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TRANSFER RESEARCH AND IMPACT STUDIES PROGRAM

Annual Report 1975

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

During 1975, the Denver Research Institute continued research under the Transfer Research and Impact Studies Program (TRIS) toward:

. . . the development of methods for stimulating interest in the transfer of NASA-originated technology by

- Preparing three new information packaging concepts (see Section III):

  -- The NASA Benefits Briefing Notebook alerts selected decision makers to the ways in which nonaerospace users have applied NASA-developed technology; at year's end, it contained 262 paragraphs covering 19 subject areas of key societal interest;

  -- The Solar Energy Dissemination Package, a 14-minute color film and 28-page printed Guide, is directed specifically to the heating-ventilating-air conditioning (HVAC) contractor to make him aware of NASA-developed technology relevant to the use of solar technology in the HVAC industry;

  -- The LANDSAT Demonstration Package encourages the application of NASA-developed remote sensing technology in land use planning and resource management, especially coal surface mining; each of four brochures is addressed to a specific audience with special interest in the area.

- Participating in various professional communication activities (see Section I and Appendix C):

  -- TRIS personnel attended 11 professional meetings and published three reports and articles.

- Responding to special requests (see Section I):

  -- TRIS staff responded to 43 special requests, ranging from identifying transfer cases for use in speeches to compiling an inventory of 1,200 transfer cases, for use by NASA management.

. . . a better understanding of the mechanisms of technology transfer by

- Updating a 1969 perspective on the technology transfer process (see Section II);

- Developing a methodology for analyzing technology transfer via people transfer (see Section IV); and

- Conducting a comparative channels study to discover which of two different mechanisms is more effective in supporting technology transfer (see Section V).

. . . a more efficient management information system by

- Converting the TRIS Transfer Example Files to an automated microfilm storage and retrieval system (see Appendix A);

- Initiating conversion of the General Subject Files; and

- Continuing case development activity by adding over 8,000 Technical Support Package (TSP) requests to the TRIS data bank, mailing questionnaires to some 3,000 TSP requesters, and completing approximately 300 telephone interviews with persons who have used NASA-developed technology in nonaerospace applications (see Appendix B).

SECTION I. OVERVIEW*

The Transfer Research and Impact Studies (TRIS) Program at the Denver Research Institute has two basic objectives: (1) to enhance the effectiveness of the National Aeronautics and Space Administration's Technology Utilization Program by providing a more thorough understanding of the technology transfer process through analysis of specific operating experiences; and (2) to increase the awareness and interest of various groups in the technical and economic impacts of large, mission-oriented R&D programs on significant areas of industrial and societal concern.

Orientation of TRIS research. Initiated in November 1967, the TRIS Program** has become one of the major sustained efforts in this country to monitor, evaluate and explore options for improving government-directed--especially NASA-operated--technology utilization (TU) efforts. TRIS research has focused primarily on assessing the impacts of horizontally-oriented TU efforts, that is, attempts to link together potential technology users in one economic sector (e.g., health and medical services) with technology generators and resources in another economic sector (e.g., aerospace).

The particular orientation of the TRIS Program toward analysis of horizontal, or intersectoral, federal technology transfer activities is rarely duplicated by other technology transfer research projects. This derives from the fact that NASA, the sponsor of TRIS research, is one of the few federal agencies with intersectoral technology transfer objectives. This is not to suggest that NASA personnel do not share with other federal employees a major interest in and commitment to the vertical transfer of technology, that is, the movement of innovations from discovery to application within specific economic sectors. These and other issues related to the complex technology transfer process are reviewed in Section II of this report.

New information packaging activities. A core concern in the transfer of technology is to create awareness among potential users of the existence of technology that relates to their interests; this is a necessary condition for transfer. The simple fact of communication with potential users, however, is not sufficient to promote widespread use. Communication must also be directed toward building user interest in appropriate technology (i.e., products, processes, or knowledge that "fit" a potential user's technical, economic, social, political requirements). Beyond informing and persuading, a successful technology communication effort should motivate potential users to take some action

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*Prepared by James E. Freeman.

**TRIS was known as the Program for the Analysis of Technology Transfer until March 1972.

vis-a-vis relevant technology (e.g., contacting the innovator, purchasing and testing the technology).

Even user-oriented technological communication does not guarantee the transfer of technology because so many other--often nontechnical--factors (e.g., changing market conditions, inflation, insufficient return on investment, unexpected changes in government regulation) can interrupt or terminate the transfer process. When the transfer process works, however, effective technological communication is an essential element.

During 1975, TRIS personnel initiated three demonstration projects designed to support technological communication with selected audiences. One of these three demonstrations, known as the NASA Benefits Briefing Notebook, addresses the problem of improving public awareness of the ways society has been able to use NASA-developed technologies.

TRIS Program staff also developed a prototype communication package in the area of solar energy. The specific task was to design an integrated, multimedia information package directed toward heating, ventilating, and air conditioning (HVAC) contractors. The resulting package, to be tested in 1976, surveys the considerable quantity of technology--some of it developed by NASA--that is related directly to the design and installation of solar-based HVAC systems; in addition, the package reviews the economic and technical reasons for using that technology in the HVAC business. A critical feature of this package is that it presents relevant NASA technologies from the HVAC contractor's perspective, rather than from an "aerospace" perspective.

The third demonstration project in information packaging taken by the TRIS staff during 1975 was directed toward creating a demand by the various parties involved in coal surface mining for remote sensing data--particularly data generated in NASA's LANDSAT program. A basic communication principle applied in this demonstration was the use of applications-oriented, rather than technology-available, descriptions to illustrate why the data are worth using.

Progress in implementing all three of these demonstrations is summarized in Section III.

Technology transfer via people transfer. A fundamental, but largely untested, belief has existed for many years that the single most effective means for transferring technology is the movement of knowledgeable people from one employment situation to another. This idea, while intuitively tenable, has not been a very useful tool in technology transfer policies or programs simply because so little is known about how it works. TRIS Program personnel took the first step in addressing this problem during 1975 by developing a methodology for tracing people transfer and measuring the transfer activity. To develop this methodology, a survey of some 60 former aerospace managers was conducted to determine both the how and the why of their successes and failures in attempts to apply aerospace management techniques in their new situations. The methodology, as well as the preliminary substantive results of the survey, are summarized in Section IV.

A comparative channels study. Questions concerning the function of technical societies in the technology transfer process have been examined in a number of ways in previous transfer research. An unexplored aspect of technical society transfer activities, however, concerns the republication of materials published and distributed initially by other sources. This aspect was explored in a special TRIS case study during the last six months of 1975. The study compared the technical impacts of two efforts--one by NASA, another by the American Society for Testing and Materials--to disseminate a very popular document describing a series of nondestructive spot tests that allow the rapid identification of metals. Results of that comparative analysis, along with implications for future technology transfer initiatives, are presented in Section V.

TRIS information management system. Supporting program accomplishments to date, as well as tasks to be undertaken next year, requires the constant updating and improvement of the TRIS information management system. Progress made in 1975 toward implementing a new machine-readable microfilm system for the TRIS transfer example files is reviewed in Appendix A.

Data bank operations. Since the inception of TRIS in November 1967, a primary responsibility of the project has been to maintain a data bank on the operation of NASA's Tech Brief Program. By January 1976, over 114,000 requests for Technical Support Packages associated with NASA's 6,000+ Tech Briefs had been registered in the TRIS data bank. A summary of data bank operations during 1975 is presented in Appendix B.

Special requests. The TRIS Program continued to provide TUO program support by responding to special information requests from NASA TU personnel and others. Between March 1975 and January 1976, for example, TRIS personnel responded to over 40 such requests, ranging from the identification of transfer cases for use in speech preparation, to the development of bibliographies on particular topics, to the development of an inventory of some 1,200 transfer cases documented during the past eight years.

Professional communications. TRIS personnel participate in professional activities, such as attending meetings and preparing articles, that are concerned with technology transfer matters. During 1975, TRIS personnel participated in 11 formal meetings and published three reports and articles. An example of one published article is presented in Appendix C; Appendix D presents a list of technology transfer documents produced by TRIS personnel since the inception of the Program.

Future activities. An overview of the evolution and trends in TRIS Program activities is presented in Section VI of this report. Special emphasis will be placed on initiatives in areas of TU program evaluation and support services, technology transfer policy analysis, and the public communication of transfer information.

SECTION II. THE TECHNOLOGY TRANSFER PROCESS: PERSPECTIVES GAINED IN TRIS RESEARCH*

The subject of technology transfer has come to be a matter of major concern at many levels of government and industry in the United States during the past decade. Some 25 federal departments and agencies, for example, operate programs with formal responsibilities in the area of technology transfer. Similarly, attempts are being supported financially by the National Science Foundation, NASA and other federal agencies to facilitate the transfer of technology to state and local governments. The Small Business Administration and major industrial organizations (e.g., General Electric, TRW) also have created technology transfer programs or departments to stimulate commercial use of existing technology. A sizable body of literature exists identifying, describing, and assessing technology transfer research utilization and the diffusion of innovations.**

Driving Forces

A primary driving force behind the interest in technology transfer is efficiency in achieving economic growth through the application of technology. More effective adaptation and use of existing technology, it is argued, can contribute to economic growth through improved productivity in both public and private sectors of society.

Legal considerations also have stimulated widespread involvement in formal technology transfer programs. Thus, for example, when Congress formed NASA in 1958, it required the Agency to do something radically different from the traditional requirements imposed on other federal agencies: not only would NASA have to ensure the broadest practical and timely use of technology <u>within</u> its sector, aerospace, but also the Agency was directed to work toward the same objective <u>outside</u> of aerospace--a task fraught with technical, economic, social and political difficulties. The idea behind transferring technology horizontally out of aerospace was simple: technology developed at public expense for one economic sector often can be used in other economic sectors.

The NASA mandate eventually was interpreted to mean something more than simply providing potential technology users with timely access to the knowledge. This "something more" has come to include: (a) communications specifically designed to promote interest in and use of existing technology by selected audiences, and (b) providing potential users with

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*Prepared by James E. Freeman, James P. Kottenstette, and F. Douglas Johnson.

**See TRIS documents on the subject in Appendix D; also see J.D. Roessner, "Federal Technology Transfer: Results of a Survey of Formal Programs," New York: The American Society of Mechnical Engineers, Publication No. 75-WA/Aero-4, 1975.

technical assistance in adapting existing technology to fit their needs.

Four Hypotheses Concerning Technology Transfer: A Review and Update

In the 1969 PATT* Annual Report, four hypotheses were advanced concerning industrial transfer of federally-developed technologies. To provide a brief summary of progress in understanding the technology transfer process, it is useful to review and update those hypotheses.

Hypothesis #1. *There is a tendency, largely unconscious, for many private corporations to minimize the technological benefits they may have received from federal agencies.* In 1969 and in 1976, this hypothesis is easy to understand. Corporations engage in many forms of communication with external sources of technology to keep current with, if not to move ahead of, their competition. When the external source happens to be the federal government, a considerable amount of adaptive engineering work is generally required before corporations can use federally-developed technologies. It often is difficult after a transfer has occured for corporate spokesmen to determine what "part" of the new application should be credited to the federal government, and what to call their own. The tendency is to minimize the benefits received.

This tendency is more pronounced when the transfer involves corporate use of technical knowledge in modifying existing products, processes or services (e.g., making a minor change in the quality control procedure followed on an assembly line). This tendency is less pronounced when the transfer involves corporate production and marketing of a product initially developed under auspices of the federal government (e.g., a new fire-resistant material). Interestingly, the vast majority of transfers are of the type in which corporations use technical knowledge to improve their own products and processes. Technology transfer analysts have not yet discovered satisfactory techniques for quantifying such transfers. This, in turn, reinforces the corporate tendency to minimize the significance of any benefits received.

Hypothesis #2. *The impacts of technology transfer resulting from NASA's Tech Brief-TSP Program are small in proportion to the total impacts of all transfers resulting from NASA's activities.* TRIS research since 1969 has enriched substantially the perspective for understanding the question of Tech Brief-TSP program significance treated in this hypothesis.

The following table developed by TRIS researchers identifies and describes eight different modes through which NASA-developed technologies have transferred to other economic sectors. The Tech Brief-TSP program would fall under Mode VI, i.e., formal Agency programs that disseminate Agency-generated technical information.

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*TRIS was known as the Program for the Analysis of Technology Transfer (PATT) until March 1972.

It would be false to conclude from its placement in Mode VI that this program is insignificant in terms of the transfer impacts it has produced. Between 1967 and 1976, over 120,000 requests have been made for TSP's associated with the roughly 6,000 Tech Briefs NASA has published. TRIS analysis indicates that in approximately 15 percent of these cases, the recipients have tested and/or routinely used the technology within six months after requesting a TSP. Of equal importance, approximately 12 percent of all TSP requesters report economic benefits (e.g., cost reduction, time savings) within the same time frame.

