PATT

PROJECT FOR THE ANALYSIS OF TECHNOLOGY TRANSFER

ANNUAL REPORT 1970

DENVER RESEARCH INSTITUTE | UNIVERSITY OF DENVER

PROJECT FOR THE ANALYSIS
OF
TECHNOLOGY TRANSFER

Annual Report
1970

Contract NSR 06-004-063

- Prepared for -

National Aeronautics and Space Administration

- Prepared by -

James P. Kottenstette
James E. Freeman

Industrial Economics Division
Denver Research Institute
University of Denver

July 1971

TABLE OF CONTENTS

Section		Page
I.	OVERVIEW OF 1970 PATT RESEARCH ACTIVITIES	3
	New Research Project Initiated	3
	Technology Transfer Profile Presentations	4
	Technology Transfer Model	5
	Tech Brief Modification Plan	5
	Transfer Data Bank Operations	5
	Other PATT Activities	6
II.	TECHNOLOGY TRANSFER PROFILES	9
	Initial Approach to the Problem	9
	Current Research Strategy	11
III.	A PRELIMINARY TECHNOLOGY TRANSFER MODEL	15
	Preliminary Considerations	15
	Three Basic Model Elements	19
	Concluding Comments	24
IV.	A GENERAL PLAN FOR STRENGTHENING THE TECH BRIEF PROGRAM	27
	Background Material	27
	General Plan for Modification of the Program	31
	ATTACHMENT A - CONTAMINATION CONTROL FACT SHEETS	39
	ATTACHMENT B - LUBRICATION FACT SHEETS	45
	ATTACHMENT C - PLASTICS FACT SHEETS	51

REPORT HIGHLIGHTS

- The Project for the Analysis of Technology Transfer (PATT) completed its third year at the University of Denver Research Institute in 1970. This report describes the status of research tasks undertaken or completed during the year (Section I).

- In order to develop a more comprehensive understanding of NASA-related technology transfer activities, a decision was made late in June to adopt a much broader research strategy for PATT. Implementing that decision led to the development of "technology transfer profile presentations" (Section II).

- Initial steps were taken during 1970 to formulate a conceptual model of the technology transfer process. The preliminary model that emerged was derived primarily from analyses of specific NASA technology transfer programs (Section III).

- PATT personnel have developed an operational plan for strengthening the NASA Tech Brief Program (Section IV).

SECTION I. OVERVIEW OF 1970 PATT RESEARCH ACTIVITIES

The Project for the Analysis of Technology Transfer (PATT) completed its third year at the University of Denver Research Institute (DRI) in 1970. Under contract to the National Aeronautics and Space Administration (NASA), PATT initiated or completed several major studies aimed at increasing what is known about the ways that technologies generated for government programs are acquired and applied by persons in nonaerospace sectors of the American economy. The purposes of this section are to provide a progress report on the nature and status of the research tasks and to indicate in what directions the project is moving as it enters its fourth year.

New Research Project Initiated

Early in 1970, a new technology transfer research project was undertaken at DRI which has been conducted in parallel with PATT. The new project, which grew out of and expanded upon basic technology transfer studies conducted previously, was designed to identify and assess how NASA-related work has contributed to major developments in specific fields of technology. More specifically, the project involved four principal tasks:

- Identifying major developments over the last five to ten years in selected fields of technology by means of interviews with experts in those fields.
- Determining what influence, if any, NASA work had on contributing to those major developments.
- Identifying the ways in which the NASA work was made known outside of the space agency.
- Determining the impacts of the NASA contributions.

The need for conducting a study of this sort had come into focus quite clearly during the first two years of PATT research. The scope and methodology of the new study, however, were much different from the purpose and approach of the basic project out of which it grew. As such, it appeared quite important to treat this new investigation as a relatively autonomous research effort. To this end, separate research staffs, budgets, and reporting mechanisms were organized. Interested readers are advised to refer to relevant NASA and DRI publications flowing from PATT's sister project, or "PATT II," for additional information in this area. A final report of the results of PATT II research will be prepared in the winter of 1971-72.

Technology Transfer Profile Presentations

Most PATT research prior to June 1970 dealt with identifying and assessing private sector uses of the Technical Support Packages (TSP's) associated with NASA Tech Briefs. The primary reason for this emphasis was that this particular experimental technical communication program provided the most readily traceable and validated source of technology transfer examples. The case study method was used as the principal technique for documenting specific technology transfer activities.

A decision was made late in June to adopt a much broader research strategy, one which changed both the survey and reporting methods used until that time. The new PATT approach involved the development of so-called "Technology Transfer Profile" presentations. The presentations represented an attempt to be responsive to two requirements emerging from previous PATT research. The first requirement was to find some way of integrating the individual technology transfer cases into a more comprehensive level of analysis. The second long-felt need to which the presentations were to be responsive was the idea of extending the data collection effort beyond the Tech Brief program to include other experimental information dissemination programs. With these requirements in view, PATT undertook the development of three technology transfer profile presentations in 1970.

For the fields of plastics, lubrication and contamination control, each presentation:

- Examined overall technical and economic trends in these fields;

- Identified significant NASA contributions to the field;

- Described the communications media, particularly publications (e.g., Tech Briefs, Contractor Reports), that have been used to disseminate information about NASA contributions; and

- Reviewed in profile form a number of different ways that disseminated technologies are being used outside of the space program.

A more detailed discussion of the events which led up to the development of the technology transfer profile presentations is presented in Section II of this report. For illustrative purposes, fact sheets summarizing the contents of the three profile presentations prepared in 1970 are presented in Attachments A, B, and C. These and other transfer profiles are scheduled for publication in 1971.

Technology Transfer Model

Initial steps were taken during 1970 to formulate a conceptual model of the technology transfer process. The model, derived primarily from data collected through PATT research activities, was to be useful not only in identifying and describing fundamental characteristics of the transfer process, but also in pinpointing areas where current transfer programs might be augmented. Section III of this report presents the general technology transfer model developed in this phase of PATT research.

Tech Brief Program Modification Plan

By mid-1970, PATT personnel had essentially completed a substantial analysis of Tech Brief program operations. The primary purpose of the analysis was to discover ways in which this particular experimental program might be made more effective. An operational plan for strengthening the Tech Brief program resulted. Details of that plan are described in Section IV.

Transfer Data Bank Operations

One of the major PATT responsibilities during the year was the maintenance of a data bank containing detailed information on nonaerospace uses of technologies developed initially for space program applications. The data bank, which was organized at the inception of PATT, contains information related mostly to industrial uses of Technical Support Packages (TSP's) associated with NASA Tech Briefs. During 1970, PATT received and processed 15,607 requests for TSP's which had been sent to NASA. This increment brought the total number of requests in the data bank to 47,210. Additional facts concerning TSP uses, derived from over 10,000 mail questionnaires and 1,000 telephone interviews, also were entered into the data bank.

While the data bank was used primarily to monitor Tech Brief program operations, it also served another important purpose during

1970. It was expanded to include information on the technical and economic impacts of the technology transfer activities resulting from the May 1970 "NASA Conference on Materials for Improved Fire Safety." That impact information subsequently was used in preparing a technology transfer profile presentation dealing with transfers of NASA contributions to the fire safety field (to be published in 1971).

