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Urban Development Applications Project

Urban Technology Transfer Study

FINAL REPORT

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Prepared For

National Aeronautics Space Administration
Urban Development Project Office
Johnson Space Center
Houston, Texas

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1.0 INTRODUCTION

Four years of experience, the most recent under the management of the Urban Systems Project Office of Johnson Space Center, have lead us to some conclusions about successful technology transfer. These are supported by the existing literature on the management of innovation.

In the operation of an active technology transfer program, we have encountered and solved many problems: we have been unsuccessful in solving even more. The successes have provided a firm basis for future successes, and the failures have had some educational value. This report puts forth the "enhancers of technology transfer" (the success lessons) which can improve the probability of success for current and future projects.

Contract orientation, the Technology Application Team (TATeam) composition, and the client (NASA) have all changed significantly over the years of this project. These adjustments have usually improved things, but were never without some cost of adaptation. A few organizational issues that have been effective are highlighted in this report and problems that have occurred are reviewed.

It is hoped that this report can form a basis for continuing NASA-TATeam dialogue and will improve team performance for future TATeams.

2.0 WHAT IS TECHNOLOGY TRANSFER?

For our purposes we should reconsider the definition of technology transfer. One definition is:

> Technology transfer is the process of solving a social or economic problem through the application of an existing technology -- one developed for a different problem, in a different environment.

This definition differentiates technology transfer from conventional problem solution in one very important aspect. Technology transfer transfers a cost-effective solution from the sector in which it was developed to the sector in which the need resides. This implies that those actors in the needs sector are not operationally familiar with the technology that can solve the problem in the most cost-effective way. This definition limits the candidate activities that can be considered; however, it has been the working definition of technology transfer for the Urban Development Applications Project (UDAP) for the past four years.

This is not the only definition of technology transfer: a more universal definition is:

> Technology transfer is the application of technology to a new use or user.*

The important distinction rests in the types of activities that are implied for a group whose mission is the transfer of NASA-developed technology to problems of urban construction and planning.

The first definition excludes dissemination activities that have frequently been characterized as "technology push" and

*Gee, Sherman, "The Role of Technology Transfer in Innovation," Research Management, November, 1974.

focusses attention upon applying NASA-developed technologies in critical problem areas where these technologies have not previously been considered. This process of first characterizing the need and then identifying candidate solution technologies is most frequently referred to as "market pull." The latter approach has been the focus of the UDAP project.

3.0 WHY ATTEMPT TO TRANSFER TECHNOLOGY?

Two reasons are readily available for an active technology transfer program: the first is based upon the assumed validity of the second:

- NASA's enabling legislation mandates technology transfer.
- Technology transfer is complementary to conventional research and development and can assure that the benefits of new technology are realized at the earliest possible time.

The Mandate

The National Aeronautics and Space Act of 1958 included:

> "The aeronautical and space activities of the United States shall be conducted as aso to contribute... to the expansion of human knowledge of phenomena in the atmosphere and space. The Administration shall provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof."

The programs of the Technology Utilization Office, including the Technology Application Team program, were created in response to this mandate.*

A New Complement to Research and Development

Technology transfer is nothing new. The application of tools, techniques and materials developed for one purpose to needs in another context is as old as technological innovation itself. For example, the technical expertise accumulated in the casting of metals for armaments contributed eventually to the "invention" of movable type and the advent of printing. In that case, the transfer occurred naturally as the product of complex socio-economic

*An excellent summary of all of NASA's technology utilization program appears in Federal Technology Transfer by Todd Anuskiewicz, published by the Naval Ordnance Laboratory, August, 1973.

currents and large measures of happy coincidence. However, the time lag between the development of a technical capability and its wide cultural application was very long--centuries, in fact. Even in modern times, the spontaneous movement of technology beyond the specific problem-solving application for which it was created has often required more than a decade.*

The key to reducing these long time delays is believed to be an accessible source of technology. The availability of the technology can improve the rate of technological innovation. Active programs, focussed upon particular areas of social concern, can similarly influence the direction of innovative activity, assuring that the potential of advanced technology is directed at significant social problems.