Hypothesis #3. *The amount of space spin-off which has occurred is significant.* TRIS analysis of technology transfer has identified eight modes which are summarized in Table II-1.2. Based on this perspective of transfer, the credibility of this hypothesis has been strengthened. The variety of sources TRIS personnel have tapped in each mode to identify instances of transfer is growing rapidly; so, too, is the total number of transfer cases--some 1,200 to date.

It should be noted that the primary concern in TRIS research has shifted from a relatively narrow technical research focus in 1969, to a broader analysis in 1976 of the societal impact of transferred technology. Thus, for example, in developing the NASA Benefits Briefing Notebook, the TRIS staff has classified some 250 current transfer examples according to their societal relevance (e.g., consumer products, health, environment, transportation).

It has not been possible yet, for TRIS researchers or other transfer analysts to quantify objectively the economic impacts of transfer activities. A major reason for this is that broad economic assessments are extremely difficult to perform; certain intangible economic benefits and costs even make quantification impossible (e.g., estimating the financial value of knowing not to do something, the economic value of better technical information).

Hypothesis #4. *The most attractive opportunities at this time (1969) for NASA to enhance technology transfer lie not in creating additional special programs, but in attempting to improve present technology flow through established or conventional channels.* The comparative channels study (see Section V) and other TRIS research (e.g., TSP mail questionnaire survey) support this hypothesis. Not only does NASA's use of existing channels appear to be the most effective approach, but it also appears to be the most efficient in terms of TUO's limited resources.

Thus, assessing the effectiveness of the Office's current mix of programs and redesigning them to enhance their effectiveness logically deserves priority over attempts to create novel dissemination programs. TRIS research continues to support the wisdom of reaching potential technology users via their (i.e., the users') familiar communication channels (e.g., Industry Week, Design News). (This point is taken up in more detail in Section V of this report.) Similarly, in TUO's industrial and public sector technology applications programs, TRIS research

TABLE II-1. EIGHT MODES FOR TRANSFERRING NASA-DEVELOPED TECHNOLOGIES

Mode	Description
I	Diversification by firms producing for mission-oriented programs through (a) shifts in production facilities and personnel to commercial product lines, or (b) implementation of formal organizational policies to apply mission-related expertise in commercial product development projects.
II	The general improvement of industrial production practice and product quality through Agency-initiated specifications and standards for mission hardware procurement.
III	Development of new process and product technology by industrial contractors to promote the direct interests of programs, with subsequent commercial production occuring because other markets and applications are recognized.
IV	Professional activities, including professional design code development, by researchers involved with basic and applied R&D programs in support of mission requirements.
V	Relocation of skilled individuals from mission-related employment to employment in other economic sectors, resulting in the application of acquired skills to solve analogous problems encountered in the new sectors.
VI	Formal Agency programs that disseminate, and in some cases adapt, mission-generated technology to organizations in other economic sectors.
VII	Direct access to mission-related scientific and technical information systems by other organizations as part of their normal information acquisition efforts.
VIII	Interagency projects that adapt a first Agency's mission-oriented technology to the needs of a second Agency or its sector organizations.

supports the importance of involving potential suppliers and users of resulting adaptive engineering projects early on in the problem-solving activity.

Three Additional Hypotheses Derived From Recent TRIS Research

Hypothesis #5. *The effectiveness of attempts to transfer technical information horizontally (i.e., out of aerospace) is related to the communication starting point selected: greatest impact is associated with communication which begins with the interests and concerns of potential technology users, rather than starting with characteristics of the technology itself.* Simply stated, user-oriented communications are likely to be much more effective than technology-oriented communication efforts.

This hypothesis does not appear to hold in attempts to transfer technology vertically (i.e., within an economic sector). Indeed, it appears to be highly desirable to focus on characteristics of the technology when it is reasonable to assume that an audience already is thinking in terms appropriate to the context within which the technology was developed. For potential users who have not been part of the generating sector, however, hypothesis #5 appears to hold. It is this type of thinking that went into the development of the solar energy and LANDSAT demonstration packages described in Section III of this report.

Hypothesis #6. *The perceived timeliness of a technical information product is a function, among other things, of the potential user's current knowledge requirements.* TRIS research has shown that the issue of how recently the information product (e.g., a technical report) was produced usually is less significant to a potential user than the issue of how well the information in the product "fits" the user's current requirements.

For example, several hundred U. S. technologists continue to use a handbook NASA published in 1970 that describes a nondestructive testing technique for rapid identification of metals. The age of an information product thus does not determine its relevance or utility to potential users.

TRIS experience also shows that information products formerly considered irrelevant by potential users can become relevant when the user's problems change; furthermore, new personnel or new applications can generate a demand for "older" information products. Additional research is needed to develop criteria for providing access to older information products (e.g., reissuance of publications, production of comprehensive indices).

Hypothesis #7. *The transfer impact of NASA publication programs is related to how far the potential user has progressed in the problem-solving process.* The earlier the stage of problem-solving (e.g., problem definition, preliminary interest in certain options) the greater the potential impact of NASA publications. Conversely, the later the stage of problem-solving (e.g., development of a specific option, marketing a product), the less the chance of impact because the potential user has made many strategic and tactical decisions that limit the range of what information will be useful. These considerations are relevant to decisions NASA TU program personnel make in publicizing TU services and products, and in encouraging persons to make more effective use of those services and products.

SECTION III. NEW INFORMATION PACKAGE ACTIVITIES

Three new information packages were developed during 1975 to provide NASA management, heating-ventilating-air conditioning (HVAC) contractors, and different parties involved in coal surface mining and reclamation activities with access to technical information relevant to their current responsibilities. TRIS personnel worked closely with the TU office and other Agency program offices in developing the NASA Benefits Briefing Notebook, the solar energy demonstration package, and the LANDSAT demonstration package.

NASA Benefits Briefing Notebook*

A new approach to packaging and distributing transfer information from the TRIS files was introduced in response to a request from NASA management late in 1974. The NASA Benefits Briefing Notebook was designed to provide Agency management with convenient access to accurate, timely transfer information in an integrated format. The format, growth, and content of the notebook are described in this subsection, together with a review of key production factors in its continuing growth after one full year as an operation task for the TRIS Program.

Format, growth, and content. The notebook consists of a looseleaf binder divided into three sections: (1) Benefit Cases; (2) Transfer Overview; and (3) Indices. The benefits section is currently subdivided into 19 subject areas. Each subsection presents one or more key issues of current interest (e.g., consumer products, construction, health services) with discrete transfer cases related to each key issue. Additional transfer examples relevant to each subject area are then presented in numbered paragraphs. Pertinent transfer data are given at the end of each paragraph (viz., communication link, TRIS Automated Transfer File and individual case number(s), and date of the latest information used). Each paragraph refers to specific NASA-generated technology and describes one or more transfer examples for that technology.

The Transfer Overview section provides a general perspective for technology transfer from NASA to other organizations. In addition to a description of the basic transfer modes, the selection criteria for notebook examples and the kinds of benefit data they contain are presented. Four indices (General, Organization, Geographic, and Field Center) provide convenient access to the transfer information for speeches, articles, or other purposes based on factors such as location, audience composition, or subject matter.

Approximately 75 copies of the notebook have been distributed. They are regularly updated with new editions every four months. Each new

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*Prepared by F. Douglas Johnson.

edition generally consists of one or more new subject areas, 35 to 45 new paragraphs, updated or revised paragraphs and new indices.

The first notebook edition, distributed in November 1974, contained 102 paragraphs in 11 subject areas. In 1975, editions were distributed in January, May and September. As of the January 1976 edition, the notebook contained 262 paragraphs in 19 subject areas. The latest edition is characterized in Table III-1 by data on key issues, total paragraphs, and number of organizations mentioned in those paragraphs. The January and May 1975 editions of the notebook were also reproduced in large numbers for wider distribution than is possible with a looseleaf binder format.

Notebook paragraphs contain information about actual, rather than potential, nonaerospace uses of NASA-generated technical innovations. Some of these innovations were developed for direct applications in aircraft designs, weather forecasting, etc. Most NASA-developed innovations, however, do not have direct application outside of the Agency's programs and, therefore, require adaptation for each secondary application. NASA, for instance, has undertaken the development of a fireman's breathing system. The results of such application projects often are innovations in their own right. All benefit examples from NASA innovations, regardless of why the innovations were developed, are being added to the notebook as these examples are identified and verified. NASA also purchased off-the-shelf products for use in its programs. If this type of procurement activity led to product improvements or otherwise contributed to innovations in commercial product lines, the products are included in the notebook.

In addition to the technological innovation, each paragraph also describes organizations that are using the innovation, how it is being applied, and what benefits are achieved through the application of NASA technology. For each example cited in the notebook with a TRIS case number, a personal interview with a knowledgeable person in the organization has been conducted by a TRIS staff member and supporting documentation is available in the TRIS transfer files.

Many of the interviews for potential transfer examples reveal that the recipient organization is still in the early stages of transfer (viz., awareness, evaluation, prototype testing) and is not routinely using the technology at the time of the interview. This information is stored in the TRIS files for subsequent recontact and is generally not used in the notebook. In addition, the interviewee may designate all or part of the information as proprietary and such information is not used in the notebook. The proprietary situation also exists for many Industrial Application Center (IAC) transfer examples. Although the TRIS staff does not conduct interviews with IAC clients, a coordinated effort is being developed between TRIS and the IAC's to ensure that appropriate IAC transfer examples are included in the notebook.

In summary, the major criteria for using transfer information in the notebook paragraphs have been: (1) specificity regarding the NASA

TABLE III-1. DATA FROM THE NASA BENEFITS BRIEFING NOTEBOOK*

				Number of Organizations Mentioned				
Subject Area	Key Issues	Paragraphs	Companies	Industry Associations	Federal Agencies	State/ Local Agencies	Educational Institutions	Health Institutions or Organizations
A. Manufacturing Consumer Products	2	11	13					
B. Manufacturing Capital Goods	1	42**	47		2			
C. New Consumer Products & Retailing	2	14	16					
D. Electric Utilities	3	13	25	1	3	1		
E. Environmental Quality	2	15	10		3	1	3	
F. Food Production & Processing	2	16	12		4	4	1	
G. Government	2	23	13		12	11	2	
H. Petroleum and Gas	2	15	23	2	2		1	
I. Construction	1	15	21		2	1	1	
J. Law Enforcement	1	7	6		1	4	1	
K. Highway Transportation	1	8	13		1	3		
L. Rail Transportation	2	9	9	1	2	1	1	
M. Air Transportation	1	17	22	1	1			
N. Insurance, Banking & Real Estate	1	7	13					
O. Education	---	13	7		4	2	17	
P. Health Services/ Rehabilitation	1	13	13		2		3	16
Q. Health Services/ Diagnosis & Treatment	1	11	11					7
R. Health Services/ General	1	4	2				1	4
S. Water Transportation	1	9	9		2			
TOTALS	27	262	285	5	41	28	31	27

*Data as of the January 1976 Edition.
**Not counting deleted paragraph B-13.

technical innovation, recipient organization, application and benefits; (2) routine use by the recipient; (3) verification and documentation; and (4) relevance to notebook subject areas.

Production factors. The notebook has created a centralized activity for gathering and distributing transfer information. Due to the cooperation and communication among NASA personnel, contractors, and the TRIS staff, there has been a substantial increase in the number of potential transfer examples that TRIS receives for further investigation. The effect of this cooperation on the notebook production activity is indicated by the increasing proportion of paragraphs derived from these sources of leads--over 25 percent in the January 1976 edition.

The growing number of leads from new sources, combined with the traditional TRIS sources (e.g., TSP requester files, data bank, contractor contacts, clippings), is creating a potential transfer case reservoir at the same rate, if not faster, than the leads can be investigated and documented. Thus, a favorable production situation exists, and is expected to continue. This will permit greater selectivity in the choice of examples for paragraphs. In addition, the efficiency of producing each edition from the reservoir of potential transfer examples continues to increase with each edition as TRIS personnel gain more experience with the process.

Solar Energy Dissemination Package*

In March 1975, TRIS began a feasibility study that has resulted in the production of an integrated media package. The package is composed of a 14-minute orientation film entitled, Look to the Sun, and a 28-page information guide entitled, "A Contractor's and Engineer's Guide to Space Heating Thru Solar Energy Technology." The film and the guide introduce solar energy applications to a technical audience. The package will be available for limited distribution in 1976.

Objective. The objective that shaped the production of the package was to test the following assertion: more effective use of aerospace technology can be achieved if this technology is presented in context with other information, from a variety of sources, such that comprehensive applications information is aggregated for potential users. The purpose of the solar energy dissemination package, then, is to provide a vehicle to demonstrate this assertion and, in so doing, to provide the public with information on how to use solar energy for low-grade thermal applications, specifically solar space heating.