Other PATT Activities

Conference impact analysis. In May 1970, the "NASA Conference on Materials for Improved Fire Safety" was held at the Manned Spacecraft Center in Houston, Texas. Approximately 500 industrial representatives and NASA personnel attended the conference to discuss fire safety technology developed originally for use in the space program. As noted above, a survey of the conferees was conducted to determine the technical and economic impacts of the technology transfer activities associated with the conference. In October, questionnaires were mailed to 182 non-NASA engineers and scientists who attended the conference. The six month time lag was considered sufficient for participants to make initial decisions concerning their use of the technology presented. Sixty-two percent of the persons contacted returned questionnaires. Telephone interviews then were conducted with respondents who indicated on questionnaires that they had made substantial progress in their attempts to apply fire safety technology described at the conference. The results of this survey will be presented in a technology transfer profile presentation to be published in 1971.

Technology Transfer Example Files. The files are being developed primarily to supplement the technology transfer profiles described above; however, it also is the objective of the PATT program to provide interested persons with ready access to additional information on NASA-related technology transfer activities. By the end of 1970, 346 individual files--involving 634 transfer cases associated with NASA-developed technologies--had been established, 44 of which were created during the last two quarters of the year. A total of 79 files containing comprehensive summaries for 188 transfer cases had been prepared. Of the 188 cases, 106 were developed in 1970; 53 which had been developed earlier were revised to include more up-to-date information. For a detailed discussion of the files and the related information retrieval system, see Section III of PATT Quarterly Report #1-1970.

Technology transfer library and bibliography. Holdings in the PATT library increased to 2,028 titles by the end of the year. During the same period, the DRI "Technology Transfer Bibliography" was revised and updated. It was scheduled for republication in 1971 as a NASA Contractor Report. *

NASA-related news clippings analysis. To augment PATT sources of leads to technology transfer activities, news clippings taken from magazines and newspapers published in the United States were reviewed regularly throughout the year. The clippings, compiled for the space agency by a professional clipping service, included all news items which referenced space program activities. The majority of the clippings dealt with NASA contracts being awarded, current events (e.g., moon landings), and newly-developed technology. During 1970, PATT processed 1,913 clippings taken from 521 different magazines and newspapers. In screening the clippings, PATT personnel were particularly concerned with identifying items that indicated some kind of technology transfer activity in progress. Such items subsequently were used to generate several new transfer cases for inclusion in the technology transfer profile presentations.

---

* Now available as NASA Contractor Report CR-1724.

SECTION II. TECHNOLOGY TRANSFER PROFILES

The Project for the Analysis of Technology Transfer (PATT) was established at the University of Denver Research Institute in November 1967, under contract with the National Aeronautics and Space Administration, to undertake an inquiry into the ways technologies generated for use in the American space program are disseminated and utilized in other sectors of the economy. The following brief description of PATT activities focuses on some of the factors leading up to one recent major change in the strategy used to meet research objectives.

Initial Approach to the Problem

When PATT began, principal attention was devoted to arriving at some specific understanding of the ways technologies generated for use in the American space program are adapted for use in other sectors of the economy. The need for systematically investigating particular instances of technology transfer was justified on two grounds. Previous attempts to explain the transfer process were considered inadequate in terms of their empirical underpinnings: often too few instances of transfer were available to clarify, in any quantitative way, the extent to which different kinds of transfer phenomena occur or fail to occur. In addition, and perhaps more importantly, it appeared desirable to generate information indicating the extent to which private sector attempts to use technologies developed originally for space program purposes are producing tangible benefits for the rest of society.

PATT was organized primarily to identify particular instances of technology transfer associated with the NASA Tech Brief program, since this was the most readily traceable and validated source of transferable technology. A Tech Brief is used to announce the occurrence of a technical innovation growing out of NASA research and development activities. It is a one- or two-page bulletin concisely describing an innovation and explaining its basic concepts and principles. The reader may obtain more information about the innovation, in the form of a Technical Support Package (TSP), by writing to the address given on the Tech Brief. Since the space agency kept records of the names and addresses of persons requesting TSP's, an obvious and straightforward link could be established with persons showing an interest in technologies developed for use in the space program.

By June 30, 1970, NASA had issued over 3,500 Tech Briefs. PATT personnel, by the same date, had processed nearly 40,000 requests for TSP's. Questionnaires had been mailed to approximately two-fifths of those requesters, of whom roughly 9,600 had returned questionnaires. Approximately 750 telephone interviews also had been conducted with questionnaire respondents who indicated making substantial progress in adapting the technologies for their private use. The interviews served the purpose of pinpointing not only what difficulties had been encountered to date in attempts to transfer the technologies, but also of roughly estimating in some cases to what extent financial and other nontechnical benefits had resulted.

Among other things, PATT research by mid-1970 confirmed the following:

- Technology transfer can usefully be described as occurring in four stages. Stage one transfers involve the recognition of opportunity and searches for additional information to determine the relevance of a technology to organizational activities. Stage two transfers include laboratory verifications of materials or techniques. Stage three transfer behavior involves either market testing of prototypes or actual use of new technology in operational activities. Stage four transfers include those situations in which adopters are marketing technical products or processes developed originally either by or for NASA. Regardless of the type of technology involved, over three-fourths of the TSP users contacted six months after they requested the documents could be grouped into stage one.

- Technical innovations developed by or for NASA rarely transfer "intact." In most cases, only certain elements of an original technical configuration survive the transfer process. While a few cases of intact transfer involving the use of TSP's were identified, most often, as transfer activities progressed through the four stages, only certain technical elements of an innovation were retained.

- Many examples of transfer are stage-limited. The largest number of TSP users indicated acquiring the documents primarily to keep up-to-date with developments in their fields of interest; their reason for acquiring the documents literally was satisfied in in the first transfer stage. Other TSP users indicated they were in a type of "holding action" situation: they understood the technology, had tested and favorably evaluated it, and intended to proceed with adaptation activities after financial, political, or other kinds of transfer barriers were overcome by perceived need or benefit.

- Annual cost savings of at least $3 to $4 million are estimated to have accrued to TSP users during the last two years. This estimate is conservative because, among other things, it does not include the unknown benefits associated with the use of Tech Briefs when TSP's were not requested or the monetary gains resulting from sales increases.

The examples of technology transfer identified in the first 30 months of PATT activity thus were useful in generating a frame of reference for describing NASA's use of Tech Briefs to initiate technology transfer activities. That frame of reference not only mirrored, but also expanded in some fundamental ways, models of the technology transfer process developed previously by other investigators. Since the Tech Briefs report a wide array of technical innovations, and in view of the fact that a monthly average of more than 1,000 individuals request TSP's, the transfer examples cited in Congressional hearings and elsewhere tended to reflect society-wide attempts to utilize technologies developed originally for space program applications.

Current Research Strategy

PATT research thus generated a considerable number of useful results concerning the operation of the Tech Brief program. It became quite clear late in 1969, however, that other mechanisms used for initiating and facilitating technology transfer also should be examined. For several months, PATT personnel had been reviewing thousands of magazine and newspaper clippings that described a variety of ways people outside of the space program had learned about and were using technologies developed for or by NASA. In addition, late in 1969 PATT began processing approximately 200 transfer example files received from NASA's Technology Utilization Office (TUO). Those files, which TUO had compiled over a period of several years, contained a number of transfer examples involving the operation of transfer mechanisms other than Tech Briefs. Contractor commercialization activities, participation by NASA in-house and contractor personnel in technical conferences, Biomedical Applications Team and Regional Dissemination Center activities, and trade magazine articles describing technology developed for the space program were among the types of transfer mechanisms involved. The fact that such mechanisms operate on a substantial scale in the technology transfer process was, of course, well known before 1970. PATT research, however, did not focus on identifying specific instances of transfer through these mechanisms until mid-1970, primarily because of the emphasis on understanding the operation of the Tech Brief program.