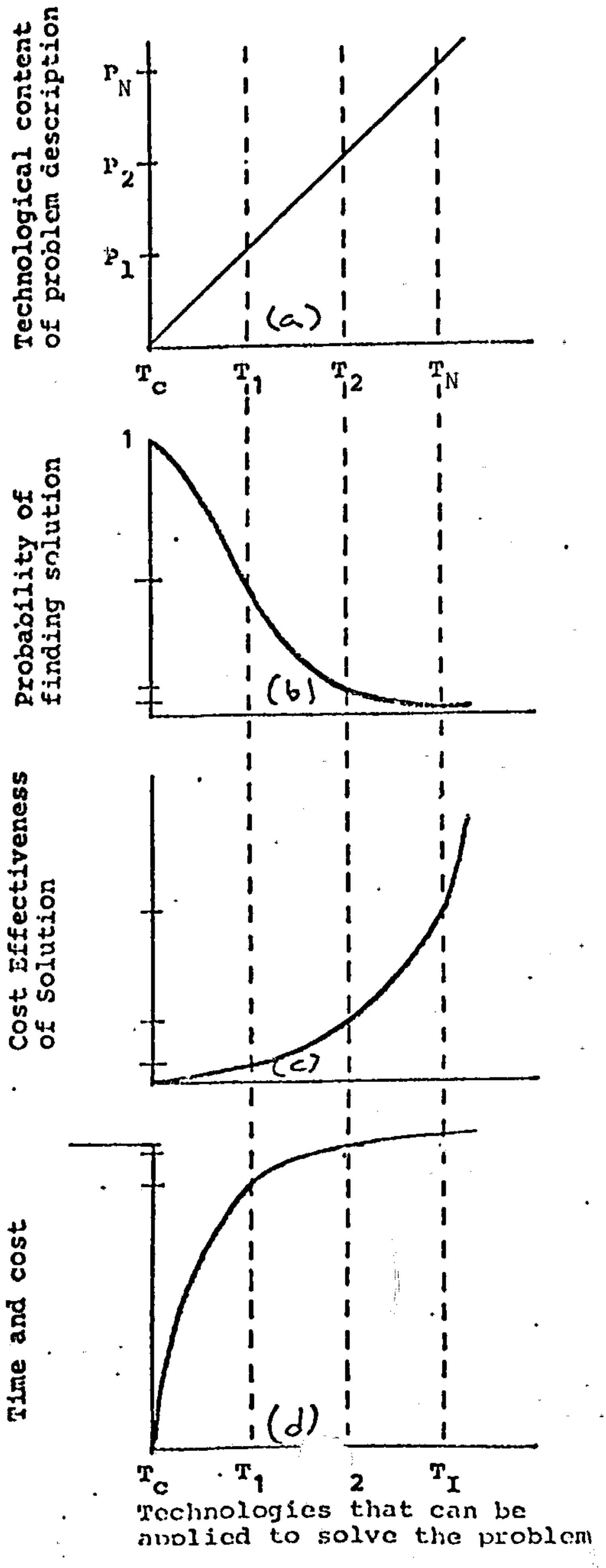
Technology Transfer vs. Conventional Problem Solving

Most new technologies are the subject of great expectations at the outset. For those areas where the technology is applicable a transfer usually occurs--eventually. The primary problem with technology transfer "by accident" is that it takes a very long time to match a need with an appropriate new technology.

The experience of technology transfer is graphically shown in the accompanying series of graphs. Reviewing these graphs can help our understanding of the important contribution that technology transfer can make to our problem-solving methodologies.

The top most graph (a) is a representation of the range of technologies that can be applied to a problem as a function of the flexibility of the problem statement. As an example, if we describe a problem as:

*See "Chronological Outline of the Development of the Mandrel-Wrapped Fibre-Shell Concept for Housing," Quarterly Report #5, Urban Development Applications Project, 31 March 1971.


Technological content of problem description
P1
P2
PN
(a)
Tc
T1
T2
TN
1
Probability of finding solution
(b)
Cost Effectiveness of Solution
(c)
Time and cost
(d)
Tc
T1
2
TI
Technologies that can be applied to solve the problem

P_1 "Walls of excavations must be restrained to prevent injury and death of workers who must work in the excavation."

Then we are constrained to technologies (from T_c - T_1) that restrain the excavation walls; shoring, soil stabilization, etc. If, however, we state the problem as:

P_2 "We must protect excavation workers from cave-in related injury or death."

Then we can solve the problem with technologies ranging from T_c to T_2. Note that all of the previous technologies are included, however, new technologies from T_1 to T_2 would include protective armor for the worker, emergency breathing apparatus, and even automatic machinery to replace the worker in the danger area.

Similarly we can describe the problem as:

P_N "Liquid waste must be disposed of without endangering excavation workers."

This allows the consideration of technologies that circumvent the need to dig trenches for sewer construction.

It is clear that the problem statements differ significantly, that the solutions to the earlier problems are also solutions to the more general problem definitions. Let's now examine the implications of this problem flexibility.

Graph (b) shows the form of the probability curve that indicates where the solution is most apt to be found. The origin represents the current technology, therefore, the probability of a solution at that point is 1.* Solutions close to the current solution (evolutionary changes) are also highly probable. The probability that a solution exists diminishes rapidly as we move to technologies increasingly distant from that current uti-

*There is a companion concept that problems can only be defined in an evolutionary way. At least a poorly suited solution is necessary to recognize and articulate the problem.

lized. This, along with considerations of available resources is a strong determinant of the behavior of industrial R&D organizations.