Approach. Prior to arranging for film production or preparation of the guide, several preliminary inquiries were made to establish the feasibility of undertaking the proposed task. The inquiries included: (a) an extensive literature search, along with acquisition of resource

*Prepared by James P. Kottenstette and William B. Pratt.

materials; (b) engaging a consultant to help consolidate information about important issues in the application of solar energy; (c) screening a file of some 4,000 persons who requested NASA TSP 73-10156 ("A Practical Solar Energy Heating and Cooling System") to identify heating, ventilating and air conditioning (HVAC) contractors and engineers; (d) conducting interviews with TSP requesters to analyze their information needs and the "context" of the target audience; (e) attending regional and national conferences concerned with solar energy applications to identify key people and to determine the application issues; and (f) conducting interviews with local experts, bankers, environmentalists, HVAC specialists, solar energy researchers, and building owners to round out the definition and understanding of the social, economic and cultural context of the HVAC contractor community.

The results obtained from these inquiries indicated that there is a definite need for technical and other information related to solar energy. The Department of Mass Communications at the University of Denver was asked to assist in the production of an orientation film to meet the general information needs identified. Production responsibility was assumed by four graduate students as part of their requirements for the Master's degree. The Department provided the cameras and editing equipment; TRIS underwrote laboratory and location expenses and provided overall production administration, liaison and technical assistance.

In order to meet the technical information needs identified during the preliminary survey, the concept of an information "map" was developed and embodied in the guide. The concept of the information "map" is straightforward: learn enough about potential technical applications to devise a simple approach for organizing the information needs of the target audience; represent this approach visually so that the issues or problems in an application can be easily understood; use the structure to aggregate and identify specific information resources; and, for maximum reader interest, provide timely comment and insight into the application issues.

Five major solar energy issues are developed in the guide: (1) solar energy collection techniques; (2) system design; (3) optimizing energy use; (4) the national focus; and (5) cost considerations. Thirty-six references are associated with these issues, including 18 documents reporting the results of NASA research and development. The principal NASA contributions, not surprisingly, are associated with the issues of solar energy collection and system design. One value that results from structuring the application issues and problems in this manner is the opportunity to identify related technology that should be of interest to the audience, technology that ordinarily is not thought of as solar energy technology per se. The guide, for example, directs the reader's attention to at least 16 additional NASA publications treating such topics as plating methods, metal forming and structural design.

Dissemination plan. Preparation of the film and guide brought about extensive contact with organizations and interest groups in the solar energy field. These contacts provide NASA with access to very large audiences if initial distribution leads to sufficient interest in the NASA contributions.

Initial distribution of the package has been planned to determine user response. Following screenings of the orientation film, approximately 500 copies of the guide will be distributed at chapter meetings of professional groups in the HVAC field. Requests for solar energy information resulting from this distribution will be handled by the University of New Mexico's Technology Application Center (TAC) on a full-cost-recovery basis so that preliminary assessments may be made about the value of the package as a communication concept. This approach to distribution will be evaluated to determine its utility as a marketing tool for NASA Industrial Application Centers.

LANDSAT Demonstration Package*

Another significant departure in 1975 from previous TRIS tasks was the development and demonstration of a methodology for disseminating remote sensing data from the LANDSAT satellites. This information packaging task was funded by the NASA Office of Applications-User Affairs (Code EK) as part of its continuing effort to assess different approaches for accelerating the use of LANDSAT data.

Purpose. While substantial benefits should occur from the application of remotely-sensed data in resource management, it may take several years before the natural diffusion process leads to routine use of these data in decision-making and resource assessment. To promote broad use of the data, NASA has relied heavily on demonstrations of technical feasibility for various resource applications as well as on publications that describe the availability of new remote sensing techniques. The TRIS demonstration project consisted of preparing and distributing four different promotional brochures that emphasize successful application results, rather than the techniques involved. The common purpose of these packages is to generate awareness of and interest in the use of LANDSAT data by four different audiences. Potential users interested in obtaining more information are directed to send the brochure response card to the NASA Office of User Affairs (Code EK).

Methodology. The user-oriented, rather than technology-oriented, brochures were developed by first selecting a single resource management area on which to focus the application context. Coal surface mining and reclamation were selected on the basis of six criteria:

- Remote sensing relevant to the area;
- Known applications of LANSAT data;
- Significant socioeconomic impacts;

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*Prepared by F. Douglas Johnson.

- Parties at interest (e.g., coal companies, state regulatory agencies) from a spectrum of potential LANDSAT data user groups;

- Definable population in each party at interest; and

- No known major barriers to performing the demonstration tasks.

These criteria were carefully chosen by TRIS personnel to provide a general selection process for future applications of the methodology to other resource management areas. The first four criteria appear to be more important than the last two for this purpose.

Approximately one-half of the data gathering activity and most of the literature survey were subcontracted by DRI to the University of New Mexico Technology Application Center. Interviewers from DRI and TAC contacted individuals who were attempting to use LANDSAT data in coal surface mine applications. Sufficient application information was gathered to apply the methodology in selecting the key parties at interest for coal surface mining and in developing the orientation and text for the brochure specific to each selected PAI. Table III-2 shows the audience and focus of the four brochures.

The primary potential user of LANDSAT data at the state level is the agency with regulartory responsibilities. The state legislature, however, can exert a significant leverage on that agency to use LANDSAT data by appropriating funds or setting legal standards. The audience size ranges from less than 100 for regulatory agencies to over 500 for legislators.

<u>Brochures</u>. Each brochure consists of four pages (eight sides) with text, pictures and a response card. The same photographs are used in all four brochures to minimize production cost; however, the orientation and treatment of subject matter differs in each brochure to reflect the interests of specific audiences. The coal companies brochure, for example, emphasizes the cost-effectiveness of using LANDSAT data, while for legislators the synoptic coverage of the satellite is highlighted.

The response cards are addressed to the Office of User Affairs, (Code EK) which has a package of materials for distribution. The Code EK package includes lists of published reports, ongoing projects, and remote sensing experts relevant to coal surface mine applications. These materials should facilitate the progression from initial awareness to user evaluation of LANDSAT data for coal resource management.

User Affairs will monitor responses from the brochures and may decide at some future date to evaluate the impact of this methodology on accelerating LANDSAT data utilization. At this time, however, only an informal, qualitative assessment is planned.

TABLE III-2. AUDIENCE AND FOCUS OF FOUR LANDSAT BROCHURES RELATED TO COAL SURFACE MINING

BROCHURE NUMBER	AUDIENCE	FOCUS
1	Legislators and governor's staff members	Legislation and administrative policies that include the new monitoring capabilities offered by remote sensing
2	State regulatory agencies	New monitoring and planning methods
3	Coal companies	Cost-effectiveness of remote sensing for mine development and reclamation planning
4	Producers and critics of environmental impact analysis	Data sources for improved content of impact statements

SECTION IV. TECHNOLOGY TRANSFER VIA PEOPLE TRANSFER: A METHODOLOGICAL STUDY*

The concept that the movement of people acts as a mechanism for technology transfer is widely accepted and commonly utilized. The federal government, for example, has instituted the Intergovernmental Personnel Act to promote interchange between federal, state and local government employees. The Department of Agriculture has had extension agents in the field for many years. And the National Science Foundation, under its RANN/RDI program, has an Urban Technology System experiment that has placed technical agents in 27 U. S. municipal governments.

Many private corporations rotate personnel among divisions during management training and management career development. In addition, most military management personnel are rotated systematically for various reasons.

Despite the common practice of personnel mobility, very little research has been done to evaluate the impacts of such movement on the efficiency of operations, or to identify the factors that would optimize the movement of information, skills and attitudes when people are transferred from one work setting to another. The value of understanding those impacts and factors is particularly interesting from NASA's perspective because several thousand former aerospace employees have transferred to other sectors of the economy. Knowledge of the transfer impacts and of the factors controlling transfer effectiveness could guide future decisions on the employment and reemployment of aerospace personnel.

Objective. The general objective of this research task was to develop a methodology for assessing the transfer impacts resulting from the movement of aerospace employees to other economic sectors, and for identifying the factors that could be controlled to enhance the transfer effectiveness of such movements.

More specifically, this task was designed to develop a methodology for: (a) documenting the extent to which aerospace trained and experienced personnel have moved into nonaerospace sectors of the U. S. economy as managers; (b) identifying and characterizing management tools and techniques that have either been developed in or refined within NASA and other related aerospace agencies and companies; (c) documenting the utilization of these techniques within the hiring firms as they can be attributed wholly or in part to the transfer of the people identified in (a); (d) assessing and documenting the impact of these personnel (through the management activities in which they have engaged) in selected receiving firms and agencies; and (e) generating new hypotheses regarding the ways in which NASA management technologies have been transferred and have impacted the nonaerospace sector.

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*Prepared by Alma E. Lantz and Anita S. West

It should be emphasized that this study was designed as a methodological study of transfer; no attempt to evaluate or compare the management techniques used in aerospace with alternative management methods was made.

Approach. The study included interviews with approximately 60 managers in the public or private sector of the economy who had previously worked in aerospace, but who are now employed in nonaerospace enterprises. The interviews were conducted either by personal or telephone interview or mail questionnaire. Four site visits were also made to examine the impact of the transferred techniques on the receiving agency/company and included interviews with persons who were never employed in aerospace.

The data are qualitative in nature and may be open to alternative interpretations for the following reasons: (1) the use of self-report data from respondents; (2) the alterations in the interview forms; (3) the small sample not being representative of the entire aerospace industry; and (4) the variance resulting from different interviewers. Further, since several interview forms were tested, all respondents did not answer the same questions and all percentages are based on the number of people answering that question. Therefore, the results reported here only represent a demonstration with a selected sample; and further work is required to establish the generalizability of the findings and the validity of self-report interviews in this situation.

Definition of aerospace management techniques. The management methods examined have a common characteristic, although some of the techniques were broader in scope and application than others. The common characteristic is that all of the management techniques were used widely within aerospace--the interrelated system of industrial and governmental organizations engaged in aeronautics, the space program, and related high technology enterprises. A few of the techniques may have originated within aerospace or NASA itself; in most cases, however, the techniques were generated elsewhere, adopted by aerospace management, and transformed or augmented to meet the critical needs of their programs. NASA encouraged the dissemination and standardization of the techniques and terminology by requiring the contractors and subcontractors involved in the space program to incorporate these techniques into their operations. The specific techniques studied incorporate a broad spectrum, e.g., PERT, CPM, scheduling and status methods, project management, and configuration management.

Most of the techniques are based on concepts designed to promote logical, rigorous and systematic thought processes and encourage examination of all possible alternatives.

Findings/hypotheses. The findings on the widespread impact of aerospace management on the nonaerospace world are impressive. Seventy-eight percent reported contributing to the adoption of aerospace management techniques in their current employment. Almost 50 percent of the respondents reported instituting over half of the aerospace techniques currently in use in their present employment; almost 25 percent reported instituting all of the aerospace management methods in use. Since these percentages are based on the entire sample, including the respondents reporting transferring no management methods, it is reasonable to conclude that personnel movement is a major vehicle in the transfer of aerospace management methods.

Another finding of this survey is that the sophisticated hardware and software utilized in the aerospace application may not be necessary or cost-effective for other situations, but, the method of thinking and decision-making, i.e., a basic disciplined attitude, is applicable to most companies, agencies, and organizations. In many cases, it was observed that the persons changed the environment of the receiving organization (e.g., clarifying objectives and creating a "team" concept so that the appropriate environment for applying aerospace techniques was established).

These findings provide a basis for the following hypotheses concerning the variables that facilitate or inhibit utilizing personnel to transfer information and skills.

Hypothesis #1. *Personnel who institute change must (1) be convinced of the value of the underlying philosophy; (2) be familiar enough with the techniques to modify them according to the prevailing conditions of current employment; and (3) believe that change is possible.* When these conditions are met, more than one specific change will be instituted.

Hypothesis #2. Although many methods of introduction are possible, *the success of attempts to implement new procedures is dependent on well-defined, agreed-on goals.* Implementation may be easier when the persons are in positions of authority and have colleagues with similar backgrounds, but neither is a necessary condition.

Hypothesis #3. *Change is most easily implemented when personnel turnover occurs frequently, when superiors are supportive, when the receiving agency is small and/or new, and when the changes can be perceived as beneficial to all affected personnel.*

Recommendations. A major recommendation of this study is to develop this research area further by using the questionnaire form that evolved from this work on an identifiable large random sample of transferees. Such use would help: (1) increase the generalizability of the results; (2) establish the replicability of the findings; (3) make a stronger case for transfer by including large numbers of less visible personnel; and (4) establish the breadth of the impact of aerospace training and experience throughout the nation.

In addition, the very important questions related to understanding the processes by which people can move ideas and skills need to be more thoroughly investigated in order to develop a strategy for purposefully optimizing the environment to encourage transfer.

SECTION V. A COMPARATIVE CHANNELS CASE STUDY*

What impacts on the technology transfer process can be associated with the republication by a technical society of a document initially published by NASA? Does republication merely duplicate in a needless way the original publication and distribution, or does it materially strengthen the NASA effort to achieve the broadest practicable dissemination of aerospace R&D results? Finally, does the intervention of a technical society achieve such impressive results that it calls into question the continuation of a basic NASA publication activity?