Several project planning conferences were held in the spring of 1970 with Technology Utilization Office personnel and other persons knowledgeable in the field of technology transfer to determine how PATT operations should be reshaped to reflect the improved understanding of the technology transfer process which had evolved. A decision was made in July 1970 to develop a series of "technology transfer profiles." Each profile presentation would focus on a specific field of technology (e.g., plastics, contamination control, fire safety). For each technical field, the profile presentation would examine overall trends in the field; identify NASA contributions to the field by using appropriate technical and economic impact data; describe the ways such contributions have been communicated to persons outside of the space program; and finally, review the ways in which the communicated technologies are being utilized in nonaerospace sectors of the American economy. The following resources were to be used in developing the profile presentations:

- Information concerning NASA contributions should be derived primarily from related NASA documents and personal interviews with in-house and contractor personnel involved in the development of the technical contributions.

- Data on the operation of different communication mechanisms should be derived from personal interviews with NASA in-house and contractor personnel, a review of NASA-funded formal transfer programs (e.g., Technology Application Teams, Regional Dissemination Centers, Tech Briefs), and a review of magazine and newspaper clippings.

- Instances of technology transfer activities associated with NASA contributions to the field should include those cases generated in the course of PATT research on uses made of Technical Support Packages, as well as others identified in the examination of different transfer mechanisms.

Two fundamental considerations, one pragmatic and another theoretical, led to the decision to develop technology transfer profile presentations of the sort described above. For some time, NASA descriptions of technology transfer activities focused on individual, and usually isolated, cases involving secondary applications of technology developed for the space program. This practice--citing instance after instance of transfer activity--was found wanting in several respects, particularly in terms of an audience's ability to understand what the transfer examples meant in some broader context. The technology transfer profiles, at least in concept, presented an alternate and hopefully more effective approach for dealing with the mode-of-presentation problem. At the same time, the development of a meaningful model of the technology transfer process required that the investigation of transfer activities be expanded systematically beyond the framework of the Tech Brief program.

The newly-integrated PATT program proceeded with the development of technology transfer profiles in July 1970. During the remaining months of the year, profile presentations were developed for the fields of plastics, lubrication, and contamination control. For illustrative purposes, fact sheets summarizing the contents of these presentations are presented in Attachments A, B and C. These and other transfer profiles are scheduled for publication in 1971.

SECTION III. A PRELIMINARY TECHNOLOGY TRANSFER MODEL

The Project for the Analysis of Technology Transfer, from its inception late in 1967, has been operated to achieve both theoretical and practical objectives. One of its principal activities has been to accumulate accurate and comprehensive data related to the acquisition, adaptation, and use by nonaerospace firms of technology developed initially for use in America's space program. At the same time, contacts with others involved in technology transfer research in other parts of the country have been established and maintained for the purpose of exchanging ideas and discussing emergent problems. Not infrequently, attempts to analyze and interpret the data collected through PATT field research benefitted considerably from the insights developed elsewhere. There were a number of occasions, however, when the interpretation of field data required the generation of new concepts. This is not surprising since the particular set of transfer activities under PATT examination differed from the special interests of other transfer analysts.

It became quite clear early in 1970 that many previously developed technology transfer theories or models simply were not useful in examining NASA-related transfer activities. While most of those models are logically consistent, clear, and integrated, they often are not relevant to space agency transfer experiences. And in cases where relevance can be demonstrated, the language used often is so specialized that only trained analysts can use the models comfortably.

In November 1970, NASA's Office of Industry Affairs and Technology Utilization requested that PATT deal directly with the need for an understandable and relevant technology transfer model. This section presents an initial progress report on the results achieved by the end of 1970 in formulating such a model.

Preliminary Considerations

Technology transfer may be described broadly as the process through which technical capability generated in the public sector of a socio-economic system becomes widely adopted in the private sector of that system. For present purposes, the transfer process is defined to include (1) the National Aeronautics and Space Administration (NASA) as the generating sector and (2) private industry in its many manifestations as the adopting sector.* This approach is somewhat narrow, but its purpose is to clarify several problems in technology transfer from the vantage point of practical experience: experience gained by NASA through the operation of its Office of Industry Affairs and Technology Utilization and experience gained by the University of Denver through the Project for the Analysis of Technology Transfer.

Among the several areas of concern in technology transfer research, one of the most important involves the selection and definition of concepts used in describing the transfer process. Six concepts are singled out here for special attention: sectors, transfer completion, transfer integrity, technology, technology diffusion and diffusion of innovation. Different uses of these terms often have been responsible for masking the occurrence of transfer or promoting unrealistic measures of benefits associated with transfer activities.

Sectors. The concept of technology moving between sectors is idealized: generating and adopting sectors do not exist in isolation. There are different types of relationships between these sectors which should be recognized. As a generator of technology, NASA is actually comprised of its in-house capability, found in the respective research centers, and its contractor capability, found in industries and organizations that extend far beyond the "aerospace" complex. Thus NASA-generated technology often originates in organizations identified with the private sector. For present purposes, such technology is treated as being publicly held and available for use in the private sector.

Other important transfer relationships linking the public and private sectors occur when (a) NASA requirements create a "first market" for technology, one that is largely dormant in the private sector (e.g., the growth of the contamination control industry) and (b) NASA-sponsored research creates new capabilities in specific organizations operating in both the generating and in the adopting sectors (e.g., TRW, General Electric).

Transfer Completion. Another area of confusion in technology transfer research arises in attempts to determine when transfer is complete. Technology transfer is a process usually having two distinct

---

* It should be noted that the transfer activities of the NASA Technology Utilization Office are not confined to the private sector; this focus was chosen deliberately to limit the scope of the model.

phases: adaptation and diffusion. These phases are quite different from each other in terms of what is being done and who is doing it. Adaptation occurs when someone in the private sector recognizes the value of an innovation and adapts the innovation to the needs of that sector. In a practical sense, a company completes the adaptation phase when it introduces the transformed innovation to the industry or markets in which it participates. With this introduction or emergence of the innovation in the private sector, the diffusion phase of transfer begins. Diffusion proceeds as other organizations in the private sector also adopt the transformed innovation.

This distinction between adaptation and diffusion is crucial to the description and understanding of the transfer process because examples of transfer often are cited while the adaptation phase is still predominant. Since the diffusion phase is controlled by social, economic, and performance factors usually outside the influence of the generating sector, diffusion may or may not occur. Successful adaptation without subsequent diffusion is understandably seen as a transfer failure since widespread use is not achieved. This partial transfer situation, which occurs frequently, is mistakenly interpreted by some as a negative reflection on the transfer efforts of NASA. The real issue, however, is that adapters can and do misunderstand or miscalculate the needs of prospective adopter groups. In other words, adapters' judgements sometimes are not timely, economical or technically beneficial.

Transfer integrity. The concept of transfer integrity addresses the following question: "What actually transfers?" Rapid and intact transfer of an innovation is possible only when the need for adaptation is minimal. Such transfers occur only when an original requirement and potential application in the generating sector has a counterpart requirement and application in the private sector. Close matches between NASA mission requirements and private sector requirements occur rarely. Since the requirements usually differ, the emergent innovations also differ. In general, therefore, an innovation does not transfer intact; instead, the technical elements underlying an innovation transfer. During adaptation, an innovation is broken down into its component elements; the components then are reassembled, usually in combination with other technical components, in order to meet perceived needs in private sector applications. A technical "chain" is forged, therefore, through adaptation in which the original technical elements form some of the links. It is this new chain that usually undergoes diffusion and not the original innovation. There has been a strong tendency to measure the effectiveness of NASA transfer efforts using evidence from rapid and intact transfer examples. Unless the reason for the rarity of such occurrences is appreciated, the adaptation effectiveness of transfer efforts cannot be understood.

