THE TECHNOLOGY UTILIZATION PROCESS: AN OVERVIEW

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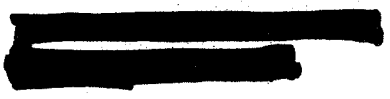

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James N. Holtz

Billions of dollars have been expended since World War II by the Department of Defense (DOD), the National Aeronautics and Space Administration (NASA), and the Atomic Energy Commission (AEC) on research (both basic and applied) and development in a variety of scientific areas. The primary mission of these expenditures is to create and maintain a comprehensive base of technology to generate and support advanced operational military and space systems. The substantial level of effort devoted to this mission has unquestionably been successful.

It soon became apparent that this vast pool of technology, created by the expenditure of public funds, could also provide a resource base for the generation of numerous commercial applications, or uses. At first, this commercial adaptation was considered to be a by-product of the military and space efforts. Some sporadic attempts were then made to search for by-products, or technological spin-off. The potential for these efforts appeared to be unlimited and some proponents of spin-off hypothesized that the spin-offs could eventually result in greater value to the economy than was obtained by the accomplishment of the original mission. Thus began the search for a systematic process to "transfer technology" from the public sector to the commercial sector of the economy.

It is very sensible to explore the possible uses of an innovation. Through this utilization the nation can reap the greatest returns on

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its original investment. This search for applications must, however, be constrained by the costs of the search and transfer process. These generalizations apply to all innovations. There is nothing unique in this respect about a transfer from the public (or military) to the commercial sector as distinct from an intrasectoral transfer, or one from the commercial to the public sector as far as the nation as a whole is concerned. Consequently, it is appropriate to analyze the utilization of technology irrespective of the sector of origin.

During this period, large aerospace firms with commercial product divisions began an intensive effort to identify relevant technologies and to exploit them commercially. These particular firms are a logical vehicle for technology utilization (TU) for several reasons. These large firms have access to substantial amounts of capital which enable them to adapt and to further develop a specific technological innovation and to exploit the market. In addition, they already possess the technological know-how which produced the innovation and they have the potential marketing staffs to merchandise the resulting adaptation.

In spite of these advantages, the large aerospace firms have not been successful in generating a widespread utilization of technology. Several factors are held responsible for this unfavorable experience. Frequently, the resulting adaptations are not within the area of interest to the corporation in view of its long-range market and product strategy. In addition, the resulting market may be perceived as being too limited to occupy the talents, and merit the investment, of the large firm. Occasionally, too much risk is attached in the technical development of the product, or in the possible exploitation of the market. At times, the payoff on the investment is too uncertain, or too distant, to merit the requisite effort. These innovations generally are turned over to the corporations' patent and licensing departments in the event that they can be of some use to other firms.

Another vehicle for TU is the small firm which generally thrives on exploiting one or two innovations. Small firms, however, face several formidable obstacles in this regard. First, a serious problem exists in searching for and identifying the innovations that are being generated in the public sector. Once the innovation is

identified, some licensing arrangement has to be made with the firm that developed the innovation. Frequently the patents and proprietary rights aspects are clouded due to the joint financing between the firm and the government. This factor could delay and discourage commercial exploitation of the innovation.

Furthermore, the innovation itself possibly requires substantial additional development before it is commercially marketable. In addition, the market for the innovation may be uncertain, or may require expanded marketing effort on the part of the firm. These efforts require financing and the small firm does not have access to financing on the terms, or the scale, available to large firms. Finally, the payoff from the process may be too distant, or too uncertain, or both to risk the life of the enterprise on that single undertaking. These barriers encountered by the small enterprise do not permit technological utilization to be widespread.

The individual entrepreneur faces all of the obstacles encountered by the small firm only magnified for the simple reason that his resource base is more limited than that of small firms. The individual entrepreneur could at minimum only play the role of a middle man ferreting out sections of the transfer process and selling these pieces to interested parties; or at best act as a promoter of a particular innovation and its exploitation by a newly created firm. In brief, none of the existing mechanisms for TU was entirely satisfactory.

This situation, in turn, led to various government agencies taking a more active interest in stimulating the transfer process. Advice was sought on ways to facilitate TU, and numerous conferences were held on the topic of overcoming the various obstacles to the transfer of technology. It became evident that all technologies are not equally transferable. The easiest transfer is where the innovation is a product (i.e., an airplane, an improved paint, etc.). Other innovations might consist of a new process (i.e., microminiaturization of circuits); new techniques (i.e., welding); new managerial systems (i.e., PERT, systems analysis). It also became evident that the market may exhibit varying degrees of readiness for different innovations. The situation leads one to speculate that perhaps a different transfer process is required for each type of innovation.