Background. During the past 15 years, the NASA Technology Utilization Office (TUO) has operated a variety of programs designed to support the transfer of technology from aerospace to nonaerospace sectors of the American economy. The Tech Brief Program is one example of TUO efforts to provide nonaerospace engineers and scientists with access to information aggregated initially for aerospace applications.

Both on purpose and by chance, a number of TUO programs have reached potential nonaerospace users both directly (e.g., Tech Briefs distributed by mail) and indirectly (e.g., technical society publications). In 1970, for instance, the Langley Research Center worked with TUO to produce and distribute (via mail) a Tech Brief--numbered 70-10520--and an associated Technical Support Package (TSP), entitled "Nondestructive Spot Tests** Allow Rapid Identification of Metals"; as of May 31, 1975, 1,224 requests for this highly popular TSP had been submitted directly to NASA; copies of the TSP were distributed free of charge.

In 1972, NASA Langley and Headquarters approved a request by the American Society for Testing and Materials (ASTM) to reprint the TSP as ASTM Special Technical Publication 550 under the same title. As of May 31, 1975, approximately 2,500 copies of the ASTM reprint had been sold at $4.00 per copy.

This case raises some interesting and important questions concerning Code KT's technology transfer mission. How do the two dissemination channels differ in supporting the transfer of technical information? How do the two different populations acquiring the spot test handbook compare with each other in such terms as industries represented, technical information requirements, and difficulties in using the information contained in the NASA and ASTM documents? What differences, if any, exist between the two populations in their progress throughout

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*Prepared by James E. Freeman and James P. Kottenstette.

**A "spot test" involves the use of common chemical reagents to identify metals or alloys.

the various technology transfer stages--from awareness through application? What impacts, if any, did ASTM endorsement have in promoting utilization of the spot test technology?

It was with these types of questions that this comparative analysis was concerned.

Approach. The following steps were taken in this analysis: (1) identifying persons who requested the original NASA "spot test" TSP or the reprinted ASTM version; (2) constructing and validating a mail questionnaire for data collection; (3) collecting data to the extent feasible within the limits of the resources available; and (4) analyzing the data to determine answers to the questions raised above.

The mail questionnaire survey was conducted in the fall of 1975. Returned questionnaires for both sample groups averaged 40 percent: 430 ASTM/TSP requesters, and 253 NASA/TSP requesters, responded. Comparisons of respondents with nonrespondents in terms of their standard industrial classifications revealed no notable differences between the two samples. Reasons for nonresponse were not explored; this was not considered necessary since a basic purpose of this case study was to develop, rather than to quantitatively test, a basic understanding of the transfer differences between the two channels. More case studies, conducted under stricter data collection conditions, would be required before any overall generalizations could be made concerning the major questions addressed in this project.

Results. R1. The overall effectiveness of the two channels in transferring the "spot test" technical information appears to be approximately equal. Roughly two-fifths of the respondents in both samples indicated moderate or strong interest in the information, and reported that the information has been moderately or quite important in solving specific technical problems.

R2. The two groups reported similar progress in applying the technology. Forty-three percent of the ASTM group and 36 percent of the NASA group indicated in-house or full-scale uses of the technology. This finding is not surprising since the use of spot test technology is inexpensive and straightforward for a chemist. In this sense, the high proportion of receivers in the later stages of technology transfer compares with the experience of other persons using processing technologies contained in handbooks (e.g., lubrication, contamination control).

R3. The economic benefits reported by the two groups are roughly comparable. For example, 13 percent of the ASTM requesters and 14 percent of the NASA requesters indicated recurring cost savings that they can associate with use of the technological information. It must be noted, however, that 55 percent of the respondents in both groups expressed difficulties identifying benefits in economic terms, at least in quantifiable financial terms. One ASTM respondent, who was not able to quantify economic impacts, commented, "(The ASTM publication) provided, and continues to provide, rapid identification of metallic alloys which capability we would ordinarily not have." This manager of a primary aluminum reduction facility concluded, "It has been a welcome--and crucial--addition to the array of tools we have at our disposal." Similar comments were made by other ASTM and NASA respondents.

R4. Major differences exist between the two channel user groups in terms of how they first learned about the availability of the documents they requested. Approximately four-fifths (79 percent) of the ASTM sample first learned via announcements sent out by ASTM (e.g., flyers, journal ads, press releases), whereas NASA requesters first learned through a wide variety of sources (e.g., 28 percent via a Tech Brief, 27 percent via an announcement in a trade publication). In other words, ASTM and NASA were reaching into two very different communication networks of potential technology users when they announced the availability of the spot test document.

R5. No major differences in transfer effectiveness exist between ASTM and NASA channel users when their basic type of organization--manufacturing, service, government--is considered. (Seventy-five percent fall into the manufacturing category.)

R6. Substantial differences exist between different types of manufacturing organizations whose members order via the ASTM or NASA channels. In the "primary metals industries" category of the Standard Industrial Classification (SIC) Code, for example, ASTM requesters outnumber NASA requesters 2 to 1; conversely, in the "electrical and electronic machinery" SIC category, NASA requesters outnumber ASTM requesters 2.5 to 1. In other words, the ASTM and NASA channels are reaching into very different manufacturing subgroups. DRI did not compare the transfer effectiveness of the two channels at the level of manufacturing subgroups partly because the number of cases in some of the SIC categories was too small. Until other comparable case studies are conducted, analysis at the micro SIC level does not appear justifiable in terms of expected cost or usefulness.

R7. Substantial differences in the transfer effectiveness of the two channels exists in terms of the jobs held by requesters. Almost half (47 percent) of the ASTM requesters are managers, whereas only about one-third (35 percent) of the NASA requesters are managers. While one-fourth (24 percent) of the ASTM requesters are engineers, one-third of the NASA requesters classify themselves as engineers. Fourteen percent of the ASTM group, but only 8 percent of the NASA group, describe themselves as scientists. In terms of information transfer, 65 percent of the scientists using the ASTM channel, compared to only 30 percent of the scientists using the NASA channel, report moderate or strong interest in the technology. Differences of similar magnitude exist between these two scientist groups on four of the six dimensions of transfer effectiveness examined; interestingly, about three-fourths of the scientists using both channels reported "no difficulty" using the information contained in the documents. The only difference between the two manager groups worth noting concerns estimates of the problem-solving importance of the "spot test" technology: over two-fifths (42 percent) of the ASTM manager group, but slightly less than one-third (32 percent) of the NASA manager group, classified the information as being moderately or quite important to their organizations.

Tentative conclusions. The "joint venture" character of the NASA publication and ASTM republication of the spot test handbook has achieved a combined impact that far exceeds the impact obtainable through either channel in isolation. NASA's purpose, then, in promoting the broadest practical dissemination and use of this technology was enhanced substantially through ASTM's republication. The data suggest that two different potential user groups were reached and that substantial benefits have occurred within both groups. Had the distribution of the technical information been channeled only through ASTM, several hundred persons outside of the ASTM network would not have learned about, or benefitted from use of, the spot test information. This argues both for the continuation of the basic NASA publication effort and for energetic pursuit of opportunities to assist technical societies in republishing information of the sort contained in the spot test handbook.

Future TRIS research on this topic will be to develop recommendations concerning possible republication initiatives that might be undertaken by the Technology Utilization Office.

SECTION VI. TRIS RESEARCH: A LOOK AHEAD*

TRIS research activities are evaluated regularly to ensure their continued relevance to the evolving needs of NASA's Office of Industry Affairs and Technology Utilization (TUO). When possibilities for improving the match between TRIS activities and TUO evolving needs are identified, appropriate modifications are made in TRIS staff and/or informations systems.

During 1975, the TRIS automated transfer file became operational and searches that previously required as much as a day to complete may now be finished in 15 minutes. In addition, the new TRIS service of preparing updated editions for the NASA Benefits Briefing Notebook represents a research and management activity that is very different from the previous activity of preparing technology transfer profile documents. The cumulative effect of such changes for the TRIS Program in the past year are of a magnitude to warrant a review of objectives for the program, particularly in relation to the increasing integration of the Agency's technology utilization activities.

Major TRIS Program Objectives and Procedural Changes

Previous TRIS research created a practical understanding of the major factors that affect the process of transferring NASA technology into nonaerospace applications. Such factors include the type of technical innovation, the communication mechanism employed, and the application context of the recipient. Transfer analysis techniques, models, and information systems have been developed and refined to provide practical research tools for performing transfer research tasks. While technology transfer and related evaluation research may never become a predictive science like physics, the present state-of-the-art is sufficient to perform operational tasks as illustrated by the dissemination, communication, and other special tasks described in this report. Basic research concerning the transfer process will continue as a component in the performance of TRIS tasks, but the research objectives can now be defined by operational requirements since a satisfactory foundation of understanding has been established.

Two other basic activities are key components for all TUO support tasks: data collection and information system maintenance. These are performed by standard procedures that can be adapted to the evolving TUO Program elements such as the planned revision in the Tech Brief format. The data collection activity, however, is considerably broader in scope as a result of the NASA Benefits Briefing Notebook task; the TRIS information system is becoming a central repository for transfer cases from the TUO system as well as other NASA offices. An increasing number

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*Prepared by F. Douglas Johnson.

of transfer cases in the TRIS system are derived from benefits reporting by Industrial Application Centers and from TUO leads for potential cases.

The changes reviewed above are primarily internal to the TRIS operations and, therefore, less apparent than the introduction of new program outputs. In keeping with the output pattern created in 1975, research objectives and products are discussed below for three major areas: program evaluation and support services; policy analysis; and public communication of transfer information.

Program Evaluation and Support Services

This research area includes monitoring the results of TUO dissemination efforts, demonstrating new dissemination package concepts, and providing various services such as new editions for the NASA Benefits Briefing Notebook and information system searches requested by TUO or its contractors. In part, the objectives for this area have been changed only by placing an increased emphasis on special searches and increased coverage for the monitoring activities.

Three new information packaging activities were introduced in 1975: a notebook containing benefits information and two dissemination demonstrations. Specific aspects for each of these activities were presented in Section III. As a regular service task involving discrete transfer examples, the notebook caused an increase in the data collection activities. A primary objective in collecting these data has been to develop transfer examples that can be used in more than one task (e.g., notebook and program evaluation). A secondary objective has been to identify dissemination opportunities for one or another of the TUO programs.

The Solar Energy Demonstration Package will be tested and evaluated during the first six months of 1976. The objective of this and other new dissemination package tasks will be to provide TUO with a market-tested package complete with samples, reproduction copies, test results, and a plan of action for dissemination. This activity is limited to new dissemination concept development and demonstration, as contrasted with repeated applications of the same package concept using different subjects.

In general, the pattern for TRIS activities in this area is one of specific relevance to TUO's operating programs and their evaluation.

Policy Analysis

Policy issues are identified from time to time during the performance of other tasks or may be suggested by TUO as the subjects for analysis. The results of previous policy analyses by TRIS have appeared in various forms (e.g., annual reports, memoranda, informal reports). To some extent, this has decreased their retrievability for TUO. As greater emphasis is placed on integrating the TU program elements, formal reports of policy analyses and increased emphasis on issue identification may become useful. The objectives in this area include (a) preparation of advisory memoranda for all significant issues identified during TRIS tasks; and (b) preparation, at TUO's request, of policy study documents complete with an overview of the issue, relevant data, analytic results and recommendations. Another objective is to aggregate previous policy studies by TRIS and others so that a historical perspective is available for TUO review.

Public Communication of Transfer Information

During the past year, TRIS staff members published articles and gave speeches for special interest audiences (e.g., American Society of Safety Engineers). Transfer examples from the information system, together with other materials, were used to illustrate technological change resulting from the space program. In some instances, communication opportunities also were used to inform audiences about TUO dissemination programs. Such opportunities have been identified during the performance of other tasks as well as by contacting the specialized publications that serve particular audiences. Another type of communication opportunity is available by providing writers and speakers with relevant transfer case documentation.

A major problem for any type of public communication is the translation of transfer case documentation into a language that the particular audience can understand. Many citizens, for example, have expressed an interest in how they have benefited from the tax dollars spent on the space program. Such interests can be satisfied, in part, by plain-English descriptions of transfer examples. Different perspectives may be required in the treatment of transfer information (e.g., social, industrial, technical impacts); in addition, non-technical descriptions of technology are generally necessary.

The objectives for this area include: (a) identification of and response to specific communication opportunities with special interest audiences; (b) development of general guidelines for the preparation of public communication materials from TRIS documentation; and (c) assessment of the potential for different types of public communication (e.g., articles, basic speaking packages, assistance to television writers). Wherever appropriate, communication packages will also inform the audience about TUO dissemination programs and how to use them.

Summary

The results of previous TRIS research, the extensive information system, and the broad-based data collection activity have been applied in a variety of new tasks directly related to operational TUO program elements. For new initiatives that provide useful output for TUO, the next step will be to reduce the task performance to a standard process so that additional initiatives can be tested and developed. In this fashion, the range of demonstrated options for TUO can be routinely expanded in a prudent manner.