The change in cost effectiveness of possible solutions is represented in (c). The new solution may be less costly than the conventional system, or it may be more effective, or both. The NASA smoke detector will lower cost (from $ 50 to $ 5 or less) and be more effective (false alarm rate will be 2 in 3 rather than 9 in 10).

There are two possible interpretations of graph (c). The first interpretation is that highly unusual approaches (from T_2 to T_N) must of necessity be particularly cost effective in order to succeed. The second interpretation is simply that the more the technological content of the problem solution differs from the conventional, the more effective it is. Historical evidence supports this latter conclusion, and this evidence is one of the compelling arguments in favor of a technology transfer experiment.

The time and cost of finding a solution to a problem both increase substantially as the technology applied differs from current practice. This is indicated in the combined graph (d). It is probable that the cost (and time) increase greatly as soon as the technology does not fit current resources (human, production, etc.), and varies little more as it becomes more unusual.

Considering these relationships we are lead to believe that all arguments do not favor technology transfer. That is clearly the case, otherwise technology transfer would be normal R&D behavior. The problems of cost and time coupled with the probability curve (b) are the factors that have brought conventional R&D to its current state. Evolution is efficient and current practices are near optimal if a system has had a chance to evolve. Changes in the system have occurred in the past 10 years and processes of research have not yet adapted to them; hence the opportunity exists to demonstrate technology transfer as a more efficient means of solving society's problems.

The major system changes have been: the creation of large scientific and technical data bases, and the growth of interdisciplinary firms like Abt Associates. The data bases and the interdisciplinary teams facilitate time, cost and uncertainty reduction in the search for and implementation of unfamiliar technologies.

It is important to note that the data base is a mechanism for identifying promising approaches to a problem. When a technological reference is found, we can locate the technology within industry with a very few telephone calls (usually fewer than 5). Applying that technolgoy to the new problem area will develop and strengthen domestic capabilities.

The viability of a technology transfer process based upon utilizing existing technology relies upon the quality, diversity, and accessibility of the available technology sources. When the utilization of federally-financed technology is a secondary objective (secondary only to solving important social problems) then the mechanisms for accessing and applying this technology must be clearly delineated. The versatility and accessibility of technolgoy sources is an important consideration and should be carefully evaluated, since the cost/benefit of using the various technolgoy sources has been found to be quite variable.

A primary concern is that altered organizational behavior and relationships have characterized successful technology transfer projects. For many reasons the firms which operate in the various markets are unwilling to innovate in those markets. This behavior must be considered in the conduct technology transfer. At present the change agent (TATeam) is a necessary part of the technology transfer project, providing the linkages among market needs, appropriate technologies, and producers/marketers.

4.0 HOW SHOULD ONE GO ABOUT TRANSFERRING TECHNOLOGY?

The important elements of active technology transfer include.

- Problem Identification
- Technology Search/Match
- Establishment of Market Mechanism
- Applications Engineering
- Commercialization

Our experience in each of these areas is substantiated by findings of others who have examined the process of technological innovation. In the following section (4.1) we discuss these findings and in 4.2 we discuss their operational implications. Section 4.3 discusses the management aspects of technology transfer.

4.1 Theoretical Models

Although there are no comprehensive models of the processes of invention or the diffusion of innovations, a great deal of research has been done since a landmark 1967 Department of Commerce Study.* In this section several of these perspectives will be reviewed. They accurately reflect our experience, and are based upon stronger evidence than the anecdotal evidence we can present from our limited number of innovation efforts.