Technology. While it is important to ask what is transferred, it is equally appropriate to ask what is generated. A principle, a process, an embodiment, a technique, a concept, a study result, and even a complete technical field have often been discussed as though each were part of a homogenous mass called "technology." Such a definition may be useful when generalities are developed, but in terms of an ongoing program to facilitate transfer, certain refinements are necessary. In each instance when NASA has generated technology, something innovative occurred relative to the existing state-of-the-art. If questions of importance and complexity are ignored for the moment, it should be clear that a technical contribution which redefines the state-of-the-art (e.g., laser, transistor) in a particular field must have a very different adaptation process compared to the adaptation process required for a technical contribution which incrementally advances the state-of-the-art only (e.g., improved nondestructive testing techniques). The essential difference in the adaptation process concerns the type of resources and facilities that the adopter must bring to bear during the various stages of the adaptation phase of transfer. This relationship between the technical contribution and the requirements for adaptation is completely hidden when the word technology is used loosely.

Contributions to any technical field can be classified roughly in two categories: principles and practices. These categories are not mutually exclusive. Principles include concepts and basic research results having primarily a professional or disciplinary appeal. Practices include techniques or methods having primarily an operational appeal. When principles transfer, the adaptation phase of transfer usually is not clearly visible: often a single individual will perform the adaptation work utilizing few organizational resources. Transferred principles are recognized mainly in the diffusion phase, embodied in emerging private sector innovations. By contrast, practices tend to have more easily identifiable adaptation characteristics because of the large scale involvement of organizational resources. To date, it has been easier to identify the effectiveness of NASA transfer efforts in cases involving practices rather than principles.

Technology diffusion. It is useful to make a distinction between technology transfer and technology diffusion. Technology transfer may be viewed as one type of intersectoral movement of technology, the kind associated with the implementation of public policy. Technology diffusion occurs outside the influence of such public policy. Transfer usually involves the operation of publicly funded and operated technical information dissemination programs. Diffusion, by contrast, includes the variety of purposive and accidental types of technical information exchange that occur daily both in the private and public sectors through efforts of the trade press, supplier-customer relationships, professional society activities, informal person-to-person contacts, etc. Commonly, however, the phrase technology transfer has been used to refer to both types of activities. It is used as a global concept to encompass any transfer of a technology from the environment in which it was generated for original use to another, and usually unintended, secondary environment for subsequent application. Technology transfer is restricted here to the intersectoral movement of technology resulting from implementation of public policy.

Diffusion of innovation. The technology transfer process cannot be considered complete until an innovation is adopted widely in a sector which did not generate the technology. The patterns of innovation adoption throughout a second sector is the special concern of diffusion theory. In Everett Rogers' classic work, Diffusion of Innovations, the origin and adaptations of different technologies are appropriately ignored: innovations appear within the adopting sector, and then diffuse in certain characteristic ways. The movement of different technologies between sectors, however, usually involves an adaptation phase, and it is this phase together with the subsequent adoption phase that comprises research in technology transfer.

Three Basic Model Elements

To work successfully with the imposing variety of interrelated issues in technology transfer requires the use of a conceptual framework that realistically encompasses basic dimensions of transfer processes and systematically sets them within the broader socio-economic context in which they occur. In the preliminary considerations portion of this section, the context of transfer was described. That description drew heavily from state-of-the-art knowledge in the field of technology transfer. The purpose in this subsection is to identify and define three basic dimensions of technology transfer which have become centrally important in recent PATT examinations of NASA transfer activities. The three dimensions are known as technical contributions, transfer stages, and technical communications.

Technical contributions. Three different types of contributions can be identified which advance the state-of-the-art in a technical field. They are described in Figure 1.

Type of Technical Contribution	Description	Examples From NASA Files
I	Redefines the state-of-the-art; tends toward principles rather than practice	Inventing HYSTL (a new high temperature polymeric material)
II	Makes incremental advance in the state-of-the-art; tends to balance principles and practice	Improving highway grooving techniques (although known about previously, now substantially refined)
III	Consolidates the state-of-the-art; tends toward practice rather than principles	Compiling contamination control principles (although contamination control procedures were within the state-of-the-art, NASA was the first to present an integrated statement of practices)

Figure 1. Descriptions and Examples of Three Different Types of Contributions to a Technical Field.

Contributions have inherent characteristics of complexity and importance. The amount of resources and facilities required for adaptation is related to complexity. Importance is related to the adapter's perception of benefits And finally, the type of contribution, in terms of the state-of-the-art, defines the kinds of resources and facilities required.

The purpose of highlighting this relationship is to explain why it is so important to study an innovation and determine its implications for the adaptation process. For instance, the more complex an innovation, the greater the need for laboratory space, equipment, specialists, and capital in order to adapt. There are fewer potential adapters as a consequence. The more important the innovation in terms of the state-of-the-art, the greater the potential for multiple sector adapters because benefit is more readily perceived. The type of contribution thus equates with the scale of the adaptation effort: while Type I implies extensive adaptation, Type III suggests minimum adaptation effort.

One consequence of this conceptualization that should be emphasized is that there are many ways to make a transfer program more effective, ignoring cost considerations. These include, but are not limited to, developing more adequate methods for identifying potential users, and intervening in the adaptation process by providing some or all of the resources and facilities required. Either of these approaches can be operationalized; however, they may entail substantial political considerations as well as high program cost.

Transfer stages. Any specific transfer of a technology may be described as a series of related activities that progress through four different stages. Figure 2 illustrates this "transfer stages" concept.

1	2	3	4
Initial Awareness and Review	Engineering Evaluation	In-House Use or Market Testing	Full-Scale Marketing

Figure 2. Four Technology Transfer Stages.

Stage one is characterized by an initial awareness on the part of a potential innovator working in the private sector of the existence of a new technology generated for space program purposes. During this transfer stage, the potential innovator may search for additional information concerning the technology in order to determine its relevance to his interests. Stage two involves specific attempts to adapt the new technology to fit the requirements of the private sector. These attempts usually involve laboratory tests and evaluations. A transfer experience progresses into stage three under one of two conditions: either an industrial firm begins to use the adapted technology in its own operational (e.g., processing) activities, or a firm begins to market test prototype versions of the adapted innovation. Only those firms with plans to market a technology ever progress into the fourth transfer stage. In that stage, a commercial firm promotes the diffusion of an adapted technology in the private sector.

Throughout this description of transfer stages, an important distinction is made between two kinds of transfer activities: adaptation and adoption. Adaptation activities, in which a technology generated in the public sector is shaped to fit the requirements of a private sector firm spans across the first three transfer stages. While the adaptation work usually is conducted by a private sector (i.e., commercial or industrial) firm, the important point to note is that the technology originating in the public sector cannot emerge as a force affecting diffusion throughout the second sector until adaptation is complete. With the completion of adaptation activities, diffusion of the adapted innovation begins in the private sector--usually in the fourth transfer stage. For example, an innovation in clothing designed for lunar exploration must undergo a process of adaptation before it can be utilized by a textile manufacturer; following adaptation, social and economic constraints are operative that affect the diffusion of the transformed clothing innovation into different textile markets.

Technical communications. The issue of how potential adopters in the private sector come to know about and evaluate technology generated under public sector funding has remained implicit up to this point. As a dimension of technology transfer programs, however, this issue is of fundamental importance. Its basic role in transfer activities is most obvious in the foregoing description of the first transfer stage: without technical communication, adaptation and diffusion processes could never get underway. Similarly, technical communications can facilitate the movement of technology through the various transfer stages by making relevant additional information available to private sector organizations.