APPENDIX A

TRIS INFORMATION MANAGEMENT SYSTEM

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TRIS INFORMATION MANAGEMENT SYSTEM*

A major activity in 1975 involved the development and implementation of a new, comprehensive TRIS Information Management System (TRIS-IMS) for more effective handling of technology transfer information. This activity, when completed, will aggregate several large data base systems developed during the past six years to support the basic activities of the TRIS Program. These data systems collectively provide the foundation for program output (e.g., technology transfer profiles, case studies, the NASA Benefits Briefing Notebook); in addition, they are used in a variety of ways by NASA Headquarters and field center personnel (e.g., responding to Congressional inquiries, preparing professional papers, completing special studies).

In mid-1974, a decision was made to convert these data systems to MIRACODE II**--an automated microfilm storage and retrieval system. This system, which employs a machine-readable code capability, provides: (1) an efficient and rapid means for locating specific transfer information; (2) an easy means for data file expansion; and (3) readily available "hardcopy" output.

The first phase of the MIRACODE conversion effort involved the TRIS Technology Transfer Example Files (TEF). The TEF subsystem contains 600 separate TEF's, involving over 1,300 individual transfer cases, with each file based on a specific item or type of technology (e.g., anti-fog coating, computer programs to analyze combustion, heart pacemakers). Each file contains information on the NASA technology and its use in meeting mission objectives; all available documented transfer cases and supporting materials (e.g., product literature, photos, letters, articles); and all available general materials such as negative follow-up reports, file memos, magazine and newspaper articles, Congressional testimony and technical papers.

Given the variety of uses for the material in the TEF subsystem, a detailed indexing scheme was developed to provide for highly selective access to transfer case information. The 13 code categories are identified and described in Figure A-1.

Within each TEF, three types of information are indexed in the TRIS-IMS: (1) the NASA document; (2) the TEF Summary; and (3) all documented transfer cases, including BATeam, TATeam and RDC cases. All other TEF materials were simply filmed behind the coded items. Table A-1

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*Prepared by Eileen R. Staskin.

**Equipment produced by Eastman Kodak Company.

FIGURE A-1. IMS CODE SCHEME
FOR THE TEF SUBSYSTEM

CODE CATEGORIES	DESCRIPTION
TEF Number	The distinct accession number for each file
Document Number	The NASA document(s) associated with the TEF (e.g., Tech Briefs, Special Publications, Contractor Reports, Technical Notes)
NASA Center	The NASA installation(s) associated with the TEF as the originator of the technology or the contracting agent
TEF Summary	A general description of the NASA-developed technology, its role in meeting mission objectives, and one or more cases of non-aerospace applications (completed for only 258 TEFs)
Date	The date each transfer case or TEF summary was prepared
Transfer Stage	The stage of application activities associated with the transfer case (e.g., initial awareness and review, full-scale marketing)
Company Name	Organization or individual involved (e.g., company, institution, agency, individual)
State	Location of the organization
License or Waiver	The NASA license or waiver (if any) associated with the transfer case
Transfer Mechanism	The linkage mechanism(s) between the use and the technology (e.g., Tech Brief, trade press, personal contact)
Use of Technology	The organization's purpose(s) in using the technology (e.g., to improve a product, to provide a service)
Benefits	Benefits derived from use of the technology (e.g., produced or increased sales, cost savings, time savings)
Application/Technical Subject Areas	Selected terms for describing the technology, application(s) of the technology, and, to the extent possible, the type of organization (e.g., plastics manufacturer)

illustrates how the code scheme categories were utilized in converting the TEF material to the automated system.

TABLE A-1. CODE SCHEME CATEGORIES
UTILIZED ON TEF MATERIAL

CODE CATEGORIES	NASA DOCUMENT	TEF SUMMARY	TRANSFER CASES	GENERAL MATERIALS
TEF Number	X	X	X	
Document Number	X	X	X	
NASA Center	X	X	X	
TEF Summary		X		
Date		X	X	
Transfer Stage			X	
Company Name			X	
State			X	
License or Waiver			X*	
Transfer Mechanism			X	
Use of Technology			X	
Benefits			X	
Application/Technical Subject Areas		X	X	
FILMED ONLY				X

*If applicable

The application of this index for developing "information packages" is extremely diverse. Routine questions can be answered by using only one or two of the code scheme categories. Thus, for example, the TRIS-IMS can identify all transfer cases related to a particular NASA Tech Brief, or all fire safety-related transfer cases in the State of California. When more complex information is required, however, a combination of code terms can be used to sort the materials. The TRIS-IMS, for example, can identify all transfer cases involving fire safety-related Tech Briefs developed at Ames Research Center that are being used to improve the construction of new buildings in the State of California. Regardless of the complexity of the questions being asked, the new TRIS-IMS greatly reduces the amount of time involved in finding answers: searches that formerly required days or weeks of effort now take from just a few minutes to only a few hours to perform.

The second major data base to be converted to the TRIS-IMS is the General Subject File (GSF) subsystem. The GSF subsystem contains newspaper and magazine articles, NASA press releases, speeches, and commercial or governmental pamphlets and brochures on a variety of technical subjects (e.g., bioinstrumentation, welding technology, fire safety, pollution, transportation).

This conversion effort was initiated in the fall of 1975 and is expected to be completed in late 1976. The code categories used are identified and described in Figure A-2.

FIGURE A-2. TRIS-IMS CODE SCHEME FOR THE GSF SUBSYSTEM

CODE CATEGORIES	DESCRIPTION
Source of Information	The type of publication or source (e.g., trade press, professional journal, regional/local newspapers and magazines, papers, speeches)
Date	The publication or release date noted on the material
Document Number	The NASA document(s) if specifically identified in the material
Application/Technical Subject Areas	Selected terms for describing the information presented in the material (same list of terms from the TEF code scheme)

When the two subsystems are used in conjunction with each other, comprehensive benefits information packages will, for the first time, become readily accessible in a systematic way. Interested parties will not only have access to specific DRI-developed transfer case information but, also, to all other DRI-collected materials bearing on the same subject. While this capability will greatly enhance TRIS Program activities, it will also enable NASA's Technology Utilization Office to provide improved services to Agency personnel and to persons outside the Agency who are interested in the technical and economic impacts of NASA-developed technologies.

APPENDIX B

REVIEW OF 1975 TRIS DATA BASE RESEARCH ACTIVITIES

APPENDIX B

REVIEW OF 1975 TRIS DATA BASE RESEARCH ACTIVITIES*

Data base activities conducted under the Transfer Research and Impact Studies (TRIS) Program during the period of January through December 1975 are reviewed in this appendix.

Tech Brief-Technical Support Package Program

During 1975, NASA received 18,721 requests for Technical Support Packages (TSP's) from persons seeking additional information on technology described in NASA Tech Briefs. The three major mechanisms used for generating those requests are the regular Tech Brief (TB) distribution system; Technology Utilization Compilations (TUC's); and Small Business Administration (SBA) publications which announce the availability of NASA Tech Brief-TSP documents.

TSP requests generated by the TU Compilations and SBA publications totaled 9,831 (53 percent); the other 8,890 resulted from regular Tech Brief distribution. As Figure B-1 illustrates, the TSP requests received during 1975 were fewer than one-half of the requests received during the final six months of 1974. This probably was due to the fact that the number of requests resulting from the distribution of TUC's and SBA publications declined sharply in 1975; it should be noted that the number of requests generated via the regular Tech Brief distribution held fairly steady during the 18 month period analyzed. The dramatic increase in TSP requests during October-December 1974 is attributed primarily to the dissemination of several TU compilations in mid-to-late 1974.

A review of TSP requests resulting from all three mechanisms from 1969 through 1975 shows a slight, but definite, increase in the number of requests resulting from regular Tech Brief distribution (see Figure B-2). The rise in SBA-initiated requests during 1972 was the result of a new SBA publication series entitled, Current Index of Technical Briefs (C1 Series). This series produced 26,840 requests in 1972, 28,499 in 1973, and 3,712 in 1974.

While TU Compilations and SBA publications have had a positive impact on the level of TSP requests received by NASA during the seven-year period, their impact has been of a sporadic type: sharp increases in demand followed by major declines. Nonetheless, their contribution to the accomplishment of OTU dissemination objectives has been significant. Since their introductions in 1970 and 1971, the SBA and TUC publications have accounted for approximately three-fourths of all TSP requests.

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*Prepared by Nancy G. Gundersen.

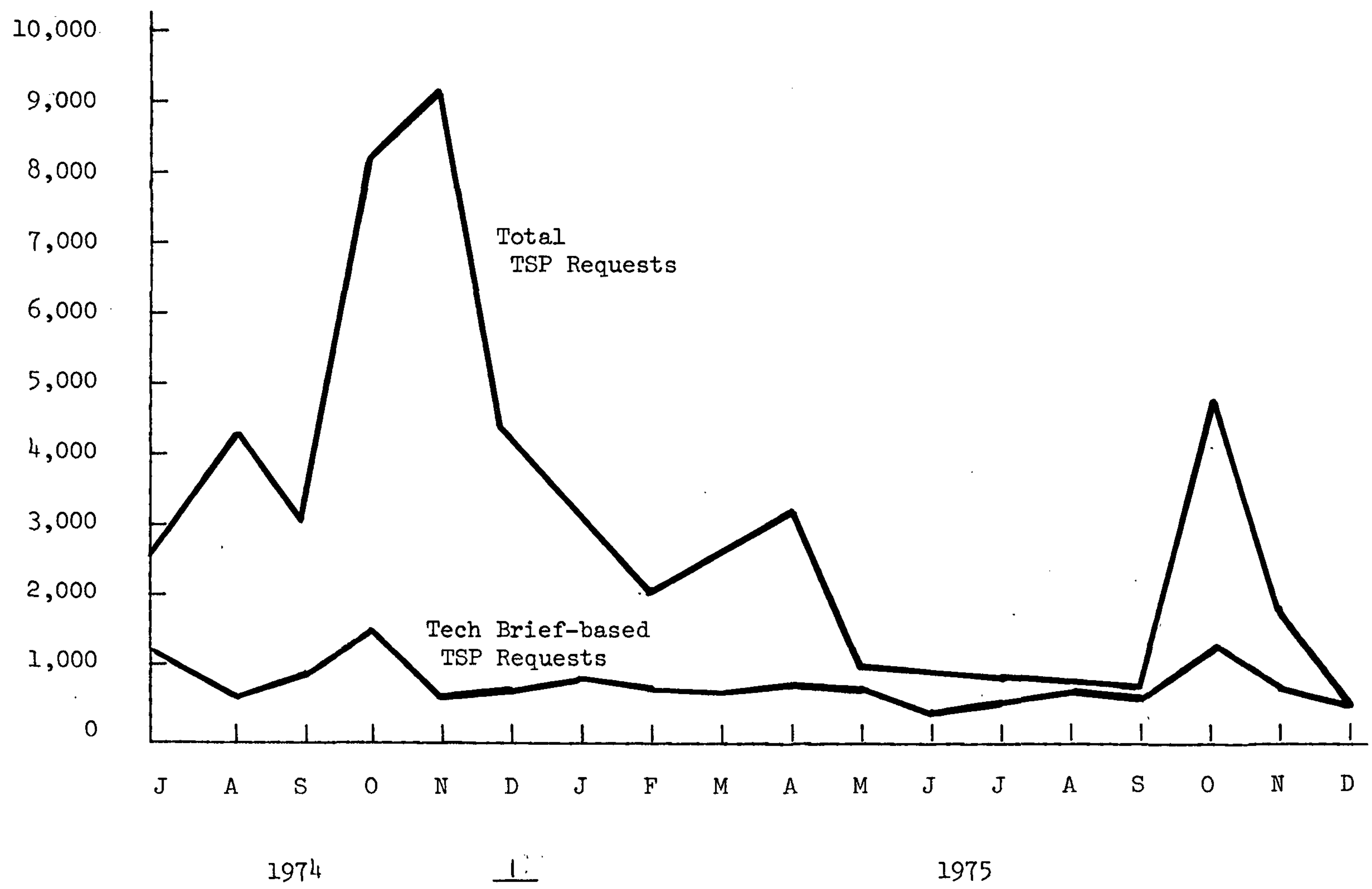

FIGURE B-1. Monthly TSP Requests Resulting From the Distribution of SBA Publications, TU Complications, and Tech Briefs During July 1974-December 1975.