The first obstacle to be attacked was the "information gap." NASA took the lead in fostering the systematic transfer of technology. Their first efforts were devoted to the dissemination of information on innovations originating on NASA contracts. This has recently been expanded to include DOD and the AEC. NASA at first requested, now requires, its contractors to document or disclose innovations arising from NASA contracts. These disclosures are compiled and various documents are published and made available to the public detailing these innovations. A list of these documents would include Scientific and Technical Aerospace Reports (STAR) and C-STAR for classified disclosures; and International Aerospace Abstracts (IAA). STAR is mainly unpublished disclosures arising from in-house activity, whereas IAA is internationally published disclosures.

In addition, NASA publishes Technical Reports (TR) which are broad in scope covering a particular technology, Technical Notes (TN) which are more narrow, and Technical Memorandum (TM) which are published as soon as a worthwhile innovation appears. Other documents include Technical Transfer Reports, Special Reports, and Contractor Reports. All of these documents are readily available to the public (some limitations on C-STAR).

Experience soon indicated that it is not sufficient to use the shotgun approach to the dissemination of knowledge, and NASA inaugurated the concept of the Regional Dissemination Centers (RDC). The function of the RDC is to contact individual firms in their region, to identify the interests of these firms, to search the data bank on innovations, and to match as closely as possible the innovations with the interests of the individual firms. The RDC conducts retrospective searches of the data bank for the firms upon request, and a staff of university-affiliated scientific and technical personnel is available as consultants to evaluate the material on innovations and the specific interests of the individual firms.

The value of this approach to the transfer of technology is uncertain at present. NASA has been subsidizing the RDCs since their inception, but has established a requirement that they become self-sufficient in the next few years. Some of the RDCs are making progress

in this direction, but it is not certain that they will succeed. In principle, it is good that they must meet the test of the market place, but questions of appropriate fee structures to be charged member firms must be resolved. In addition, some subsidy by government may be of merit for not all of the benefits of a new innovation can be captured by a private firm. For example, a reduction in unemployment, beautification of an area, etc., are social benefits, but not available as profit for the innovative firm.

The latest approach to be employed by NASA involves the exploitation of technology concerned with a specific commercial application--the field of medicine. Several Biomedical Applications Teams (BAT) have been formed to apply technology to the field of medicine. This selective approach appears promising due to the large market potential for the relevant applications as well as the potential for technology to improve upon and augment the present techniques.

Other endeavors currently are being made to utilize technology; for example, the Small Business Administration (SBA) is working with small business concerning innovations at their Argonne Laboratories near Chicago. Various universities are studying aspects of the transfer process. Entrepreneurs are attempting to combine technical, economic and financial capabilities into a system which licenses and exploits technology. Various writers have stressed the importance of components of the process (i.e., the link between scientist and engineer, faculty members serving as consultants to small firms, etc.). Progress is being made on several fronts.

The above discussion is intended to be a brief description and summary of the state of the arts in technology utilization. Numerous diverse approaches with uneven thrusts are occurring in a smorgasbord fashion. The remainder of this paper will focus on the theoretical foundation of the TU process. The current efforts will be placed in perspective, and areas for further activity will be emphasized.

THE TRANSFER PROCESS

If a private enterprise economy is to participate in the transfer process, the innovations will be utilized only if the prospective returns are perceived to exceed the prospective costs. Consequently, the basic theoretical structure is primarily economic, although it can be extended by political, or even psychological, considerations. The approach that is presented here will rely primarily on economic analysis.

A conceptual framework for TU could be described as follows:

(1) The scientific community engages in various open-ended basic and applied research that is unbounded concerning the potential innovations that can be forthcoming.

(2) Their research efforts culminates in an existing set of new technological innovations at any given point in time.

(3) A subset of these new innovations are eventually identified, disclosed, and made available to the public in one firm or another.

(4) At the other extreme, an unbounded set of potential uses of technology exists.

(5) A subset of these uses results in perceived demands.

(6) A subset of the set of perceived demands results in an effective demand for a commercial application of an innovation.

(7) Finally, a systematic link between the disclosures and effective demand remains to be established.