It is useful to identify three different groupings of communications media that technology transfer programs employ to disseminate technical information. The three groupings--professional-technical, trade, and mass communications media--are described in Figure 3. They tend to differ from each other in terms of their specific audiences and the information needs and media use preferences of those audiences.

Media Grouping	Usual Audiences	Audience Media Preferences	Dimensions of Technology Usually Treated
Professional-Technical	Research-oriented scientists and engineers	Interpersonal contacts, conferences, journals, technical reports, textbooks	Principles rather than practices in considerable depth
Trade	Commercially-oriented engineers, technical managers and salesmen	Interpersonal contacts, trade shows, industrial magazines, vendor catalogs	Technical practices; economic and marketing considerations in considerable depth
Mass	Laymen	Science fairs, popular magazines and newspapers, papers, television, radio	Social and economic significance of new technologies

Figure 3. Descriptions of Three Communications Media Groupings Through Which Audiences in the Private Sector Often Come to Know and Interpret Technologies Generated in the Public Sector.

Formal technology transfer programs, such as the one operated by NASA, are designed principally to insure that information concerning technical developments resulting from government-sponsored research and development is made available to the maximum extent possible for the nation's benefit. To achieve this objective requires, in NASA's case at least, the identification, documentation, and dissemination of a broad spectrum of technical information concerning innovation in the public sector. Technology dissemination efforts by the government have relied both upon the use of existing technical communications media (e.g., conferences, industrial magazines) and upon the development of new media (e.g., NASA Tech Briefs, Technology Utilization Surveys).

The information presented in Figure 3 identifies two important facts which must be considered in evaluating the communications effectiveness of technology dissemination programs. The first is that different audiences prefer to employ certain media in obtaining information on emergent technology; the second is that these audiences are searching for quite different information when they use particular media. Some of the communications media, such as NASA Special Publications, match the media preferences and specific information needs of different audiences quite closely. Other general announcement media, such as NASA Tech Briefs, satisfy the most general information needs of a large number of various audiences; at the same time, however, they necessarily ignore the media preferences and specific information needs of particular audiences. When, as sometimes happens, the information disseminated through general announcement media is repackaged and republished in more traditional media, the dissemination effort more closely satisfies the information requirements and media preferences of potential private sector users of the information.

At the heart of this conceptualization is a distinction between dissemination and communication: both are necessary in order to achieve planned technology transfer. Dissemination is that element of the transfer process that can be planned. Communication, however, usually cannot be planned; furthermore, it occurs only in conjunction with user participation and as a consequence of adequate dissemination activities.

Concluding Comments

In the preliminary considerations portion of this section, a distinction was drawn between the occurrence of transfer between closely related sectors and the occurrence of transfer between widely separated sectors. A common example of transfer between closely related sectors is encountered when NASA contractors develop new technologies. In cases where contractors have rights to inventions, they are free to develop private sector applications. Such occurrences of "transfer" are characterized by the fact that the resource and facilities requirements for completion of adaptation have been favorably influenced by the concentration of professional activity leading to the innovation. In other words, one adapter is in an advanced stage of adaptation when the innovation is announced. In such cases, an innovation is moved more rapidly into the diffusion stage of transfer.

Another special case of transfer arises when contractors generate innovations in order to meet NASA procurement specifications. By creating a "first market" condition for these contractors, the space agency stimulates internal contractor activity that improves products or processes on a selected basis. Innovations of this type may diffuse rapidly because adaptation is complete when NASA purchases and applies the technology.

Finally, it should be noted that the generators of technology (particularly government generators) ordinarily cannot directly affect the rate of transfer beyond the first transfer stage unless an agent or agency is developed to intervene in the second and third transfer stages. The adaptation process is energized and sustained only when perceived benefits are viewed as sufficiently high; the stronger the perceived benefits, the more likely needed organizational resources and facilities will be committed to the transfer effort. While technical considerations tend to be more significant in the first two transfer stages, social and economic factors become far more important as transfer activities proceed into the third and fourth transfer stages.

SECTION IV. A GENERAL PLAN FOR STRENGTHENING THE TECH BRIEF PROGRAM

One of the major objectives of the NASA Technology Utilization Office involves "improving means for dissemination of the new technology resulting from NASA aerospace activities to scientific and engineering communities, other Government agencies, and interested public and private organizations" (NASA NMI 1134.8, June 1, 1966). During the reporting period, PATT personnel completed a substantial analysis of the Tech Brief program. Part of that analysis was aimed at identifying ways in which the program could be made more effective. This section presents an operational plan for strengthening the Tech Brief-Technical Support Package (TSP) program. Preceding the plan is a summary of background material which provides a basis for the proposed changes.

The background material was generated in four different aspects of research conducted on the Project for the Analysis of Technology Transfer: (1) TSP request letters sent to NASA; (2) questionnaires returned by persons ordering TSP's; (3) interviews with certain questionnair respondents whose answers suggested the desirability of further contact; and (4) the technology announced in Tech Briefs.

The common denominator for each of these aspects was the user's request for TSP's. The point to be emphasized is that facilitating technology transfer, in this context, reduces to a problem of inducing potential users to order TSP's. Inducement can be thought of as a marketing strategy, an operational plan.

I. BACKGROUND MATERIAL

Characteristics Based on TSP Requests and Returned Questionnaires

Non-NASA Users of Space Technology

- Of all requesters of Technical Support Packages, 55 percent worked in firms employing fewer than 500 employees.

- Persons in manufacturing firms accounted for 65 percent of all TSP requests. Within the manufacturing category, electrical and non-electrical machinery industries represented nearly one-half of all TSP requests. Few TSP requests were received from the textiles and material, furniture and wood products, paper, rubber and plastics, or the food products industries.

- Engineers and managers accounted for 75 percent of all TSP requests. Scientists represented 10 percent of all requesters, and librarians 3 percent.

- Over 80 percent of TSP requesters reported earning $12,500 or more per year.

- In terms of formal education completed, 45 percent of the requesters held bachelor's degrees, 30 percent master's degrees, and 11 percent Ph.D.'s.

The Uses Made of Space Technology

- Two-thirds of all TSP requesters reported using TSP's to keep up-to-date with developments in their technical fields.

- Only one out of eight TSP requesters reported no benefits from TSP usage. Individuals within smaller firms were twice as likely to report no benefits as those in larger firms.

- One-quarter of all TSP requesters reported using TSP's to help solve specific technical problems.

The Nature of the Technology Found Useful

- Twenty-eight percent of the documented transfers involved the development of new products or materials; 10 percent included product improvement. Twenty-one percent of the transfers represented new applications for existing products or materials; 16 percent had to do with new processes; 25 percent fell in the miscellaneous category.

- Another way of looking at the nature of the technology is to note that 75 percent of the transfers involved electrical and materials technology; by contrast, TSP's in the physical sciences category were consistently low in generating documented transfers.

User Evaluation of TSP's

- User evaluations of TSP's related to the benefits received. When no benefits resulted, evaluations tended to be low. When benefits were of an economic nature (primarily for problem solving), users gave TSP's a favorable, or above average, rating 9 times out of 10.

- There were noticeable differences in rating by technical categories. Life sciences and materials TSP's rated consistently high, while physical sciences and computer program TSP's were judged consistently low.

- Tech Briefs originating from Marshall generated over one-half of all TSP requests and rated highest in quality.