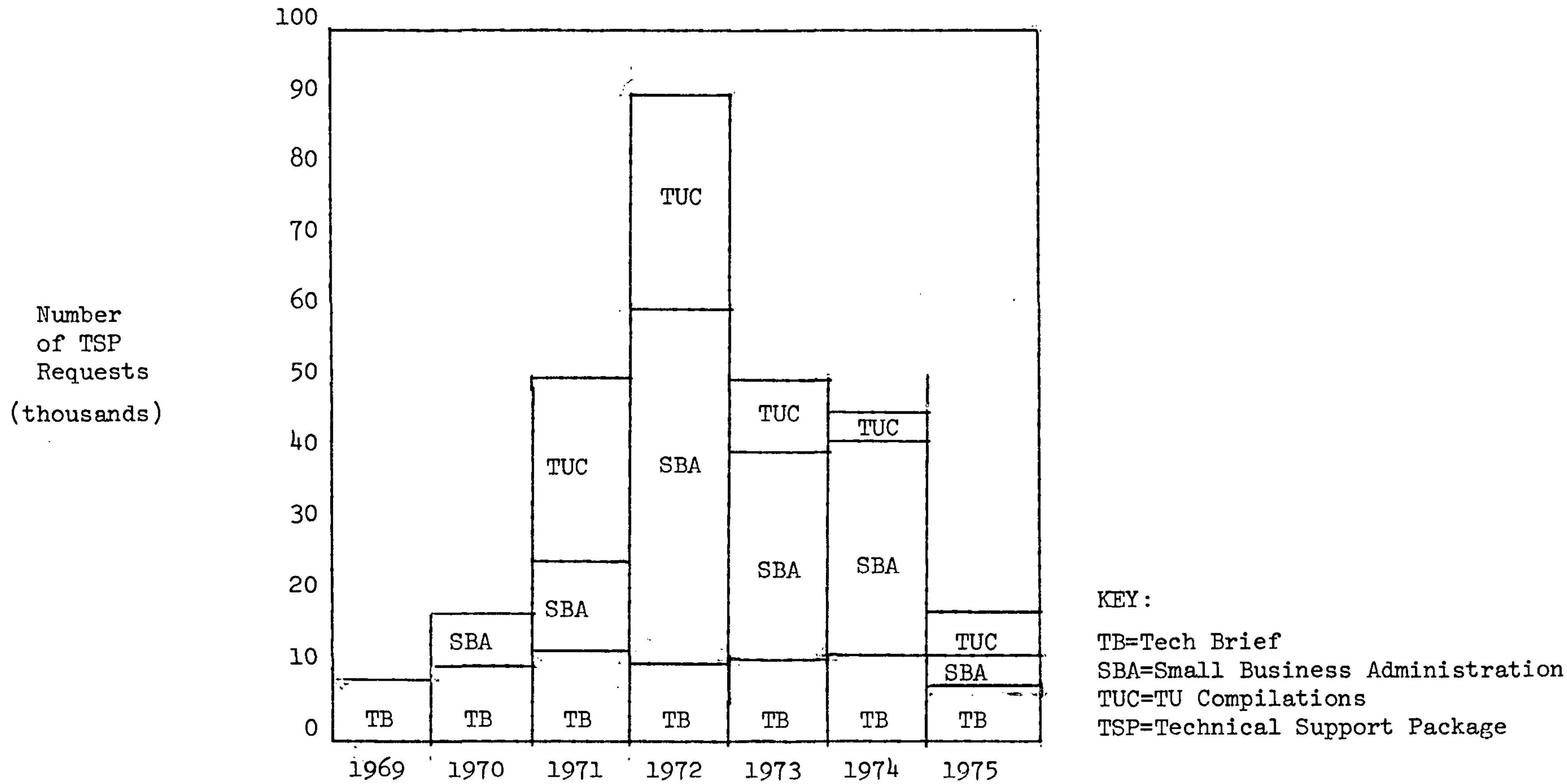

FIGURE B-2. Annual Number of TSP Requests
by Channel: Tech Briefs, SBA
Announcements, and TU Complications.

Transfer Documentation Activities

TSP requests that are generated through the regular Tech Brief distribution system are forwarded to TRIS by the NASA field centers for incorporation in the transfer data bank and subsequent transfer documentation activities. From the inception of the TRIS Program in November 1967 to January 1976,* 114,850 cases had been entered into the transfer data bank. More than 98 percent of these cases were derived from TSP requests; the remaining cases resulted from other sources, such as contractor commercialization activities and news clippings.

Table B-1 identifies the 10 Technical Support Packages most frequently requested since 1967. These 10 TSP's account for 10 percent of all TSP requests contained in the TRIS transfer data bank!

To obtain information concerning the application of NASA-generated technology, questionnaires are mailed to approximately 40 percent of the TSP requesters six months after the date of their request. This period has been shown to be sufficiently long to allow TSP users to reach tentative conclusions concerning applications for the technologies. During 1975, TRIS distributed 2,921 questionnaires, of which approximately 73 percent were returned. Of the 40,240 questionnaires mailed out since 1968, 64 percent have been returned. This response rate, which is considered excellent for mail questionnaire surveys of this type, provides TRIS staff with ample material for subsequent follow-up and transfer analysis. The more fully developed areas of technology transfer resulting from such research are entered in the TRIS Transfer Example Files (TEF's) described in Appendix A of this report.

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*The original name of this program, the Project for the Analysis of Technology Transfer (PATT), was changed to the Transfer Research and Impact Studies (TRIS) Program in 1972.

TABLE B-1. TEN MOST FREQUENTLY REQUESTED TSPs: NOVEMBER 1967-DECEMBER 1975

Tech Brief-TSP Number and Title	Number of Requests
73-10156, A Practical Solar Energy Heating and Cooling System	2,248
67-10200, Workmanship Standards for Fusion Welding	1,614
70-10520, Nondestructive Spot Tests Allow Rapid Identification of Metals	1,256
68-10392, Contamination Control Handbook	1,160
68-10069, Principles of Optical-Data Processing Techniques	1,003
73-10322, Characteristics of FORTRAN	896
67-10197, New Class of Thermosetting Plastics Has Improved Strength, Thermal and Chemical Stability	859
73-10062, Lubrication Handbook	768
73-10373, Materials Data Handbooks on Aluminum Alloys	766
73-10448, Motivation Techniques for Supervision	758
TOTAL	11,328

APPENDIX C

ENVIRONMENTAL SCIENCE AND TECHNOLOGY ARTICLE

8070

Environmental
Science & Technology

Monitoring the environment

Conrad F. Heins F. Douglas Johnson Edward C. Mangold

Volume 9, Number 8

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Spectroscopic instruments, satellites and computers: new directions for

Monitoring the environment

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Georgia recently prepared a map which, for the first time, located all of that state's more than 35,000 lakes, reservoirs, ponds, and lagoons larger than five acres. One man constructed the map in less than a week using imagery obtained from the earth resources satellite, LANDSAT (formerly called ERTS). It was estimated that comparable work on the ground would have cost well over $1 million and would have taken several years to complete. This example depicts one important trend in environmental measurement—the use of satellite remote sensing. It also suggests the amount of activity in the area.

At all levels of government there is an unprecedented demand for comprehensive, accurate, and timely information on the environment. As a result, new and greatly improved ways of obtaining environmental data are being developed to meet the demand. This article examines four developments that are transforming the entire field of environmental measurement:

- spectroscopy
- satellite transmission of environmental data
- remote sensing
- computerized data processing.

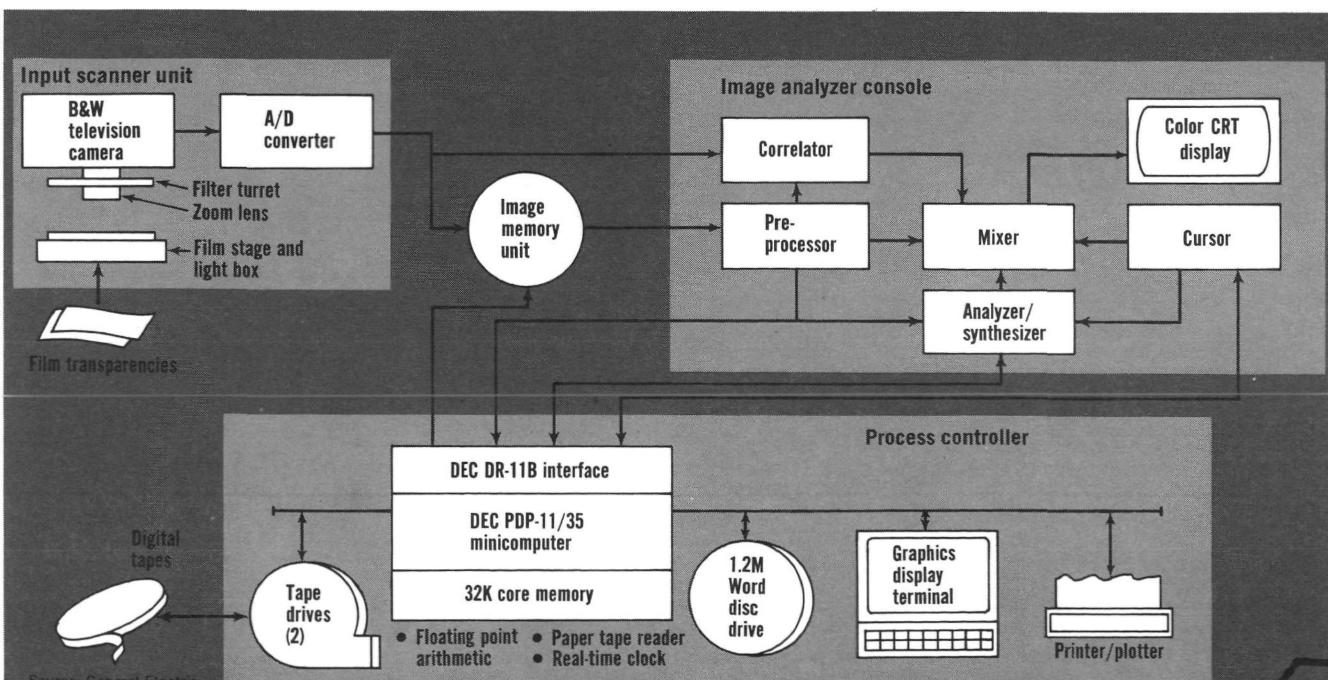
A few examples for each development have been chosen.

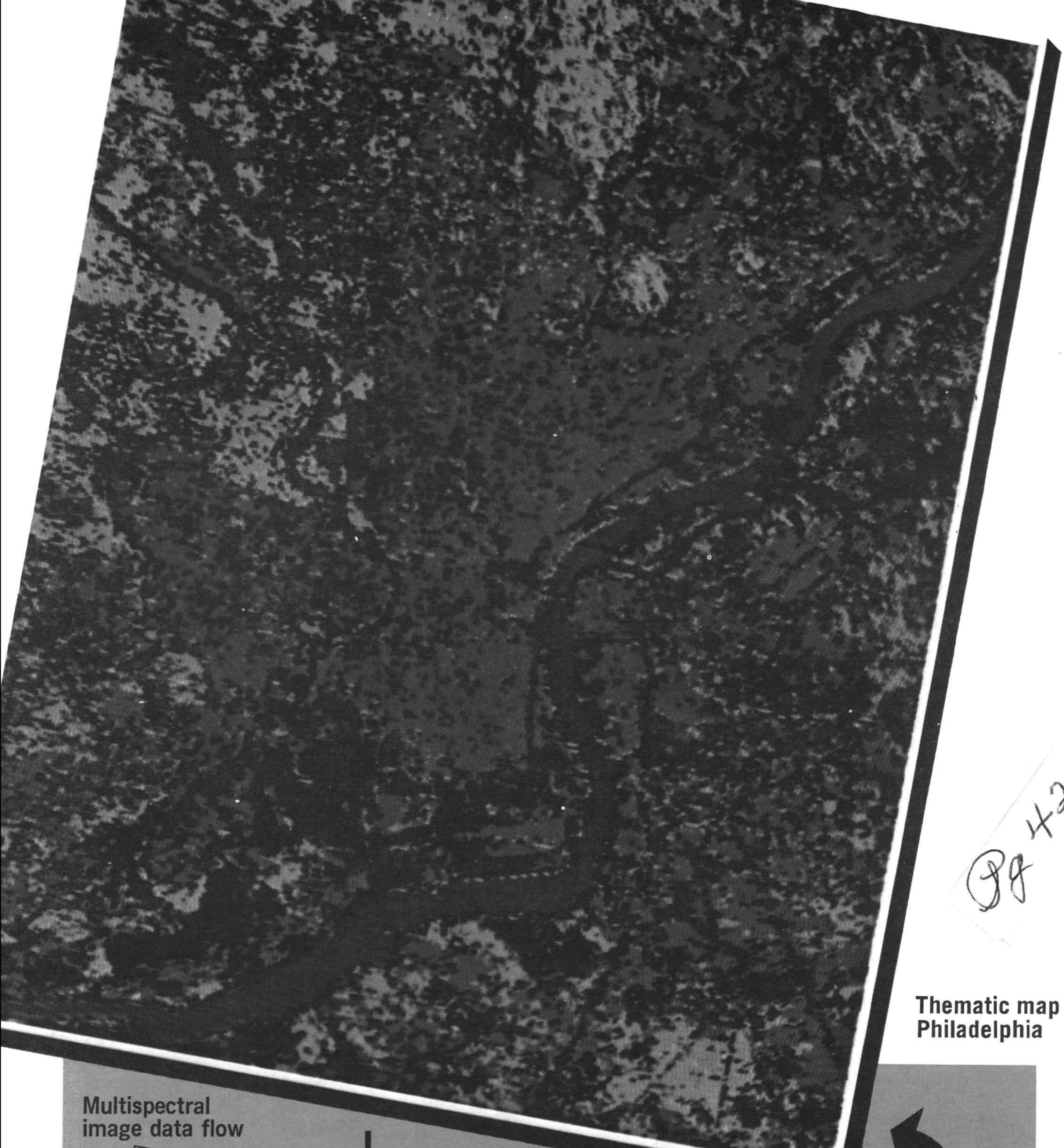
Reasons for change

A complex mixture of legislative, technological, and resources management factors are responsible for the trends we are observing. Legislation has generated a need for environmental data on a vastly greater scale than has hitherto been required. A brief review of this legislation reveals the extent to which environmental quality has become a key governmental concern, and that the need for environmental information is increasing rapidly for government regulators as well as industry.