This process can be depicted as shown in Fig. 1

It is useful to conceive of the events to the left of the systematic link as constituting the supply of technology, and those events on the right side as constituting the demand for technology. It is obvious that the impetus for transfer can be effected by either "pushing" the supply of new technologies into possible markets or by "pulling" the relevant technologies out of the supply by a clear, strong demand for a product.

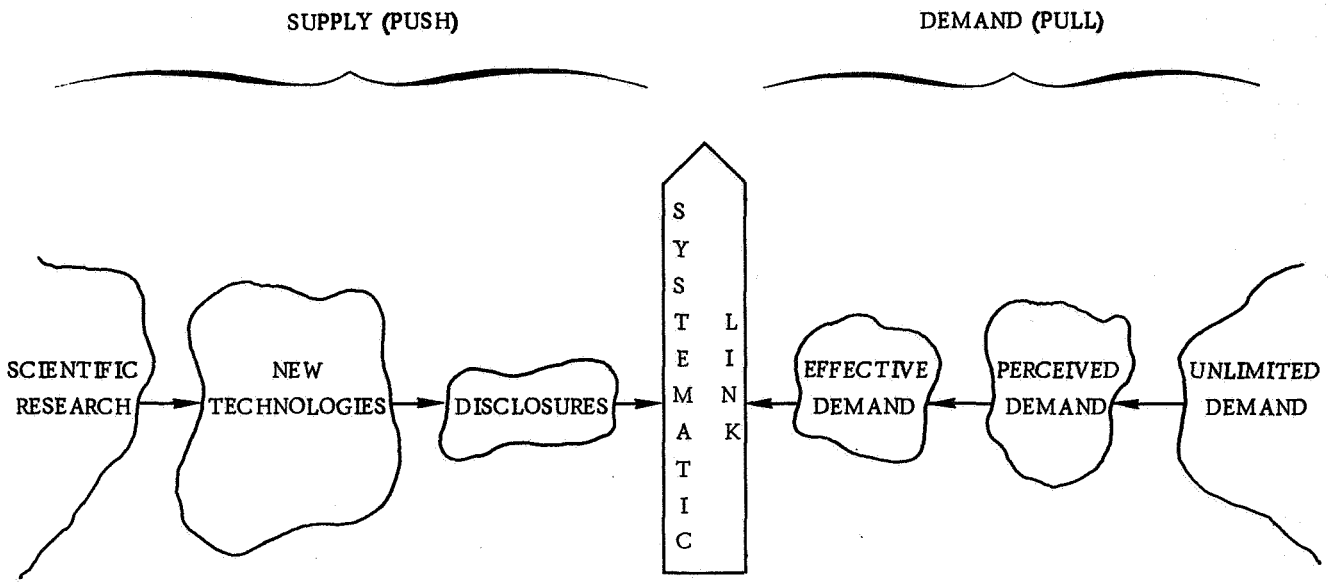

Fig. 1 - The Transfer Process

Another view of the transfer process is depicted in Fig. 2. In brief, two cycles exist: (1) the development of technologies for weapon and space systems and (2) the development of commercial products. These cycles have a common union at the technology base.

Figure 2 is more instructive than Fig. 1, as it indicates that considerably more effort is required to effect a successful transfer than is readily apparent in Fig. 1.

A third, and more elemental, view of the transfer process is simply that of a mechanism that transforms inputs into outputs, inputs being new technology and outputs being new products (see Fig. 3).

The regional dissemination centers and the Biomedical Applications Teams are two mechanisms for providing this service. It is a gross oversimplification to present only the one input/output function, for there are many in such a complex process. One clear I/O function is performed by the Scientific and Technical Information Division (STID) in the Office of Technology Utilization of NASA. Their function is to combine the disclosures generated by contractors (inputs) into the various technical documents (output) described previously. Other points in the process can readily be identified.