Characteristics of Transfer Case Studies

A strong association was noted between the number of TSP requests for a given Tech Brief and the number of documented transfers which that Tech Brief generated. Through 1968, 10 percent of the Tech Briefs had identifiable transfers; they accounted for approximately two-thirds of all TSP requests. Other characteristics of these Tech Briefs were identified:

- The Tech Briefs can be stratified into two main classes based on content: general (i.e., those dealing with problem classes) and specific (i.e., those dealing with particular hardware or techniques). The proportion of general Tech Briefs has increased each year (from 3 percent in 1965 to 46 percent in 1968). general Tech Briefs provided a significantly higher proportion of the transfer examples.

- Handbooks and manuals (part of the general Tech Brief classification) represent less than 1 percent of the Tech Briefs distributed, but generated approximately 25 percent of all TSP requests and 25 percent of the transfer cases studied.

- Within the specific content classification, Tech Briefs citing patent action or license requirements predominated (approximately 2 to 1).

Characteristics of Technologies Announced in Tech Briefs

- Certain Tech Briefs are not likely to generate many TSP requests because constraints of various types are operative, including:

  (1) highly specialized technology (e.g., basic research techniques);

  (2) highly specialized user audience or environmental extremes (e.g., turbine manufacturers);

  (3) high capital investment (e.g., purchasing costly machinery); and

  (4) cost effectiveness (or market potential) limitations on incremental technical improvements.

- The reflection of a unique technical consideration in the Tech Brief is associated with higher request frequency.

- The more mature the technology, the more likely the TSP will have a high request frequency. Conversely, Tech Briefs that report experimental or conceptual technology do not tend to generate large numbers of requests.

- Announcing the availability of TSP's in professional or trade publications appears to be associated strongly with high TSP request frequency. Tech Briefs having secondary publication have twice the probability of high request frequency for TSP's as compared with Tech Briefs not so publicized.

- The "Selected Technical Advances" series of the Small Business Administration has exercised a strong positive influence upon TSP requests; republication of Tech Briefs in that series has correlated strongly with high request frequency.

The background information presented in this section can be unified through the following observations.

The Tech Brief program, as developed, serves its users in two major ways: problem solving and current awareness. The rapid, intact adoption of announced technologies associated with problem solving should be viewed as the exceptional rather than the usual mode of transfer. Why? Primarily because the probability is quite low that relevant technology reported in TSP's will reach a potential user at the specific time he is working on a particular problem or in the exact form required. In addition, users' strong identification of a current awareness value suggests that the major impact of the program lies in slow, incomplete adaptations. In all transfer cases technical information is adapted to specific uses; embodied forms of the technology, however, do not necessarily transfer intact.

II. GENERAL PLAN FOR MODIFICATION OF THE PROGRAM

Statement of Objectives

The NASA Tech Brief program has three principal objectives:

(1) The most important program objective is to systematically identify, evaluate, and document certain NASA contributions to the store of knowledge.

(2) The next most important is to provide "awareness" resources to the technical community.

(3) The least important objective is to provide resources for rapid technical problem solving.

The point of emphasis here is that designing the system to maximize payoff for objective #3 is consistent with maximizing payoff for objectives #1 and #2. These objectives will be accomplished if the Tech Brief program is established as a basic technical resource in the industrial community.

Technology announced through the present program can usefully be divided into two classifications: general and specific. The general classification is distinguished by its relevance to broad problem areas: it usually is reported in manuals, handbooks, and compendia. The specific classification is recognized by the singular or discrete nature of its potential application: it is often embodied in devices, techniques, and incremental improvements.

For present purposes, assume that general Tech Briefs would be distributed to higher-level managers in industrial firms as is done at the present time, while specific Tech Briefs would be sent to individuals identified through professional associations. It may be expected that company officers or department heads will route general Tech Briefs to particular people because they can recognize the relevance of general information to in-house research activities. Individual professionals operate at the level where specific technology can be rapidly adapted. The strategy suggested here would be to reach such specialists with specific technology, comprised of related Tech Briefs. By grouping Tech Briefs, both current and retrospective, a relevant information unit equivalent in impact to the general Tech Brief described above could be placed in the hands of potential adopters. The operational plan attempts to outline how this strategy might be accomplished.

The Operational Plan*

The operational plan proposed is essentially a transition procedure which creates the individual mailing lists and groups specific technologies without doing violence to the present Technology Utilization Program. The approach will take certain groups of "specific" Tech Briefs which have proven relevance and distribute such Tech Briefs through corresponding professional associations so that individuals are

---

* Recommendations in the proposed operational plan are made without reference to cost considerations. It should be noted, however, that implementation of the plan would not require substantial cost increases in Tech Brief program operations.

reached on a discipline basis. The intent over the long run is to distribute all specific technologies through proven special groupings. Each special grouping will draw on both current and past Tech Briefs. Initially only two or three special groupings should be undertaken (possibly electrical, metalworking, or instrumentation). The main effort should be directed toward developing mailing lists and should be approached through professional societies. The reediting should be minimized so that available documentation can be utilized. The purpose in working with only a small part of the specific classification is to develop the detailed procedures for grouping and distributing Tech Briefs without disrupting the present flow. As these procedures are institutionalized, other special subject area groupings can be developed so that the Master Authority Address List distribution of "specific" Tech Briefs can be phased out entirely.

Points of Emphasis for the Present Program

Tech Briefs. The Master Authority Address List for Tech Brief distribution appears to have serious deficiencies. As a first step all individuals on the list should be contacted with a form letter and asked if they want to continue receiving Tech Briefs and, if so, in which of the nine technical areas. Those not responding should be dropped from the distribution list.

To further supplement the mailing list, a number of technical publications should be encouraged to present stories or announcements concerning the "new" Tech Brief program and how to participate in it. Particular emphasis should be given to trade publications serving industries that do not at the present time participate to any great extent in the program. This would include textiles and apparel, furniture and wood products, leather, rubber, plastics, and primary metals.

TSP Distribution Methods. The distribution of TSP's should continue to be handled by the NASA Centers, and efforts should be made to bring requesters into even more intimate contact with the generators of new technology through Technology Utilization Officers.

To stimulate additional TSP requests, a definite program should be developed for sending Tech Briefs and TSP's to selected trade publications. This should not be handled on a mass mailing basis, but rather should be a highly selective program working with somewhere between 25 and 50 publications which have indicated some interest in reporting interesting new NASA technology. Technical editors of candidate publications should be contacted to determine their interest and to solicit suggestions on how such a program should be handled. There is an important opportunity here to help establish the special distribution system.

Republication of Tech Briefs. The available evidence suggests that if good technology is republished in some form, it will have a continuing impact. Three specific forms of republication should be considered.

- Tech Brief "Classics." Every three months, those Tech Briefs that have generated 50 or more total requests, and where there is at least one documented transfer example, should be republished. The only suggested change in the format of the republished Tech Briefs is an indication at the top of the page that the Tech Brief is considered to be exceptional. It is also suggested that the republished Tech Brief be printed on a different colored paper. Other than these two changes, the reissued Tech Briefs would be put through exactly the same process of distribution as for a brand new Tech Brief.

- Compilations. Logical groupings of Tech Briefs and other technical materials not previously published as a Tech Brief appear to be a useful way of disseminating new technology. As indicated earlier, findings show that the more general the technology, the more likely that TSP requests will result and transfers will occur. The compilation is a way of generalizing what has previously been very specific pieces of new technology. The distribution network for compilations should be exactly the same as for Tech Briefs. In other words, the compilations themselves should be sent to everyone on the mailing list and to the technical publications. The impact of the compilations can be independently measured via the present PATT follow-up program by simply modifying the questionnaire to indicate that a TSP was ordered as a result of reading the compilation. As compilations are being prepared transfer examples should be identified for possible inclusion among the Tech Briefs and other technical materials. The inclusion of successful transfer examples probably will significantly enhance the value of the compilation by increasing its credibility. Also, inclusion of the examples should be useful in convincing scientists and engineers that useful technology is in fact coming from the space program.