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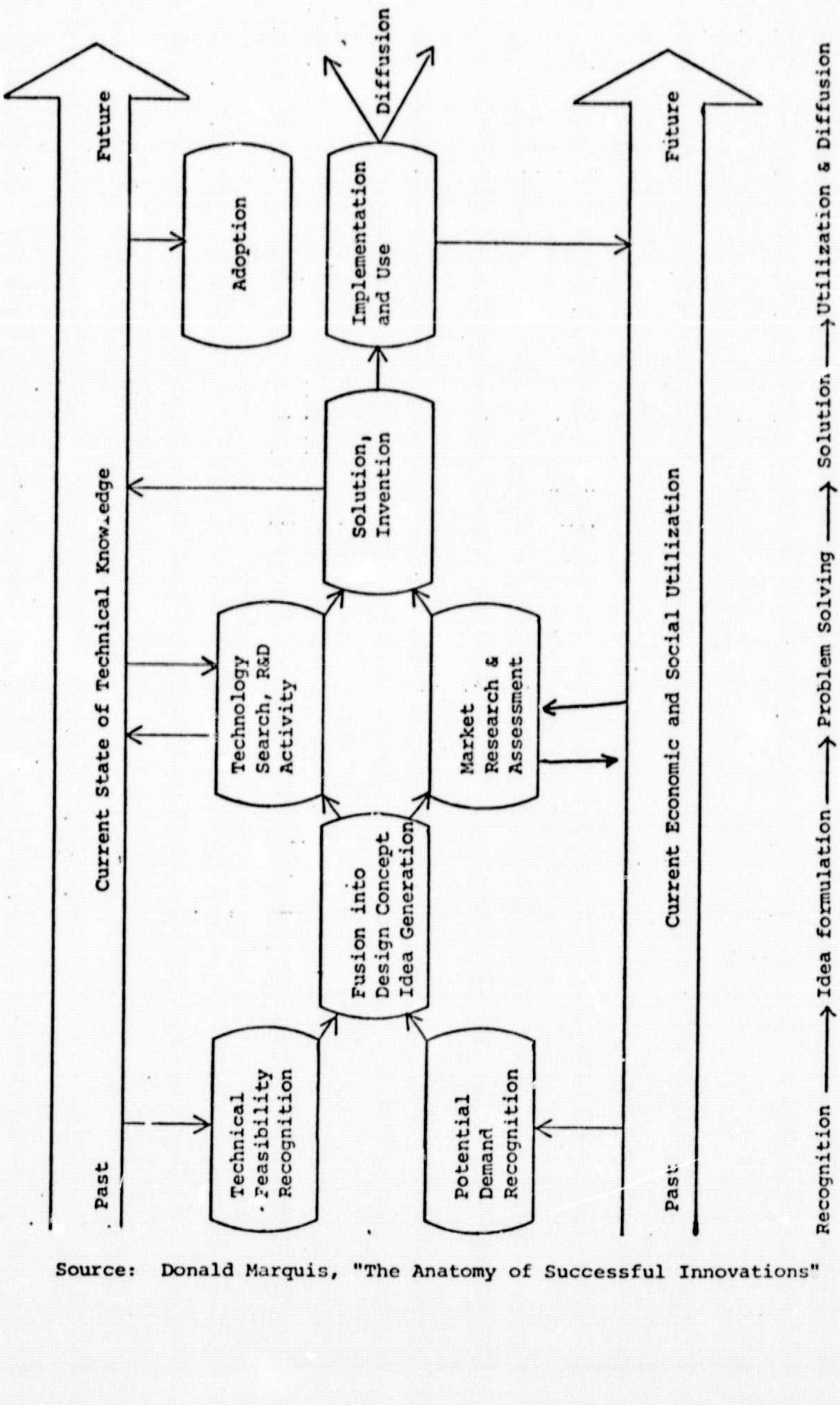
*The problem of enhancing innovation in the private sector has long been a specific concern of DOC. In 1967, the views of an advisory panel on invention and innovation were presented in Technological Innovation: Its Environment and Management, published by DOC. This panel of experienced technologists and entrepreneurs made specific policy recommendations which tended to be related to tax and patent regulation. The strength of this study was that it served as a focus and a forum for expert opinion. The weakness of this early study was that it was not solidly grounded in empirical data.

4.1.1 The Six Stages of Innovation Model

This model was first proposed by Donald Marquis in the "Anatomy of Successful Innovations," Sloan School Working Paper, MIT, Cambridge (undated). Marquis introduced it to explain the process of invention discovered in an NSF study of over 400 innovations (NSF 69-71, 1969). His model is displayed as Figure 2. The innovation process consists of the six stages: recognition, idea formulation, problem solving, solution, utilization (pre-commercial), and diffusion (commercial). At any point in time, there exists a current state of the art, or inventory of feasible technical approaches. This technology inventory is represented by the top arrow in Figure 2. Similarly, there exists a number of potential users who are applying products to applications. Marquis calls this the current state of social and economic utilization (bottom arrow in Figure 2). The innovator is more or less aware of the current state of social and economic utilization. The process of innovation begins with the recognition of match between a feasible technical approach and an unmet user need. This match or fusion into a design concept is the second or idea stage. This idea formulation is a creative process in which both elements must be balanced. If technical possibility alone is considered it may result in an innovation for which there is no demand.

During the problem solving stage, the innovator establishes the market feasibility by accessing the current state of economic and social utilization and establishes the technical feasibility by searching the current state of technical

Figure 2: The Process of Technical Innovation



Source: Donald Marquis, "The Anatomy of Successful Innovations" knowledge. Clearly, this process involves risk and uncertainty; moreover simply to evaluate alternatives consumes resources. This technology selection process inherently preceeds capital investment decisions.

