
Human Resources Laboratory
Rocket Propulsion Laboratory
Rome Air Development Center
USAF School of Aerospace Medicine
Air Force Weapons Laboratory
Air Force Engineering & Services Center

Army

Walter Reed Army Institute
U.S. Army Research Institute of Environmental Medicine
U.S. Army Medical Bioengineering Research and Development Laboratory
Letterman Army Institute of Research
Institute of Surgical Research
U.S. Army Aeromedical Research Laboratory
Institute of Dental Research
U.S. Army Research Institute for the Behavioral and Social Sciences
U.S. Army Medical Research Institute of Chemical Defense
U.S. Army Engineering Topographic Laboratories
U.S. Army Waterways Experiment Station
U.S. Army Construction Engineering Research Laboratory
U.S. Army Cold Regions Research and Engineering Laboratory
U.S. Army Tank-Automotive Command Laboratories

U.S. Army Natick Research and
Development Laboratories
U.S. Army Mobility Equipment Research and
Development Command
U.S. Army Missile Laboratory
U.S. Army Materials and Mechanics Research Center
U.S. Army Human Engineering Laboratory
Center for Communications Systems
U.S. Army Armament R&D Command
Fire Control and Small Weapon Systems Laboratory
Ballistic Research Laboratory
Harry Diamond Laboratory
U.S. Army Signals Warfare Laboratory
U.S. Army Night Vision and
Electro-Optics Laboratory
U.S. Army Electronic Warfare Laboratory
Combat Surveillance and Target
Acquisition Laboratory
U.S. Army Atmospheric Sciences Laboratory
U.S. Army Aviation Research and
Technology Laboratories
U.S. Army Avionics Research and
Development Activity
Electronics Technology and Devices Laboratory
Coastal Engineering Research Center
U.S. Army Medical Research Institute of
Infectious Diseases
Chemical Systems Laboratory

Navy

Naval Research Laboratory
Naval Ocean Research and Development Activity
David W. Taylor Naval Ship Research and
Development Center
Naval Air Development Center
Naval Coastal Systems Center
Naval Weapons Center
Naval Underwater Systems Center
Naval Explosive Ordnance Disposal
Technology Center
Naval Surface Weapons Center
Naval Personnel Research and Development Center
Naval Oceans Systems Center
Naval Submarine Medical Research Laboratory
Naval Medical Research Institute
Naval Health Research Center
Naval Dental Research Institute
Naval Civil Engineering Laboratory
Naval Air Propulsion Center
Naval Aerospace Medical Research Laboratory
Naval Biosciences Laboratory

Naval Biodynamics Laboratory
Navy Clothing and Textile Research Facility
Naval Environmental Prediction Research Facility
Naval Air Engineering Center
Pacific Missile Test Center
Naval Avionics Center

Source: General Accounting Office, 1984:14-16

Appendix B: Rogers and Shoemaker's Generalizations Related to Early Adopters of Innovations

Socioeconomic Characteristics: Earlier adopters

1. are not different from later adopters in age.
2. have more years of education than later adopters.
3. are more likely to be literate than are later adopters.
4. have higher social status than later adopters.
5. have a greater degree of upward social mobility than later adopters.
6. have larger sized units that later adopters.
7. are more likely to have a commercial economic orientation than are later adopters.
8. have a more favorable attitude toward credit than do late adopters.
9. have more specialized operations than later adopters.

Personality Variables: Earlier adopters

10. have greater empathy than later adopters.
11. are less dogmatic than later adopters.
12. have a greater ability to deal with abstractions than later adopters.
13. have greater intelligence than later adopters.
14. have a more favorable attitude toward change than later adopters.
15. have a more favorable attitude toward risk than later adopters.
16. have more favorable attitudes toward education than later adopters.
17. have a more favorable attitude toward science than later adopters.
18. are less fatalistic than later adopters.
19. have higher level of achievement motivation than later adopters.
20. have higher aspirations than later adopters.
21. have greater rationality than later adopters.

Communication Behavior: Earlier adopters

22. have more social participation than late adopters.
23. are more highly integrated with the social system than later adopters.
24. are more cosmopolite than later adopters.
25. have more change agent contact than later adopters.

26. have greater exposure to mass media communication channels than later adopters.
27. have greater exposure to interpersonal communication channels than later adopters.
28. seek information more about innovations than later adopters.
29. have a higher degree of opinion leadership than later adopters.
30. have greater knowledge of innovation than later adopters.
31. are more likely to belong to systems with modern rather than traditional norms than are late adopters.
32. are more likely to belong to well integrated systems than later adopters.

Source: Grubber, 1976:108-109

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This report provides a narrative review of concepts and issues related to domestic technology transfer. Six investigative questions are posed which form a framework for analysis. First, what definitions of technology, innovation, and technology transfer have been advanced, and what other concepts are relevant for understanding the subject matter? Second, what factors have been identified as promoting or impeding technology transfer? Third, what important roles do individuals fulfill in technology transfer? Fourth, what is the Federal infrastructure for promoting technology transfer? Fifth, what is DOD's role in promoting domestic technology transfer? Sixth, what models have been advanced to portray the technology transfer process? The literature review indicates that innovation research provides a large body of knowledge related to factors influencing technology transfer, and factors can be grouped as pertaining to management involvement or the source - user relationship. In the Federal infrastructure for technology transfer, there are notable active systems, but funding appears to be a continuing problem. Although technology transfer from DOD to other sectors is predominantly passive, a trend toward active programs is observed. A complete working model of the process does not appear to be available, however, a variety of descriptive models contribute to understanding technology transfer processes.

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