- Other Special Publications. The Small Business Administration's "Selected Technical Advances" series is an extremely important way of announcing new technology, and every effort should be made to continue to cooperate with the SBA or any other group desiring to republish NASA technology in some useful format. SBA should also be encouraged to send out Tech Brief compilations to persons on its mailing list.

ATTACHMENT A

CONTAMINATION CONTROL: FACT SHEETS SUMMARIZING MAIN POINTS PRESENTED IN TECHNOLOGY TRANSFER PROFILE*

Statement

In order to satisfy its mission requirements, NASA developed many specific technical innovations in contamination control for hardware reliability, planetary quarantine and astronaut safety. A wide variety of nonaerospace applications for these inventions has been documented.

Under contract to NASA, Sandia Corporation in Albuquerque, New Mexico produced two volumes, Contamination Control Principles in 1967 and Contamination Control Handbook in 1969, which constitute the first conceptual and methodological integration of the technology. These two references are used extensively by manufacturers and users of contamination control equipment.

NASA and its contractors provided specifications and one of the first major markets for the contamination control equipment manufacturers. This market influence extended from 1962 through 1967 and promoted the standardization and mass production for a wide range of equipment which is now used for contamination control in hospitals and industries such as television, pharmaceuticals, electronics, computer hardware and food processing.

Participants

- NASA headquarters and field centers (particularly Marshall Space Flight Center, Manned Spacecraft Center, and Kennedy Spacecraft Center);
- NASA contractors (particularly Sandia Corporation);
- Three government agencies (Department of Defense, Atomic Energy Commission, and Department of Agriculture); and
- Thirty-seven hospitals and companies (e.g., General Electric, Becton-Dickinson, Dow Chemical, Xerox Data Systems, Washington University Medical School).

---

* "NASA Contributions to the Contamination Control Field: A Technology Transfer Profile," Industrial Economics Division, University of Denver Research Institute, Denver, Colorado. (In Press)

Data

- NASA publications related to contamination control include 67 Tech Briefs, 235 Contractor Reports, 32 Technical Memorandums, 28 Technical Reports, and 25 others;
- Four major producers of laminar flow equipment have had an aggregated average annual growth rate of 34 percent in gross sales between 1962 and 1970 while the percentage of sales to the aerospace industry has dropped from 95 percent in 1962 to 10 percent in 1970. Sales to NASA and its contractors have amounted to more than half of the aerospace market. Total sales in 1970 for the four companies amounted to approximately $9 million;
- Approximately $200 million was spent by industry in 1970 on contamination control and $75 million of this was for the installation of new clean rooms;
- In 1965, only one hospital in the United States had a clean room for surgery and by mid-1970, 25 hospitals were using clean rooms for surgery, intensive care units and entire wards;
- Approximately 2,000 clean work stations were being used by the pharmaceutical industry in early 1969;
- Steri-tized, Inc., a New York chemical company, has improved two of its bacteriostatic coating products for use on textiles and vinyls and reduced their production cost by 25 percent by including some of the nonmercury chemical compounds from a bacteriostatic coating developed by NASA for its planetary quarantine program;
- More than 1,000 copies of the Contamination Control Handbook have been sent in response to requests from companies and individuals--one example is Xerox Data Systems which has used it as a primary reference to save more than $15,000 in purchasing equipment and developing production line contamination control procedures which have doubled the number of $30,000 disc files passing quality control inspection; and
- ENVIRCO, a contamination control equipment manufacturer in Albuquerque, New Mexico, has found several new markets for portable laminar flow units developed for NASA assembly lines: injection molding production lines for petri dishes, drug assembly lines, milk carton filling lines and television studios. For the latter application the equipment is installed for about $700

and increases the operating time for video tape heads between overhauls costing several hundred dollars from 70 hours to 600 hours.

Basis of Estimates

- Information on 1,872 companies and individuals requesting Technical Support Packages (TSP's) associated with 67 contamination control Tech Briefs; 382 TSP questionnaires returned by those requesters; 53 telephone interviews with TSP users;
- Telephone interviews with 11 equipment manufacturers, 7 contamination control experts outside the aerospace industry, 3 NASA contamination control experts, the editor of Contamination Control;
- Personal interviews with 3 contamination control experts at the Sandia Corporation; and
- Numerous literature sources including the Contamination Control magazine, technical journal for the American Association for Contamination Control.

Narrative Abstract

Most of the present contamination control field, which consists of a technological base, equipment manufacturers, and the industrial user group, was created since 1950 to satisfy the requirements of NASA, DOD and the AEC. Many of the related manufacturing companies were founded in the early 1960's when the aerospace industry was the primary customer. This market influence extended from 1962 through 1967 and promoted the standardization and mass production for a wide variety of equipment which is now used for contamination control in hospitals and industries such as television, food processing, pharmaceuticals, electronics and computer hardware. An estimated $200 million is spent yearly on industrial contamination control.

Two of the fundamental developments in the field were produced at the Sandia Corporation in Albuquerque, New Mexico. The first occurred in 1959 when Willis Whitfield invented laminar flow clean rooms. This provided the means for controlling airborne contaminants by using filtered, flowing air. The second, produced under contract to NASA, was a two-volume reference work which provided the first conceptual and methodological organization of the technological base for contamination control.

NASA has developed many specific technologies, which complement these major breakthroughs, to solve mission oriented problems concerning hardware reliability and planetary quarantine. Similar problems occur in nonaerospace industries, and contamination control technology is rapidly spreading to many other applications such as intensive patient care and surgery in hospitals, maintenance of laboratory animals for drug research, maintenance of pharmaceutical integrity during processing, pollution detection, protecting dairy products during containerization, nonmercuric bacteriostatic coatings for textiles and vinyls in the home, and protecting delicate equipment during production. The last application has increased, frequently doubled, the number of finished products which pass quality control inspection, and this decreases the cost of production. Typical examples include color television tubes, microcircuitry and electronic equipment for industrial and consumer products, and computer hardware.

ATTACHMENT B

LUBRICATION: FACT SHEETS SUMMARIZING MAIN POINTS PRESENTED IN TECHNOLOGY TRANSFER PROFILE*

Statement

NASA scientists have produced significant innovations in lubrication technology to satisfy performance and reliability requirements. These contributions have created a new state-of-the-art for many phases of lubrication during extreme operating conditions such as very high or low temperatures, large ball bearings at high speeds and heavy loads, vacuum, zero gravity, high reliability for extended use, and great stability. They include new dry film lubricants and methods for applying dry lubricants, testing and evaluation of lubricants and lubricating methods to generate necessary data, new metallurgical techniques for improved bearing surfaces, and new lubricating methods. Industrial applications of this technology are just beginning as design engineers realize the extent to which the frontiers and limitations formerly imposed by lubrication and bearings have been moved forward with NASA research.

Participants

- NASA field centers (primarily Marshall Space Flight Center and Lewis Research Center);
- Many NASA contractors (e.g., Midwest Research Institute, SKF Industries, New Departure Hyatt, and Bendix);
- Nineteen companies (e.g., Marlin Rockwell, Boeing, Mobil and Lipe-Rollway); and
- Two professional societies (American Society of Lubrication Engineers and American Society of Mechanical Engineers).