The conventional wisdom is that innovation proceeds along a chain of idea development: research (R)→development (D)→ engineering (E)→marketing (M).* In related work we suggest that the process is reversed in most cases of successful technical innovations. Engineering is done <u>only</u> in response to a demonstrated demand in the market, development is undertaken <u>only</u> when the attempt at engineering identifies an unmet technical need; and research is initiated <u>only</u> if that development effort should require it. This is also the view of James Utterback, who says that new alternatives will be sought only when present alternatives do not meet expectations.** If this is true, Utterback argues, then information which directs attention toward expectations will be effective in stimulating technology transfer (active or passive).

Several of the policy-relevant hypotheses that lead from the innovation process model outlined above (e.g., "Innovation is encouraged by financing the search for alternatives"), will occur again in connection with the communications process model to be discussed in the next section.

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*<u>Design of an Experimental Program of Transfer Technology to and Within Canada</u>, (1973), Abt Associates, Cambridge.

**"The Process of Innovation: A Study of the Origination and Development of New Ideas for New Scientific Instruments," <u>IEEE Transactions on Engineering Management</u>, EM-18:4, p. 121, Nov. 1971.

4.1.2 The Communication Process Model

This is a view of the innovation process most extensively studied by Thomas Allen of MIT. He finds that there is a communications process that keeps the innovator informed about the current state of technical knowledge. In this communication process, internal channels are more effective than external ones and person to person communications is more effective than journals and other printed matter.

We hypothesize that the benefit of gathering information is primarily in reducing the risk of unknown contingencies inherent in adopting untested equipment, processes, or procedures. For this reason, prior NASA experiences that evidence improved technology and are visible to others should reduce the risk and increase the rate of adoption. This is echoed by Rogers and Shoemaker, whose characterization of innovation is discussed in the next section.*

These definitions serve as a starting point because so many other studies have been (and will be) expressed in these terms. Although they are useful to the innovation theorist, they are clearly too general and broad to aid operational programs in determining the degree to which a given policy will enhance technological innovation.

Some researchers have disaggregated relative advantage into the following components: (1) functional utility,

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*Communication of Innovations, Free Press, New York, 1971

(2) ease of use, (3) acquisition cost, (4) operating cost, (5) reliability, and (6) compatibility. One nearly universal conclusion of recent work on innovation is that stated by Achilladelis, et al:*

> Successful innovators have a much better understanding of user needs. They may acquire this superiority in a variety of different ways. Some may collaborate intimately with potential customers; others may do market research or themselves have the necessary experience of user requirements. But however acquired, this imaginative understanding is the hallmark of success.

This conclusion is echoed by Marquis and Myers, in their NSF study of over 400 innovations, and summarized by James Utterback.**

Sensitivity to user needs is the single most important concept that must be incorporated into an active technology transfer program, and it is the central theme of all TATeam activity.

4.1.3 Behavior of Industrial Organizations

Given the well-documented desire of almost all industries to enter new markets, to innovate, to increase profitability, to increase their market share and to diversity, it would seem an everyday task to identify an appropriate producer for a given commercial innovation. This is not the case. Most experience in this area indicates that great difficulty is encountered when an external advocate attempts to encourage an

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*Achilladelis, B., Jervis, P. and Robertson, A.: Success and Failure in Industrial Innovation: Report on Project SAPPHO, Centre for the Study of Industrial Innovation, London, 1971.

**Utterback, James, "Innovation in Industry and the Diffusion of Technology," Science, 183, p. 620, February 13, 1974.

innovation. There are many reasons why innovation does not progress in the straightforward manner that seems appropriate.

It is the first response of anyone desiring an innovation to go to the current supplier of a related product or to a supplier who has been providing a solution to that or similar problems in the past. For many reasons, this is an inappropriate vendor selection. In Donald Shone's Technology and Change it is argued that innovation occurs when one industry invades the market of another industry. There are many reasons why this is the case. Among the most important are:

- Capital Obsolescence;
- Unfamiliar Technology;
- Economics of the Proposed Innovation;
- Social and Personal Uncertainty.

Each of these will be discussed briefly and an approach to innovation procurement will be presented.

Capital obsolescence is a component of the other considerations which follow, but is of sufficient importance to describe it individually. Capital obsolescence includes not only plant and equipment, but also includes human capital. An organization that can avoid capital expenditures by not innovating has a tendency to avoid these expenditures. Replacing a current product with a new product, particularly a new product based entirely on a different technology, almost invariably involves the obsolescence of existing production capital.

Unfamiliar technology is widely believed to be an additional reason why a firm does not innovate in its own market area. A primary reason cited is that management, familiar with current technology, is threatened with technical obsolescence and fears loss of control. There are many suggestions that more effective innovations rely on newer technologies, far removed from existing practice. For this reason, firms are hesitant to innovate.