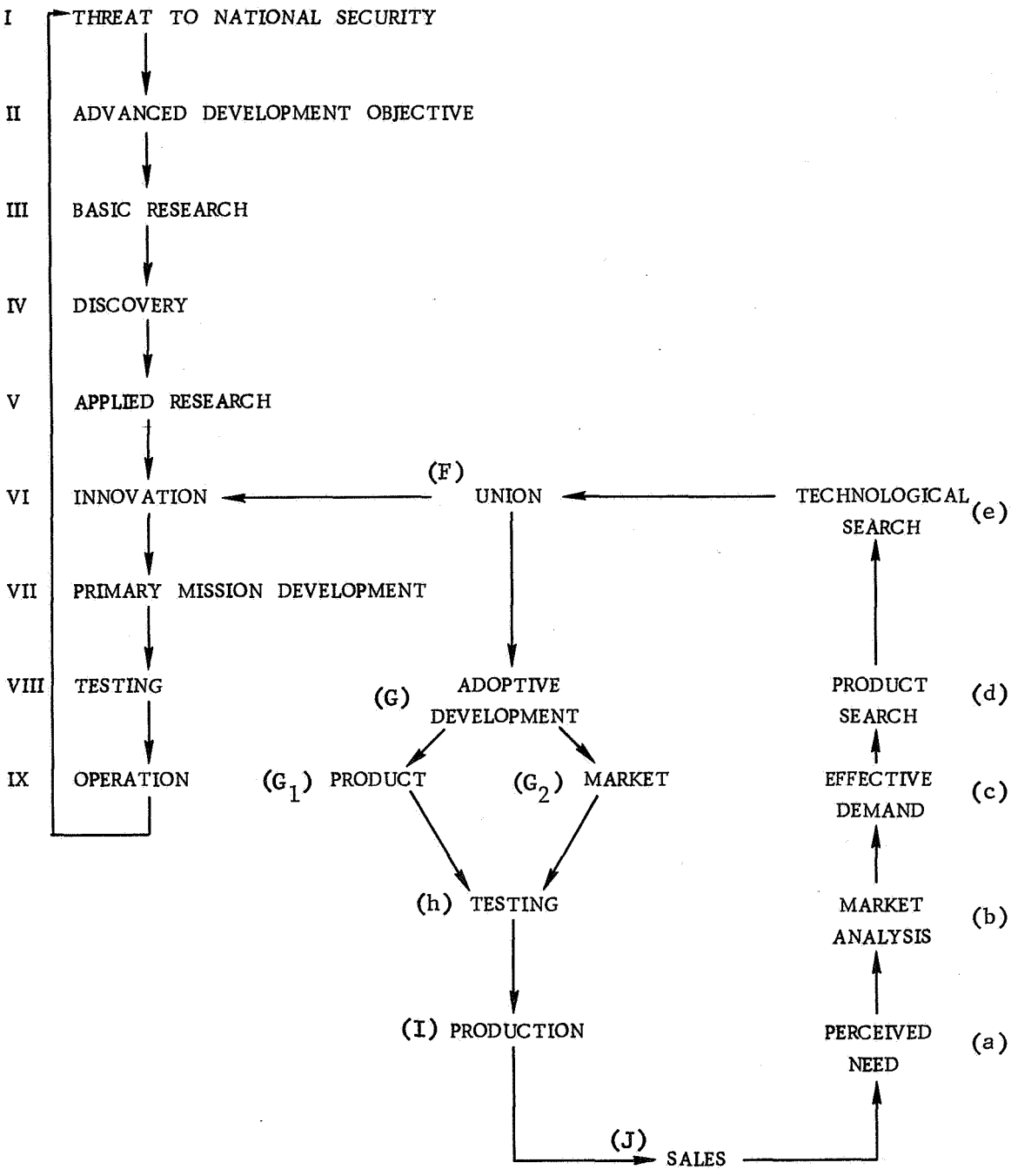

Fig. 2 - Stages of Product Development in Technology Utilization

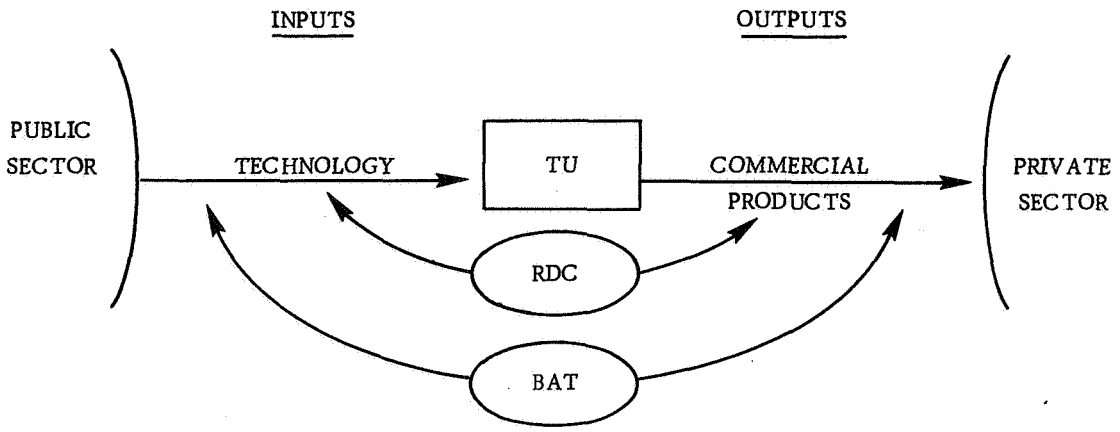

Fig. 3 - Input/Output Aspects of TU Process

What, then, can be said concerning current efforts in view of the theoretical schematic presented in this section? It appears that to date activity has centered primarily around the supply of technology. The considerable level of effort devoted to the transfer task has been expended to identify and document the disclosures, to publish the results, and to disseminate the information in numerous ways and directions. This effort has resulted in a substantial and growing data bank of innovations, Follow-on efforts to utilize this data have resulted in "pushing" the information intensively on a broad scale in anticipation that out of this wealth of disclosures numerous firms would withdraw relevant information that would lead to TU.

These efforts are proving insufficient for several reasons. One reason being that most firms were not aware of, nor familiar with, this valuable resource. Consequently, the dissemination of publications attempted to bring the attention of firms in general to the existence of this effort. Then, the RDC concept was established to concentrate selectively on specific firms in a region and make them aware of this data.

Out of these dissemination efforts, the importance of defining the user firm's interests became obvious. Recent efforts at defining these

interests in terms of creating interest profiles for each specific firm are directed toward determining in a sense each isolated market for the innovations. To the extent these efforts are successful a more appropriate matching of innovations with user interests will be realized and more transfers should occur.

It must be emphasized that each step taken to date requires considerable effort and some difficult problems must be solved. For example, the following problems are encountered: What constitutes an innovation? How can this innovation be disclosed to maximum advantage (i.e., by market potential, by functional area, by industry, etc.)? What innovations should be included or left out of such publications as technology briefs, notes, reports, surveys, etc? What are the firm's real interests categorized by product lines, by technologies? How should innovations in the information bank be coded? How should searches be coded? What is excluded? How much irrelevant material is included? What, in fact, is relevant? These are all serious and difficult questions that must be decided.