The Water Quality Control Act of 1965 provided for water quality standards to be enforced by the federal and state governments. The Water Pollution Control Act Amendments of 1972, which focused on effluent limitations, set two broad national goals: to achieve by July 1, 1983, a level of water quality that protects fish, shellfish, wildlife, and recreation; and to eliminate the discharge of all pollutants into navigable waters by 1985.

Far-reaching legislation has also been enacted to deal with air pollution. The Motor Vehicle Control Act of 1965 established the authority to set emission standards for automobiles. The Clean Air Act of 1970 required uniform national air quali-





Thematic map of Philadelphia

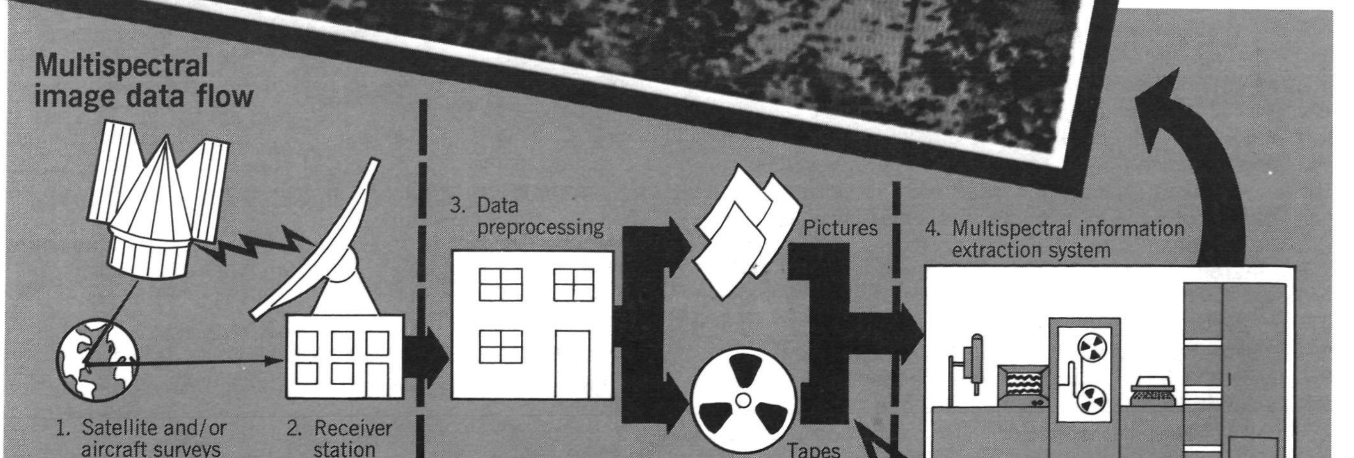
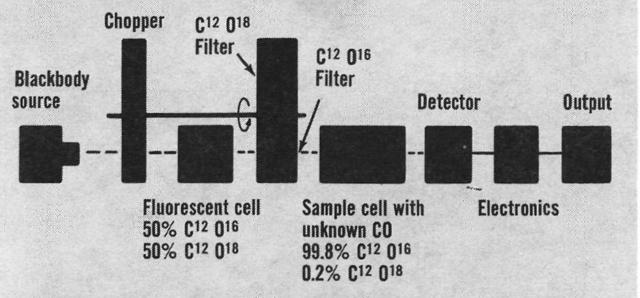


FIGURE 1

Dual isotope fluorescence carbon monoxide monitor



ty standards of two types—primary standards, which define the level of air quality necessary to preserve human health, and secondary standards, which are designed to promote the public welfare and prevent damage to animals, plant life, and property.

State and local governments have passed environmental legislation that in some cases is even more stringent than federal requirements. The California vehicle emission regulations are tighter than those for the rest of the nation. Delaware vetoed the construction of a supertanker port facility in the Delaware Bay partly on the basis of its strict water pollution control requirements.

The demand created by these laws simply could not be met by then existing instrumentation. Legally mandated environmental quality had clearly outrun the available technology. The gap was especially noticeable in measurement, the crucial parameter for legally enforced pollution standards. New techniques, instruments and apparatus were required.

Spectroscopic instruments

The Clean Air Act of 1970 generated a demand for rapid, sensitive and reliable measurements of atmospheric pollutants that provided much of the impetus for a major shift in measuring techniques. Wet chemical procedures were replaced by advanced spectroscopic methods. Spectroscopy measures pollutant concentrations by analyzing the effects of pollutant molecules on electromagnetic radiation—ultraviolet, visible, infrared and microwave. Although its potential has been recognized since the 1940's, only within the last decade have new spectroscopic techniques and advanced optical components been developed to make spectroscopy suitable for use in routine monitoring.

A key problem with spectroscopy has been one of specificity. The spectral fingerprint of a molecule consists of an array of emission or absorption lines. When two or more different kinds of molecules are present, lines can overlap and give spurious readings. This problem is particularly acute when the molecules of interest are present in very low concentrations, as is typically the case with air pollutants. The development of several new spectroscopic instruments illustrate the response to air monitoring needs.

The Akron Scientific Laboratories (now Andros, Inc.) of Berkeley, Calif., provided an ingenious solution to the problem of specificity in its development of a highly sensitive (0.1 ppm) carbon monoxide monitor for Skylab. The instrument utilizes the principle of dual isotope fluorescence (see Figure 1).

Gas samples do not have to be conditioned for the dual isotope unit because the effect of water vapor and other contaminants is eliminated by using one isotope to produce a reference beam. Similarly, performance is not degraded by dirt or condensation from the atmospheric sample—as much as 50% reduction in transmissivity can be tolerated.

In 1972, a commercial version of the Skylab monitor was developed. A built-in zero point calibrator was added, slight design changes were made to meet EPA specifications, and the unit was marketed. In 1973, Andros sold this product line to Beckman Instruments, Inc. Beckman is selling the units as they were designed at Andros for approximately $6,800, and is concurrently developing product design improvements.

More than 30 of the instruments have been sold to government agencies and industrial firms. The California Air Resources Board and the EPA are using the units for ambient, airborne, and automotive emissions air monitoring. For example, the EPA used the instrument on a helicopter to measure the CO profile in the Los Angeles basin: no other existing CO analyzer could have been used in this fashion.

A spectrophotometer that measures the concentration of atmospheric pollutants in vehicle exhausts was developed by Chrysler Corp. with technological expertise the company gained in designing the Hazardous Gas Detection System for the Saturn-1B stage at the Marshall Space Flight Center's Saturn Systems Development Breadboard Facility, a facility the Chrysler Huntsville Division installed and has operated since 1961. The dispersive infrared vehicle exhaust analyzer is being used by both the EPA and the State of California for vehicle emission analysis. The major advantage of this unit is that it simultaneously measures the concentrations of CO, CO_2, and hydrocarbons in a single sample.

By 1973 Chrysler had sold about 70 of these units at prices ranging from $15,000 to $50,000 depending on what specific instrumentation and automation components were used. The company's automobile division and General Motors, for example, are using these analyzers to test new car emissions both in their research laboratories and after production. The spectrophotometer has also been incorporated by Chrysler in a computer automated testing system for automotive emissions.

Satellite transmission

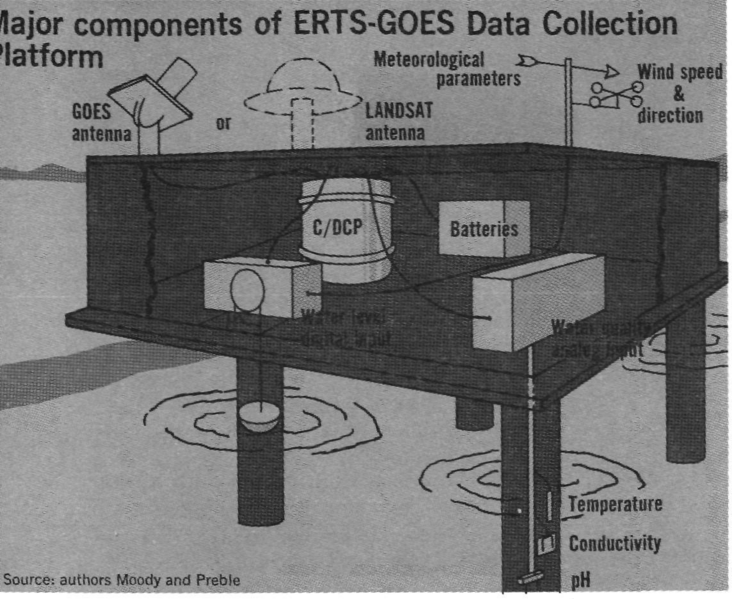
A second trend is the use of satellites to relay environmental data obtained from remotely located, automated data collection systems. Automated data collection platforms are not new. The U.S. Geological Survey uses thousands of them to monitor lake and river levels for the National Weather Service's river stage forecasts and other hydrologic applications. What is new is the use of satellites as active relay stations to permit critical information to be obtained reliably and relatively inexpensively on a near real-time basis.

The first broad scale testing of the feasibility of the satellite approach was undertaken as part of the LANDSAT program. It has proved so successful, that, with the launchings of additional satellites, agencies responsible for resources management such as the U.S. Geological Survey and the Army Corps of Engineers are gearing up to use satellite transmission on an operational basis.

NASA's Goddard Space Flight Center, the part of the agency with overall responsibility for the LANDSAT mission, funded the General Electric Co. to design and build about 220 Data Collection Platforms (DCP's) that collect and transmit data in digital form from sensors measuring up to eight different parameters. Table 1 lists the applications made by various users.

A simple timing mechanism was built into the system so that every three minutes a burst of data is transmitted. Receiving stations are located at Goddard Space Flight Center near Washington, D.C., and Goldstone, Calif. Figure 2 illustrates the overall data collection system.

In some cases the system is being used on an operational



ajor components of ERTS-GOES Data Collection latform

Source: authors Moody and Preble

basis. Canada's Department of the Environment, for example, is using DCP's to obtain data on water level and ice break-up from remote regions of the country. The U.S. Geological Survey in Miami, Florida, responsible for managing the highly complex water system of south Florida, has found satellite transmission to be the most practical way to obtain hydrologic data on a near real-time basis during the critical period when a storm is moving into the area, and direct ratio transmission is poor and unreliable.

A second generation of the data collection platforms is being developed to take advantage of the transmission capabilities of the Geostationary Operational Environmental Satellites (GOES), launched for the National Oceanic and Atmospheric Administration (NOAA). Unlike LANDSAT, which is primarily an experimental satellite, the NOAA satellites are part of an operational program to obtain hydrological meteorological, and oceanographic data. Two satellites are already in orbit, one over the Atlantic at about 45° W longitude and the other over the Pacific at about 120° W longitude. A total of five planned satellites will provide overlapping coverage of all but the most extreme polar regions of the globe. The data transmitting capabilities of GOES will also be available to other agencies through a memorandum of agreement with NOAA's National Environmental Satellite Service.

A number of companies are now making collection systems that utilize the GOES satellite. The Magnavox Corp. in Fort Wayne, Ind., is fabricating GOES Compatible Systems for the National Weather Service. Dorsett Electronics, in Tulsa, Okla., was recently awarded a contract by the U.S. Geological Survey to build 150 platforms that will be able to utilize either LANDSAT or GOES. Ball Brothers Aerospace in Boulder, Colo., also manufactures LANDSAT/GOES compatible systems. Now that the Department of Commerce has made the commitment to provide an operational as opposed to an experimental satellite system, other agencies and user groups are making the change over to this new technology for their own operational programs.

Table 1. Experimental applications for LANDSAT data collection platforms

Applications	No. of users	No. of platforms assigned
Hydrology	20	75
Volcanology	2	33
Water quality	4	26
Meteorology	5	10
Oceanography	3	9
Forestry	1	3
Agriculture	1	3
Arctic environments	1	2

Remote sensing

The use of remote sensing techniques to measure pollutants and monitor environmental quality, while still in its infancy, offers great promise. The problems inherent in remote sensing as a way of obtaining quantitative information are formidable. Much progress has been made, however, in the development and practical utilization of both ground-based and aircraft- or satellite-based instruments.

Correlation spectrometry. The use of passive measuring spectrometers for qualitative measurements of gas pollution concentrations is developing on several fronts. Barringer Research, Ltd. in Ontario, markets a correlation spectrometer that uses sunlight scattered from molecules in the atmosphere to measure concentrations of SO_2, NO_2, or CO. A key feature of the selective, highly sensitive instrument is a mask containing slits corresponding to the absorption lines of the gas to be measured.