Computations of return on investment yield lower figures when it is a question of replacing a current product line, current plant equipment, current sales techniques and even sales literature, than the yield when starting a new product that does not compete with an established product line. As an example consider that the current product returns a unit profit of $1.00. If the new product requires all new capital equipment and the new product yields $2.00 unit profits, then the capital expenditure represents only a $1.00 per unit profit opportunity to the manufacturer of the current product, but the same investment represents a $2.00 unit profit to a manufacturer that isn't obsoleting a current product. These economic considerations make innovative products more attractive to firms without vested interests.

Finally, social uncertainty may contribute to the lack of innovative activity of some organizations. When an organization does move into an innovation, a social transformation frequently accompanies the change. Something old must come apart in order for something new to come together. But for individuals within the system there is no clear grasp of the next stable state, only a clear picture of the one that is to be lost.

Hence, the coming apart carries uncertainty and anguish with it for the members of the organization, since it puts at risk the basis for self-identity that the system had provided. It does not matter that the change may later be seen to have been harmless or even beneficial; before the fact the threat of disruption plunges individuals into a state of uncertainty as intolerable as damage to vested interests. The individual puts his own conservative energies at the service of the system conservation and not at the service of the innovation.

An over simplified first response to the problem of a threat is to ignore it.* This response is very nearly universal. A stranger to an organization can usually notice things the organization has kept hidden from itself; this fact makes consulting possible. When it is no longer possible to avoid noticing a threat it may be possible to launch a counter attack or even a preventive attack before the threat has materialized. Such an approach is frequently encountered, e.g., in building codes or trade union practices when innovations are first recognized.

When the threat cannot be displaced the strategy of containment and isolation is frequently developed. The threatening change is limited in scope and kept effectively bottled up. This constraining activity usually results in the innovation withering and dying. A variation of this is co-option, or the absorption of the change to diffuse it, dilute it or turn it

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*This discussion of organizational response is adapted from Donald Schon's discussion of "Dynamic Conservatism" in his recent book, Beyond the Stable State.

to other ends.

Finally, changes can be dealt with by accepting them but limiting them as much as possible. It is probable that this behavior is only present when the threats to the individual or to the organization characterized above are present. We can develop a strategy for matching the user and the need with an appropriate commercializing organization to minimize the probability that these pitfalls materialize and to maximize the probability that a cost-effective solution will be developed. It is very important that dysfunctional behavior be recognized early because all transfer activities can encounter these barriers and be contained within a firm with a vested interest to protect.

4.2 Operational Implications

The studies that have been performed on the process of technological innovation provide guidance for the establishment of policies that maximize the probability of success in an operational program to facilitate the widespread application of advanced technology. Individual cases of successful innovation also provide "how-to" patterns for future efforts. On the other hand, studies of failures and barriers, only show one or a few of hundreds of ways to avoid success (achieve failure?). In addition it is possible that a given barrier might not stop a different innovator, therefore we can't even be sure that a past approach that failed is inappropriate for future efforts. We conclude that the elements of successful attempts warrant our attention, and that these "enhancers of innovation" will, if properly attended to, provide future successes.*

4.2.1 TATeam Orientation

"The great promise of technology transfer lies in its systematization and organization on a national scale. However, the realization of this promise remains elusive, principally because of the innumerable technological, political, economic, social, and behavioral factors which affect the outcome. As concluded by Burns, 'The mechanism for technology transfer is one of agents, not agencies'. That is, effective communications and interpersonal relationships are the most important factors contributing to successful technology transfer. But social scientists have yet to devise a way by which these principles can be practiced in a systematic or organized fashion. Furthermore, the human ego is notoriously resistant to management and control."**

- Orientation should be to solving problems, not fulfilling contractual obligations, these are necessary but secondary.

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*It must be remembered at all times that success is the rarity:

- For examples, see DRI semiannual report, 1 Jan. 1974 - 30 June 1974, Contract NASW-2607.
- For problem benefit information perhaps 1 of 10 contacts yields useful information.
- In searching technology, 100 computer references result in 10 interesting abstracts, 5 relevant technical reports, and one cooperative technologist.
- Perhaps one in five promising technical approaches can conform to a given problem's constraints.
- One marketable product results from 3 to 5 prototype developments.
- One out of five of the best selected commercial firms is willing to participate.
- etc.