In spite of these valuable and extensive efforts to transfer technology the response has been somewhat disheartening. Numerous obstacles remain. The multipronged efforts and the willingness to try new approaches to TU must be applauded and encouraged. It requires considerable time to establish a system that results in wide-scale and systematic transfers and still more time is required to realize numerous transfers.

Let us examine some further reasons for inhibition of the transfer process. One major reason that the systems to transfer technology installed to date have not resulted in greater transference undoubtedly centers around the fact that the exchange, or linkage, that occurs at the RDC-Business interface involves principally information, or disclosures. Of course, some technical and evaluation advice is also given. It is still a long journey for a firm from the time they are cognizant of a potential innovation to the eventual market exploitation of the product resulting from that innovation.*

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*See Fig. 2.

Considerable sums of money must frequently be expended to do further research and then "bend metal" to develop the product to a satisfactory commercial state. Additional sums must be expended to develop production facilities, and to establish a new, or an incremental, marketing organization. Finally, these expenditures must be made in an environment of considerable economic as well as technical uncertainty before the project becomes profitable.

The entrepreneur, and the small business firm, in most cases simply do not have access to adequate capital to undertake this process. Furthermore, even if available, the cost would be quite high (perhaps involving loss of control of the business), and/or the risks great enough to endanger survival of the firm if an adverse state of nature should be encountered.

If a truly systematic transfer process is to be established, a process for providing venture capital on relatively favorable terms to the small businessman must be established. This financial process could possibly involve a combination of public and private capital. Numerous government agencies are already established that can, and do, provide funds to business for various socially worthwhile purposes. For example, the Economic Development Administration can invest long-term funds for plant and equipment, retraining of labor force, and make some guaranties of working capital for plants that located in designated areas; SBICs can provide equity capital; the SBA can lend money; municipalities can sell tax exempt municipal bonds to finance plant and land, etc.