Data

- The U.S. petroleum industry produces oil and grease worth more than $500 million annually, and more than $1.4 billion worth of bearings were sold in 1970;

---

* "NASA Contributions to the Lubrication Field: A Technology Transfer Profile," Industrial Economics Division, University of Denver Research Institute, Denver, Colorado. (In Press)

- NASA publications on lubrication technology include 43 Tech Briefs, 79 Technical Reports, 77 Contractor Reports, 48 Technical Notes, 33 Technical Memorandums and 6 others;
- National Standard Company has produced a special coated wire since 1966 by using a dry film lubricant developed by NASA--the lubricant solved a technical problem which had prevented production of the wire;
- Lipe-Rollway is conducting a developmental project based on a NASA lubricating device to evolve new products;
- A California orthopedic surgeon is working jointly with Lewis scientists to develop better artificial hip and elbow joints from hexagonal crystal alloys invented at Lewis;
- Varian Vacuum has greatly reduced production costs and improved product wear life by using a NASA technique for applying solid lubricants to components in these products; and
- New Departure Hyatt has increased the wear life for its ball bearings which are used in General Electric's aircraft turbine engines by applying expertise developed under NASA contract for guidance gyroscope bearings.

Basis of Estimates

- Information on 786 persons requesting Technical Support Packages (TSP's) associated with 43 lubrication Tech Briefs; 141 questionnaires returned by those requesters; 19 telephone interviews with TSP users;
- Personal interviews with lubrication experts at Lewis Research Center;
- Telephone interviews with lubrication experts at Marshall Space Flight Center and five companies; and
- Literature from professional and trade publications.

Narrative Abstract

The cornerstone of mechanical design is always performance and reliability; lubrication and bearing technology directly control both of these parameters. This has been the case since man first attached wheels and box together to form a cart. The attachment mechanism and its lubrication with animal fat were, for many centuries, the state-of-the-art. This technology now enables us to have cars, jet engines, industrial machinery and even teflon-coated cooking utensils. The design of higher performance machinery with greater reliability must follow advances in this state-of-the-art. NASA scientists have produced significant innovations in lubrication technology to advance the frontiers so that NASA's mission requirements could be satisfied. These contributions have created a new state-of-the-art for many phases of lubrication during extreme operating conditions such as very high or low temperatures, large ball bearings at high speeds and heavy loads, vacuum, zero gravity, high reliability for extended use, and great stability.

Design engineers are discovering that two basic features of space age lubrication technology are relevant to their work: the variety of earth-oriented industrial applications for these same conditions such as vacuum deposition of coatings on textiles and higher speed aircraft turbines for generating electrical power; and the extent to which the frontiers and limitations formerly imposed by lubrication and bearings have been moved forward with NASA research. A few of these new applications for NASA technology include new lubricating methods being adapted for industrial roller bearings under heavy loading; new coated wire products after a NASA dry lubricant solved a basic production problem; new self-lubricating alloys for artificial hip and elbow joints; improved dry lubricant bonding techniques for X-ray machine bearings; and better lubrication and surface treatment techniques for aircraft turbine bearings to increase wear life.

ATTACHMENT C

PLASTICS: FACT SHEETS SUMMARIZING MAIN POINTS PRESENTED IN TECHNOLOGY TRANSFER PROFILE*

Statement

NASA contributions to the field of plastics include dozens of materials formulations and hundreds of new processing and design applications in such areas as high temperature polymers, fire resistant or retardant materials, adhesives and composite materials. Especially significant work has been done in the area of high temperature polymers. Three specific polymers of this type developed for NASA are HYSTL, P13N, and Pyrrones. All three have proved important enough to warrant market testing by private firms.

Participants

- Research and development by NASA's Langley Research Center and Lewis Research Center; TRW, Inc.; Avco Systems Division; and Hughes Aircraft Company; and
- Commercial producers: TRW, Inc.; Geigy Industrial Chemicals; HYSTL Development Company; Avco Systems Division; and Hughes Aircraft Company.

Data

- Pyrrones have long-term strength at 500°F, short-term strength at 1,000°F, and can withstand up to ten times the radiation that will degrade other polymers;
- P13N is produced by a process that eliminates the generation of unwanted byproducts. It has high temperature strength and is impervious to a variety of chemicals;
- HYSTL is easily processed, has a long shelf life at room temperature, is workable in the precured state and cures rapidly. It has high temperature strength, good chemical stability, and

---

* "NASA Contributions to the Plastics Field: A Technology Transfer Profile," Industrial Economics Division, University of Denver Research Institute, Denver, Colorado. (In Press)

ATTACHMENT C

PLASTICS: FACT SHEETS SUMMARIZING MAIN POINTS PRESENTED IN TECHNOLOGY TRANSFER PROFILE*

Statement

NASA contributions to the field of plastics include dozens of materials formulations and hundreds of new processing and design applications in such areas as high temperature polymers, fire resistant or retardant materials, adhesives and composite materials. Especially significant work has been done in the area of high temperature polymers. Three specific polymers of this type developed for NASA are HYSTL, P13N, and Pyrrones. All three have proved important enough to warrant market testing by private firms.

Participants

- Research and development by NASA's Langley Research Center and Lewis Research Center; TRW, Inc.; Avco Systems Division; and Hughes Aircraft Company; and
- Commercial producers: TRW, Inc.; Geigy Industrial Chemicals; HYSTL Development Company; Avco Systems Division; and Hughes Aircraft Company.

Data

- Pyrrones have long-term strength at 500°F, short-term strength at 1,000°F, and can withstand up to ten times the radiation that will degrade other polymers;
- P13N is produced by a process that eliminates the generation of unwanted byproducts. It has high temperature strength and is impervious to a variety of chemicals;
- HYSTL is easily processed, has a long shelf life at room temperature, is workable in the precured state and cures rapidly. It has high temperature strength, good chemical stability, and

* "NASA Contributions to the Plastics Field: A Technology Transfer Profile," Industrial Economics Division, University of Denver Research Institute, Denver, Colorado. (In Press)

unusual electrical properties and radiation stability. The original developer has recently invested $1,500,000 to organize a company to market this material; and

- Three Tech Briefs relating to these high temperature polymers have generated 947 requests for additional information.

Basis of Estimates

- 18 telephone interviews with developers and users;
- 354 questionnaires sent to individuals who requested information concerning these high temperature polymers; and
- Articles in three trade and professional journals.

Narrative Abstract

With an average growth rate of 11 to 15 percent per year since the early 1940's, plastic materials is one of the nations's fastest growing industries. A significant part of the progress made during the last decade in high temperature polymer development must be credited to technology developed under NASA sponsorship. The formulation of Pyrrones by chemists at Langley Research Center in 1964, for example, defined the state-of-the-art in thermal stability and radiation resistance. They have long-term stability at 500°F and can withstand up to ten times the amount of radiation that degrades other polymers.

While trying to develop ablator binders and adhesives for NASA, a California aerospace firm discovered a new method of processing a class of plastic materials known as polyimides. The new process eliminates the generation of water and volatile byproducts, permits rapid curing, and simplifies storage. The resulting polymer, named P13N, has high temperature strength and is impervious to a variety of chemicals.

During 1964, while attempting to develop new materials for rocket thrust chamber ablators, a NASA contractor discovered a new class of thermosetting plastics. While unsatisfactory for ablator applications, its potential for use in other situations was immediately obvious. The material, called HYSTL, is noted for its processing simplicity, long shelf life at ambient temperatures, workability, and rapid curing. HYSTL has high thermal strength, good chemical stability, and good radiation stability. The original contractor has recently invested $1,500,000 to form a company to market this material.

These developments and many others like them are examples of the kind of work in the space program which has the potential for generating a wide range of benefits in the private sector of the national economy.