**Sherman Gee in Research Management, November, 1974

- Technology transfer agents should always approach a transfer with optimism and persistance, expecting to encounter many near defeats, impasses, and delays. If the first failure stops an effort, then all efforts will fall short of completion. The TT agent must expect to encounter and circumvent barriers, not be stopped by them.
- An open, investigative attitude must be maintained. It is an overwhelming temptation (especially to highly technical agents) to prejudge the technology that is "most effective" or "most appropriate" for a given problem. Effective problem solutions result from searching the broad range of potentially relevant technologies: preconceptions interfere with objective search.
- Advocacy is important. A technology transfer agent responsible for a problem must be committed to its solution and believe in the chosen technical approach.
- Communication, both internally (TATeam, NASA, problem specifier, commercializer, etc.) and externally are very important. Frequent internal contacts enhance mutual understanding of needs, specifications and technological opportunities. External communication maximizes the chance of "fortunate coincidences" that are so frequently part of the innovation process.*

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*One or more chance happenings are key elements of almost all successful innovations.

- Knowledge of the problem area is very important. The transfer agent should have knowledge not only of the technical aspects of users problems, but should fully understand the environment of the problem -- organizations, vested interests, political power, other dominant influences on potential users of TT results.

4.2.2 Problem Identification

The understanding of the problem has decisive importance. Many of our operational hypotheses are concerned with this step in the process, good problem sources, characteristics of appropriate problems, means of communication, and operational treatment of individual problems:

- Desirable characteristics of problem specifiers include:
  - ability to implement a solution;
  - willingness to participate in solution development;
  - constitute a market for the solution (or have access or impact upon market).
- Government agencies whose mission includes Urban Construction and Safety are good problem specifiers.
  - Agency R&D priorities;
  - Individuals within the agencies.
- Large users, and user groups have been effective as problem specifiers.
- Professional journals and industry publications are sources for initial problem identification.
- Appropriate problems are persistent, technology transfer takes time. "One Shot" problems such as glass

breakage in a single high-rise building are usually inappropriate.

- Problems should be primarily technological. An educational television system has high technological content, but success depends upon the associated social system. Improved smoke detection faces no similar uncertainty.
- Problems should be specific. A generalized problem definition usually results in a solution that is sub-optimal for each user (e.g., early efforts for police/fireman short-range communicator). It is preferable to develop a prototype well suited to one large user and let it be modified to broaden its market. This assures maximum cost effectiveness of initial products.
- High social benefit should accrue to the solution of problems chosen for TT efforts. This is important to facilitate the rate of adoption of a solution as well as to justify expenditures of federal funds.
- A tool is needed to facilitate communication. The Clingman Guidelines* prepared for NASA is a good basis:
  - to communicate problem-relevant information;
  - to motivate the reader to take action.
- Problem statements are frequently rewritten to fit the communication and motivation needs of successive stages of the transfer process. Problem statements serve to:
  - Communicate to technologists in the search for solutions;

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*W.H. Clingman & Co. under contract No. NASW-1995, January 12, 1970.

- Communicate to potential users of solutions to improve problem specifications, delineate constraints on solutions, and establish the benefits;

- Invite commercial participation.

The problem statement is altered frequently as its function varies.

- Each problem is cycled rapidly through the full circle of problem → appropriate technology → benefit → solution.

  - The first cycle may be in the head of a TATeam member to see if it makes sense as a TT activity;

  - The second cycle may be a discussion among users and technologists;

  - Subsequent cycles occur as viable technical approaches are considered.

  Each cycle may change the orientation of the problem; a given technology may solve only a subset of the original problem or may have implications far beyond it. The purpose of the complete cycle (even if it is only conceptual) is to be sure that it is possible to achieve an end result before incurring significant expenditures.

4.2.3 Technology Search and Match

The broad range of potentially applicable technologies must be considered, the most promising must be investigated, and effective steps must be taken to implement promising solutions.

- Brainstorming is an approach that identifies the range of potential technical approaches.

- Database searches establish the work that NASA has done in each technical area.

- Dissemination of problem statements allows informal information channels to consider the problem.
- Literature reviews serve to identify those technologies where NASA has made or can make unique substantive contributions.
- While personal contact is most effective, the goal must be cost-effectiveness. Therefore, written communication, problem statement dissemination, professional publications and conferences, and telephone stages of problem solution, and personal contact is used when the actual technology application commences.
- Prioritizing technical approaches in unnecessary. It is natural to have starts and stops on each approach, with a final determination resulting from that approach that goes to completion first.
- Access to technologists can best be achieved by telephone search. Rarely is it necessary to make more than four telephone contacts to find the most qualified NASA technologist(s) in a given discipline. This process is greatly facilitated by recognition of the various "gatekeepers" at the centers.
- Formal procedures must be observed, both with technical and administrative management.
- Technologists self-select. If they aren't motivated, their contribution would be minimal. Opportunity for technical achievement is a significant motivation as are organizational rewards.

- In many instances we find that the technologist has some prior appreciation of the problem, many have already realized the applicability of his knowledge, and welcomes a mechanism to contribute to the problem's solution.