It is possible that a worthwhile innovation could receive financing from all, or a combination, of these sources if the innovation conformed to the primary missions of these agencies. Perhaps, private venture capital groups could be induced to invest on more favorable terms with the leverage provided by government funds. At least, some efforts could be expended along these lines. Conceivably, if such a financial process were established and publicized, numerous innovations could be "coaxed out" of the attics, as well as provide potential financing for a larger number of transfers arising out of disclosures.

A serious question that would be encountered is the determination of what projects are potentially worthwhile. Undoubtedly, most of the innovations "coaxed out of the attic" would have little, if any, commercial merit. Some screening device would be advisable; otherwise, the evaluations would be rapidly enmeshed in disheartening work. As it is now, only 1 out of 100 investment proposals received are eventually backed by private venture capital groups.

This area of project analysis, or value analysis, is difficult to analyze except in the most general terms, as each innovation generally has unique characteristics. The market may be broad or narrow, consumer- or industrially-oriented, etc. The project may exhibit varying degrees of technical complexity, sophistication and reliability. Other factors may arise to cloud the determination of commercial merit.

However, these analyses are currently being made by various groups, and the criteria they establish for acceptance or rejection of a project are not explicit. In addition, the real reasons for rejection of a proposal may not be explained with candor to the innovator. It would be at least useful, if not necessary, to provide a list of criteria used by each type of supplier of venture capital to evaluate the investment merits of projects. The criteria would then be made explicit and small business or other innovators could evaluate their projects for commercial merit along these guidelines. Perhaps the itemization of criteria used by various investor groups when compared to "ideal" criteria for a national investment policy would disclose "gaps" in the existing venture capital environment. These gaps could be analyzed, in turn, to determine what new, if any, financial intermediaries should be created.

In brief, the process of utilizing technology is long, complex, and arduous. Considerable effort has been, and is being, expended throughout the nation to utilize technology. These efforts so far have centered around identifying, documenting and disseminating information on technological innovations. Recent efforts have been made to identify the demand for technological innovations. These efforts are costly and subject to risk. Attempts are currently being made to match the supply of technological information with the demand for such information.

However, this transfer of information is only a first step in the process. Information has to be evaluated, products developed, markets explored, expanded facilities built, etc., before a technology is utilized. These substantial efforts must be financed, and the payoff may still be relatively distant and uncertain. If a systematic transfer process is to be established, sources of financing adequate for this task must be identified and available to the innovators. Concepts of project analysis must be ascertained before gaps in existing venture capital sources can be identified and new, or expanded, venture capital institutions established.

The recommendations for more extensive and liberal financial mechanisms to finance and evaluate innovations presented here are not a panacea for all the problems inherent in the utilization of technology. However, such mechanisms would overcome perhaps the most important obstacle to systematic transfer. Considerably more work must be done to establish the financial process, and it should be established only if the total benefits promise to exceed the total costs. Providing adequate financial mechanisms appears to be an essential movement in the right direction.

The availability of abundant financing would at least relax a significant constraint upon the utilization of technology. Numerous other problems would remain to be solved. Obviously, engineers, scientists, economists, and market analysts must be employed and interact at various stages of the development cycle. No simple formula or procedure exists, or at least has been made public, concerning the successful management of these interactions. Undoubtedly, each firm and each project must be somewhat unique due to the personalities and capabilities of the various personnel involved, as well as the varying physical characteristics of the innovations.

In brief, the establishment of a systematic process for the transfer or utilization of technology is a lengthy, complex process. The attempts evidenced to date, although substantial, are only a beginning in the vital process. These efforts are largely centered upon the dissemination of information on innovations, with some limited attempts at defining the demand for information or innovations.

It is the contention of this paper that (1) the transfer of information, or knowledge, on specific innovations is only a first step, and (2) the small enterprise is generally not endowed with,nor has access to, adequate financing on reasonable terms which would enable it to advance the innovation to a stage where it can be commercially exploited. The financial mechanisms that exist are insufficient for this task. Most of the private venture capital groups are quite conservative and of insufficient size to invest in a substantial number of risky innovations. The SBICs have tended to request too large a stake in their ventures, which in many cases discouraged innovations.

Perhaps a system employing a combination of government funds and private financing could be tested on a pilot effort. The government funds would be provided on the basis of the externalities or "public" goods aspects of the innovation, then the private financing could be forthcoming based on existing investment principles to capture the "private" goods aspects of the innovation. This financial innovation combined with other studies on the transfer process should lead to a more successful utilization of our abundant technology base.