The gas concentrations in an individual smokestack plume can be determined from a distance of hundreds of yards with the correlation spectrometer. The quality of gas above a given ground point can be monitored from a moving automobile by positioning the instrument to look vertically upward. The total vertical concentration of an entire metropolitan area can be estimated by driving for a few hours on the city's freeways. These vertical concentrations can then be compared to the predictions by mathematical atmospheric diffusion models for the area.

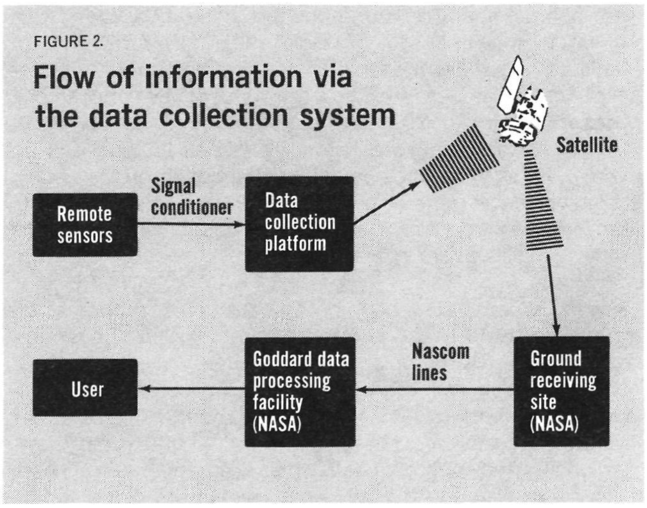


FIGURE 2.
Flow of information via the data collection system

By late 1973 Barringer had sold 38 correlation spectrometers at prices between $23,000 and $24,000 each. Pollution control agencies in the U.S., Canada, Australia, Japan, the Netherlands, France, and Spain are using the instrument to develop pollution control strategies for major metropolitan areas.

Infrared sensors. The use of the thermal infrared emission of stack gases against a cold sky background has been made by both spectrometers and interferometers. To achieve high-spectral resolution and simplify the data reduction, a gas filter correlation spectrometer was developed by Science Applications, Inc., in La Jolla, Calif. In addition to providing high-spectral resolution for greater discrimination against interfering gas species, this design approach allows for a lightweight, portable instrument that can be easily operated as a field monitoring device by a technician.

LIDAR systems. To achieve greater accuracy and over-come the limitations of using natural light sources, active sensors that use powerful lasers to excite and illuminate the target have been developed. The most direct use of these LIDAR (light detection and ranging) systems is to measure opacity of smoke plumes emitted from smokestacks. Smoke plume opacity is an important legally enforceable parameter that can be measured more accurately by a LIDAR than by a human observer who is subject to uncertainties because of lighting conditions.

By an analysis of the Doppler shift of the light as it scatters off the smoke particles, the velocity of gases coming from the stack can be measured to determine the total quantity of gas emitted.

LIDAR instruments in aircraft can monitor the total gas burden between the aircraft altitude and the ground for an entire metropolitan area. Such measurements are presently being made for the St. Louis Regional Air Pollution Study.

LANDSAT-1, launched by NASA less than three years ago, has demonstrated the enormous potential for using satellite-based sensors to monitor the environment. Satellite imagery is unique in a number of ways. For one, it is synoptic; one LANDSAT picture covers more than 10,000 mi^2. A vast amount of simultaneous data can be collected to study a variety of phenomena. The same imagery used by a hydrologist to estimate snowpack, for example, might also be used by a botanist to help determine the effects of smog on the vegetation of the area. Satellite coverage is repetitive; LANDSAT passes over the same spot at the same time of day every 18 days. Thus, comparative data over a period of time can be obtained. Finally, satellites provide global coverage that would be prohibitively expensive by any other means. However, the broad overview requires a sacrifice in spatial resolution and greater sophistication in the extraction of specific information.

It was demonstrated early-on that the multispectral scanning imagery of LANDSAT could be used to monitor phenomena such as ocean dumping. Figure 3 is an August 16, 1972, LANDSAT image of the New York Bight, a corner of the Atlantic used extensively as a dumping ground for wastes for the New York metropolitan region. Over 10,000 yd^3 of sewage sludge are disposed of daily in an area about 12 mi south of Long Island. In addition, acid-iron wastes are dispersed by barge over a hairpin-shaped course in the same region.

The photograph clearly shows the acid wastes and somewhat more dimly the sewage sludge. Scientists at the Environmental Research Institute of Michigan analyzed the imagery to extract considerably more information, such as the water mass boundaries and even the relative depth of the sewage sludge. The broad-scale data from satellites can be integrated with information from laboratory analyses to improve environmental monitoring significantly.

Computerized data processing

A much greater potential for satellite sensing is beginning to be realized with the development of specialized computer programs for data interpretation. The use of computers will become increasingly important in the next few years as more agencies begin to use vast quantities of satellite data on a routine basis, and as orbiting sensors become more sophisticated. Already the accomplishments have been noteworthy.

The Johnson Space Center developed a program that identifies bodies of water 10 acres or larger by using LANDSAT data in the form of digital imagery (computer compatible tapes) and photographic images. The program prints out the information as variable scale overlays for use with conventional topographical maps. It was used by four regional districts of the U.S. Army Corps of Engineers to verify their recently completed inventories of dams over 6 ft in height. These inventories were required by Congress under the National Program of Inspection of Dams (PL 92-367). The use of satellite data for this application was highly cost-effective, in some cases reducing the cost of verification by a factor of 10.

The Texas Water Development Board is planning to use the computer program to study and monitor playa lakes in six counties of the high plains area of Texas. The shallow lakes are left from rain storms and, although short-lived, they number in the tens of thousands. Repetitive satellite monitoring should permit the agency to determine the temporal and spatial distribution of lakes. The possibility exists for using them for irrigation or even for helping to replenish the underground Ogalalla aquifer, the life blood of the region, which is being drawn off for irrigation faster than it is being recharged.

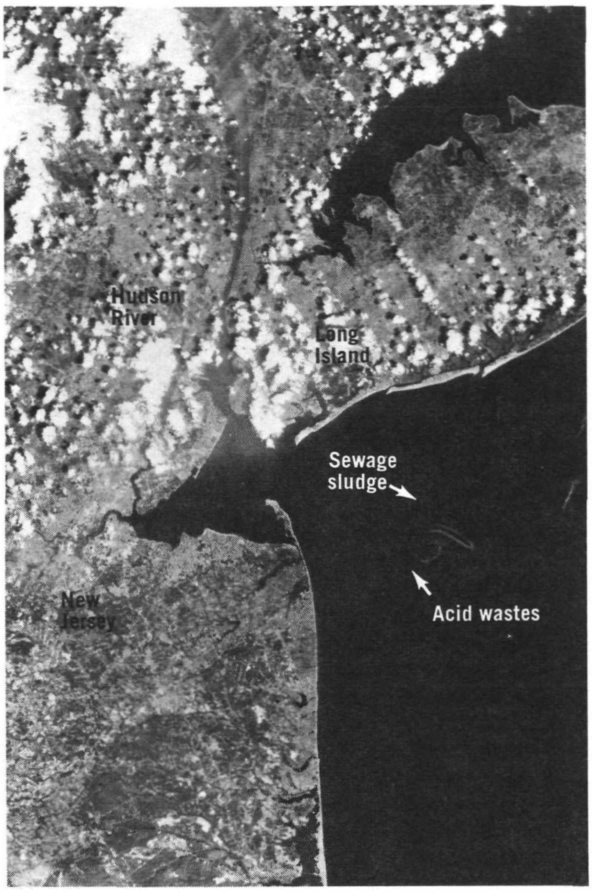
The Jet Propulsion Laboratory, working with EPA's National Environmental Research Center in Corvallis, Ore., has adapted software for lunar and planetary exploratory data analysis in order to characterize the water quality of inland lakes by using LANDSAT multispectral scanning data. The program provides a color printout of the lake in which each picture element (representing about one acre) is given a color ranking according to relative trophic status. LANDSAT classifications have correlated well with classifications based on lake samples obtained on or about the day of the LANDSAT overflight. The approach is particularly applicable to regions containing a great many lakes such as Florida, Minnesota, and Wisconsin. It promises to provide a rapid, inexpensive way for states under federal standards to obtain a broad scale classification of the trophic status of their lakes.

A computer program for land use classification was recently employed by EPA scientists to inventory the land usage status of strip coal mines in the Northern Great Plains. The acreages of mined area, spoils piles, regraded and revegetated land were determined by using LANDSAT digitized imagery data.

Because of the extensive computer operations required to process the vast amount of data being made available through satellite measurements (a single LANDSAT image, for example, contains 8 million picture elements), dedicated computer systems have been developed to use special purpose circuitry for extracting thematic information from multispectral scanning data. For example, General Electric, in Daytona Beach, Fla., developed its IMAGE 100 processor that accepts photographic and/or digital imagery data, and displays the output on a color video screen or records the information with a printer/plotter or color film recorder. Because it involves near real-time interaction with the user who can control or modify the analysis process using his own knowledge, the system has great flexibility and can quickly extract thematic information that matches the user's needs.

Half a dozen of the IMAGE 100 systems are in the field and others have been ordered. Customers include the Jet Propulsion Laboratory, the Johnson Space Center, the Canada Centre for Remote Sensing, and the Brazil Space Research Institute. At about $450,000 installed, however, the units are not for everyone. General Electric also provides, at their facilities in Beltsville, Md., IMAGE 100 processing services for multispectral imagery to a growing number of customers. For example, a crop acreage inventory of 48 million acres in the San Joaquin Valley was conducted for a major agricultural firm. Using primarily LANDSAT imagery data, the General Electric scientists were able to achieve an average classifica-

FIGURE 3.
LANDSAT imagery of the New York Bight



Source: NASA

tion accuracy of about 97% and to demonstrate that crops could be inventoried at a cost of approximately a penny an acre.

The Aerospace Systems Division of the Bendix Corporation in Ann Arbor, Mich., is marketing the Multispectral Data Analysis System (M-DAS), also a user interactive system. It differs from IMAGE 100, however, in that it uses only digitized data for input. The system will handle up to 16 channels of multispectral data and, with Bendix's special purpose hardware, M-DAS can produce a series of colored thematic map overlays to be used with USGS topographical maps. Multicolored hard copy prints showing all colors of thematic interest can also be prepared.

Bendix's Earth Resources Applications Department has an active program to provide multispectral data analysis services on a contractual basis. The company's largest job to date involved using LANDSAT data to classify vegetation cover into 16 categories for a 120,000 mi^2 area of Alaska. The thematic maps, which were prepared in three months at a cost of $25,000, were of sufficient detail to permit an Eskimo tribal corporation to select new lands most suitable for maintaining the tribal lifestyle of hunting and fishing. An aerial survey of the same region would have cost almost $2 million and taken about 18 months.

The future

By the 1980's the present, limited operational use of satellite imagery will in all likelihood greatly expand. For example, this imagery may well be used on a regular basis in applications such as monitoring the sediment loadings and current patterns of lakes, estuaries, and oceans. Monitoring urban area development through the changes in spectral signatures caused by construction of new housing developments and industrial complexes will permit updating of urban area maps on a regular basis. This is not economically feasible at the present time, but should be especially useful in rapidly growing areas such as the western U.S. and Alaska where energy development is causing dramatic increases in the population.

Higher spatial resolution and additional spectral bands will increase the utility of multispectral scanner imagery from space. Beginning in 1980, the Earth Observation Satellite is expected to provide seven-band spectral coverage at 30 m resolution and four-band coverage of special targets at 10 m resolution. LANDSAT, by comparison, affords four-band spectral coverage at 80 m resolution.

Closer at hand is NASA's next research and development satellite, Nimbus G (Nimbus 7 once it is placed in orbit), scheduled for launch in the fall of 1978. The satellite has as a primary mission objective the detection, identification, mapping, and measurement of air and ocean pollution. These data will be used to establish baseline levels so that long-term trends can be determined and to provide information about location, movement, and disposition of pollutants.

In summary, the trends are toward real-time acquisition of environmental information from even the most remote parts of the globe. Using sophisticated measuring instruments, satellites and computerized data processing, we are moving into an era in which pollution and environmental quality are not treated simply as regional or even national problems, but are being understood and dealt with as global concerns.

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F. Douglas Johnson *is a research technologist with the Industrial Economics Division of the Denver Research Institute. He is deputy manager of a major NASA-funded project to study the impact of aerospace technology by examining changes in industrial practice.*

Edward C. Mangold *is a physicist with the Environmental Protection Agency's National Enforcement Investigations Center in Denver, Colorado. He has held assignments in the design and development of instrumentation for aerospace and environmental applications. Dr. Mangold's recent work has involved environmental applications for multispectral scanning instruments.*

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APPENDIX D

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APPENDIX D

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