4.2.4 Establishment of Market Mechanism

The market mechanism is the process by which an innovation can be introduced. If an innovation is a direct replacement for a higher cost item, the the market mechanism is straightforward. Safety is a typical attribute that has no obvious market mechanism. Consider a "safer" bathtub: the builder isn't the user and doesn't perceive that a safe bathtub will enhance his marketing, therefore the manufacturer of tubs won't offer such a tub even though enough homeowners to make an attractive market segment would gladly pay the additional cost of safety (especially the elderly, parents of infants.)

- The market mechanism should be determined prior to significant development effort.
- Conventional direct mechanisms are best (lower cost, or at least cost-effectiveness).
- It is necessary to identify actors responsive to the problem solution throughout conventional marketing channels, users, retailers, wholesalers, and suppliers, or a market mechanism will be elusive.
- Aggregated markets or large single purchasers are excellent for initial marketing.

4.2.5 Applications Engineering (A/E)

It is very unusual that a technology can be transferred without adaptation. A means must be provided to assure that appropriate applications engineering occurs.

- NASA is willing in many instances to fund efforts to demonstrate technical feasibility. This practice should be continued.

- The TATeam should actively promote TU activities as attractive RTOP opportunities among technologists.
- Industry can be involved in many aspects of A/E activity:
  - under contract;
  - under license;
  - in cooperative effort.
- NASA technologists should be made available to industry.

4.2.6 Commercialization

Because there is often a threat to vested interests, and because entrenched industries may effectively discourage an important innovation, there are desirable characteristics of industrial participants in Technology Transfer.

- The product shouldn't replace a current product in the firm's line;
- The commercializing firm should understand both the technology and the market.
- Established marketing channels are preferred.
- Financial strength is important, consider not only the development cost, but also the demonstration, production and marketing investments.
- Some degree of proprietary treatment, patent or license protection is usually required to interest a manufacturer.
- Advocacy of all departments and at all levels, upper management to operating management, marketing and in R&D is important and should be encouraged by providing decision relevant information as appropriate.

4.3 Management of Technology Transfer

Perhaps the greatest variety among the current NASA TATeams is evidenced by the management approach that each uses. Making our approach explicit allows comparison. The "technology transfer" activities associated with team operation include:

- Management and other non-mission activities (reports, briefings, publicity, etc.);
- Problem Identification;
- Technology search/match;
- Market Research and Economic Evaluations;
- Management of Innovation (by project).

We estimate that economies of scale are possible in this operation.* The fixed price is estimated at roughly $100,000 to $120,000 per year, and the marginal cost per transfer project is on the order of $20,000 to $50,000. The minimum efficient scale of operation is approximately $250,000 per year. A program, with <u>continuity</u> can be expected to result in 2 to 4 completed transfers yearly.** The many disruptions, re-directions, and organizational changes that have occurred have reduced the effectiveness of any of the operating approaches that have been attempted. The cost to the TATeam of new government technical representatives, of adapting to new organizational relationships, and of changed and broadened missions has not been negligible. From this experience of yearly reductions in level of effort, accompanied by transient operating requirements we have developed a highly adaptive management style.

*See Dr. R.N. Foster's, "Organize for Technology Transfer," Harvard Business Review, Nov.-Dec., 1971, Page 118.

**This is a steady state condition. There is a delay of two to three years while the pipeline fills.

The operating hypotheses that we pursue are intended to achieve maximum leverage of the TATeam efforts. This is achieved with significant sacrifices in Time and Control.

- Schedul. and monitor transfer projects.
- Schedule and perform the contractual obligations (reporting, briefings, etc.).
- Define and structure problems as a "background" or "fill-in" activity.
- Search for technology as a "fill-in" activity as other scheduled activities permit.
- Maintain constant level of effort with over 50% commitment of each team member.
- Use NASA elements of program for technology search.
- Externalize the advocacy role to both users and commercializers.
- Determine decision criteria of key actors and develop only the informat'on required for those decisions. (This is far different from the past rigid process of state-of-art surveys, market studies, competitive market analyses, brainstorming, thorough technology searches, etc.)
- Maintain frequent contact with all actors so that communication channels remain open.
- Provide technical assistance to a broad range of potential users to assure that operation will be available when it is needed.
- As with most activities, time pressure enhances efficiency, this implies that if we attempt slightly more than can be accomplished, we will achieve more efficient operation than if we set our goals, objectives and operational plans at lower, easily achievable levels. It also implies slipped schedules and some "falling between the cracks." The answer is to maintain a dynamic resource management approach that assures that the lowest priority items are the ones slipped, and the ones that "fall between the cracks" are among those that would have been omitted in less ambitious planning.